# Module Manual

Master of Science (M.Sc.)

# Process Engineering

Cohort: Winter Term 2019

Updated: 25th July 2020

# Table of Contents

# Program description

## Content

Graduates have acquired in-depth, wide-ranging engineering, mathematical and scientific knowledge that equips them to undertake scientific work and to act responsibly both professionally and in society. They have a critical awareness of more recent findings in their discipline.

Graduates can:

- Analyze problems scientifically and solve them even if they are unusually or incompletely defined and feature competing specifications;
- Abstract and formulate complex problems in a new or developing area;
- Apply innovative methods to solving basic research-oriented problems and develop new scientific methods.

Graduates can:

- Develop concepts and solutions for basic research-oriented, and in some cases unusual, problems, bringing in other disciplines as appropriate;
- Create and develop new products, processes and methods;
- Apply their engineering judgment to work with complex, possibly incomplete information, to identify contradictions and deal with them.

Graduates can:

- Recognize the need for information, find and source information;
- Plan and execute theoretical and experimental investigations;
- Critically assess data and draw conclusions from it;
- Examine and evaluate the use of new and emerging technologies.

Over and above the qualifications gained on the Bachelor’s course, students can:

- Methodically classify and systematically combine knowledge from different fields, and deal with complexity;
- Familiarize themselves systematically and speedily with new tasks;
- Reflect systematically on non-technical impacts of engineering activity and exercise a sense of responsibility in taking them into account in their actions.
- Devise solutions requiring more detailed methodological competence.

The key qualifications for engineering practice acquired on the Bachelor’s course are augmented during the Master’s course.

# Core qualification

## Module M0519: Particle Technology and Solid Matter Process Technology

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Advanced Particle Technology II (L0051) | Project-/problem-based Learning | 1 | 1 |
| Advanced Particle Technology II (L0050) | Lecture | 2 | 2 |
| Experimental Course Particle Technology (L0430) | Practical Course | 3 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Stefan Heinrich |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basic knowledge of solids processes and particle technology |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After completion of the module the students will be able to describe and explain processes for solids processing in detail based on microprocesses on the particle level. |
| *Skills* | Students are able to choose process steps and apparatuses for the focused treatment of solids depending on the specific characteristics. They furthermore are able to adapt these processes and to simulate them. |
| **Personal Competence** | |
| *Social Competence* | Students are able to present results from small teamwork projects in an oral presentation and to discuss their knowledge with scientific researchers. |
| *Autonomy* | Students are able to analyze and solve problems regarding solid particles independently or in small groups. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |

**Course achievement**

| Compulsory | Bonus | Form | Description |
|---|---|---|---|
| Yes | None | Written elaboration | fünf Berichte (pro Versuch ein Bericht) à 5-10 Seiten |

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|---|---|
| **Examination** | Written exam |
| **Examination duration and scale** | 120 minutes |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Environmental Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory<br>Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory |

### Course L0051: Advanced Particle Technology II

| | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Stefan Heinrich |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L0050: Advanced Particle Technology II | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Stefan Heinrich |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | • Exercise in form of "Project based Learning"<br>• Agglomeration, particle size enlargement<br>• advanced particle size reduction<br>• Advanced theorie of fluid/particle flows<br>• CFD-methods for the simulation of disperse fluid/solid flows, Euler/Euler methids, Descrete Particle Modeling<br>• Treatment of simulation problems with distributed properties, solution of population balances |
| **Literature** | Schubert, H.; Heidenreich, E.; Liepe, F.; Neeße, T.: Mechanische Verfahrenstechnik. Deutscher Verlag für die Grundstoffindustrie, Leipzig, 1990.<br><br>Stieß, M.: Mechanische Verfahrenstechnik I und II. Springer Verlag, Berlin, 1992. |

| Course L0430: Experimental Course Particle Technology | |
|---|---|
| **Typ** | Practical Course |
| **Hrs/wk** | 3 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 48, Study Time in Lecture 42 |
| **Lecturer** | Prof. Stefan Heinrich |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | • Fluidization<br>• Agglomeration<br>• Granulation<br>• Drying<br>• Determination of mechanical properties of agglomerats |
| **Literature** | Schubert, H.; Heidenreich, E.; Liepe, F.; Neeße, T.: Mechanische Verfahrenstechnik. Deutscher Verlag für die Grundstoffindustrie, Leipzig, 1990.<br><br>Stieß, M.: Mechanische Verfahrenstechnik I und II. Springer Verlag, Berlin, 1992. |

## Module M0523: Business & Management

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|---|---|
| **Module Responsible** | Prof. Matthias Meyer |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | None |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | • Students are able to find their way around selected special areas of management within the scope of business management.<br>• Students are able to explain basic theories, categories, and models in selected special areas of business management.<br>• Students are able to interrelate technical and management knowledge. |
| *Skills* | • Students are able to apply basic methods in selected areas of business management.<br>• Students are able to explain and give reasons for decision proposals on practical issues in areas of business management. |
| **Personal Competence** | |
| *Social Competence* | • Students are able to communicate in small interdisciplinary groups and to jointly develop solutions for complex problems |
| *Autonomy* | • Students are capable of acquiring necessary knowledge independently by means of research and preparation of material. |
| **Workload in Hours** | Depends on choice of courses |
| **Credit points** | 6 |

| **Courses** |
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| **Information regarding lectures and courses can be found in the corresponding module handbook published separately.** |

## Module M0524: Non-technical Courses for Master

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|---|---|
| **Module Responsible** | Dagmar Richter |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | None |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | **The Nontechnical Academic Programms (NTA)**<br><br>imparts skills that, in view of the TUHH's training profile, professional engineering studies require but are not able to cover fully. Self-reliance, self-management, collaboration and professional and personnel management competences. The department implements these training objectives in its **teaching architecture**, in its **teaching and learning arrangements**, in **teaching areas** and by means of teaching offerings in which students can qualify by opting for **specific competences** and a **competence level** at the Bachelor's or Master's level. The teaching offerings are pooled in two different catalogues for nontechnical complementary courses.<br><br>**The Learning Architecture**<br><br>consists of a cross-disciplinarily study offering. The centrally designed teaching offering ensures that courses in the nontechnical academic programms follow the specific profiling of TUHH degree courses.<br><br>The learning architecture demands and trains independent educational planning as regards the individual development of competences. It also provides orientation knowledge in the form of "profiles".<br><br>The subjects that can be studied in parallel throughout the student's entire study program - if need be, it can be studied in one to two semesters. In view of the adaptation problems that individuals commonly face in their first semesters after making the transition from school to university and in order to encourage individually planned semesters abroad, there is no obligation to study these subjects in one or two specific semesters during the course of studies.<br><br>**Teaching and Learning Arrangements**<br><br>provide for students, separated into B.Sc. and M.Sc., to learn with and from each other across semesters. The challenge of dealing with interdisciplinarity and a variety of stages of learning in courses are part of the learning architecture and are deliberately encouraged in specific courses.<br><br>**Fields of Teaching**<br><br>are based on research findings from the academic disciplines cultural studies, social studies, arts, historical studies, communication studies, migration studies and sustainability research, and from engineering didactics. In addition, from the winter semester 2014/15 students on all Bachelor's courses will have the opportunity to learn about business management and start-ups in a goal-oriented way.<br><br>The fields of teaching are augmented by soft skills offers and a foreign language offer. Here, the focus is on encouraging goal-oriented communication skills, e.g. the skills required by outgoing engineers in international and intercultural situations.<br><br>**The Competence Level**<br><br>of the courses offered in this area is different as regards the basic training objective in the Bachelor's and Master's fields. These differences are reflected in the practical examples used, in content topics that refer to different professional application contexts, and in the higher scientific and theoretical level of abstraction in the B.Sc.<br><br>This is also reflected in the different quality of soft skills, which relate to the different team positions and different group leadership functions of Bachelor's and Master's graduates in their future working life.<br><br>**Specialized Competence (Knowledge)**<br><br>Students can<br><br>• explain specialized areas in context of the relevant non-technical disciplines,<br>• outline basic theories, categories, terminology, models, concepts or artistic techniques in the disciplines represented in the learning area,<br>• different specialist disciplines relate to their own discipline and differentiate it as well as make connections,<br>• sketch the basic outlines of how scientific disciplines, paradigms, models, instruments, methods and forms of representation in the specialized sciences are subject to individual and socio-cultural interpretation and historicity,<br>• Can communicate in a foreign language in a manner appropriate to the subject. |
| *Skills* | **Professional Competence (Skills)**<br><br>In selected sub-areas students can<br><br>• apply basic and specific methods of the said scientific disciplines,<br>• aquestion a specific technical phenomena, models, theories from the viewpoint of another, aforementioned specialist discipline,<br>• to handle simple and advanced questions in aforementioned scientific disciplines in a sucsessful manner,<br>• justify their decisions on forms of organization and application in practical questions in contexts that go beyond the technical relationship to the subject. |

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| **Personal Competence** | |
| *Social Competence* | **Personal Competences (Social Skills)**<br>Students will be able<br>• to learn to collaborate in different manner,<br>• to present and analyze problems in the abovementioned fields in a partner or group situation in a manner appropriate to the addressees,<br>• to express themselves competently, in a culturally appropriate and gender-sensitive manner in the language of the country (as far as this study-focus would be chosen),<br>• to explain nontechnical items to auditorium with technical background knowledge. |
| *Autonomy* | **Personal Competences (Self-reliance)**<br>Students are able in selected areas<br>• to reflect on their own profession and professionalism in the context of real-life fields of application<br>• to organize themselves and their own learning processes<br>• to reflect and decide questions in front of a broad education background<br>• to communicate a nontechnical item in a competent way in writen form or verbaly<br>• to organize themselves as an entrepreneurial subject country (as far as this study-focus would be chosen) |
| **Workload in Hours** | Depends on choice of courses |
| **Credit points** | 6 |

| **Courses** |
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| **Information regarding lectures and courses can be found in the corresponding module handbook published separately.** |

## Module M0540: Transport Processes

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Multiphase Flows (L0104) | Lecture | 2 | 2 |
| Reactor Design Using Local Transport Processes (L0105) | Project-/problem-based Learning | 2 | 2 |
| Heat & Mass Transfer in Process Engineering (L0103) | Lecture | 2 | 2 |

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|---|---|
| **Module Responsible** | Prof. Michael Schlüter |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | All lectures from the undergraduate studies, especially mathematics, chemistry, thermodynamics, fluid mechanics, heat- and mass transfer. |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to:<br>• describe transport processes in single- and multiphase flows and they know the analogy between heat- and mass transfer as well as the limits of this analogy.<br>• explain the main transport laws and their application as well as the limits of application.<br>• describe how transport coefficients for heat- and mass transfer can be derived experimentally.<br>• compare different multiphase reactors like trickle bed reactors, pipe reactors, stirring tanks and bubble column reactors.<br>• are known. The Students are able to perform mass and energy balances for different kind of reactors. Further more the industrial application of multiphase reactors for heat- and mass transfer are known. |
| *Skills* | The students are able to:<br>• optimize multiphase reactors by using mass- and energy balances,<br>• use transport processes for the design of technical processes,<br>• to choose a multiphase reactor for a specific application. |
| **Personal Competence** | |
| *Social Competence* | The students are able to discuss in international teams in english and develop an approach under pressure of time. |
| *Autonomy* | Students are able to define independently tasks, to solve the problem "design of a multiphase reactor". The knowledge that s necessary is worked out by the students themselves on the basis of the existing knowledge from the lecture. The students are able to decide by themselves what kind of equation and model is applicable to their certain problem. They are able to organize their own team and to define priorities for different tasks. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 15 min Presentation + 90 min multiple choice written examen |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Core qualification: Compulsory<br>Energy and Environmental Engineering: Core qualification: Compulsory<br>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory |

| Course L0104: Multiphase Flows | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Michael Schlüter |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Interfaces in MPF (boundary layers, surfactants)<br>• Hydrodynamics & pressure drop in Film Flows<br>• Hydrodynamics & pressure drop in Gas-Liquid Pipe Flows<br>• Hydrodynamics & pressure drop in Bubbly Flows<br>• Mass Transfer in Film Flows<br>• Mass Transfer in Gas-Liquid Pipe Flows<br>• Mass Transfer in Bubbly Flows<br>• Reactive mass Transfer in Multiphase Flows<br>• Film Flow: Application Trickle Bed Reactors<br>• Pipe Flow: Application Turbular Reactors<br>• Bubbly Flow: Application Bubble Column Reactors |
| **Literature** | Brauer, H.: Grundlagen der Einphasen- und Mehrphasenströmungen. Verlag Sauerländer, Aarau, Frankfurt (M), 1971.<br>Clift, R.; Grace, J.R.; Weber, M.E.: Bubbles, Drops and Particles, Academic Press, New York, 1978.<br>Fan, L.-S.; Tsuchiya, K.: Bubble Wake Dynamics in Liquids and Liquid-Solid Suspensions, Butterworth-Heinemann Series in Chemical Engineering, Boston, USA, 1990.<br>Hewitt, G.F.; Delhaye, J.M.; Zuber, N. (Ed.): Multiphase Science and Technology. Hemisphere Publishing Corp, Vol. 1/1982 bis Vol. 6/1992.<br>Kolev, N.I.: Multiphase flow dynamics. Springer, Vol. 1 and 2, 2002.<br>Levy, S.: Two-Phase Flow in Complex Systems. Verlag John Wiley & Sons, Inc, 1999.<br>Crowe, C.T.: Multiphase Flows with Droplets and Particles. CRC Press, Boca Raton, Fla, 1998. |

| Course L0105: Reactor Design Using Local Transport Processes | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Michael Schlüter |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | In this Problem-Based Learning unit the students have to design a multiphase reactor for a fast chemical reaction concerning optimal hydrodynamic conditions of the multiphase flow.<br><br>The four students in each team have to:<br>• collect and discuss material properties and equations for design from the literature,<br>• calculate the optimal hydrodynamic design,<br>• check the plausibility of the results critically,<br>• write an exposé with the results.<br><br>This exposé will be used as basis for the discussion within the oral group examen of each team. |
| **Literature** | see actual literature list in StudIP with recent published papers |

| Course L0103: Heat & Mass Transfer in Process Engineering | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Michael Schlüter |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Introduction - Transport Processes in Chemical Engineering<br>• Molecular Heat- and Mass Transfer: Applications of Fourier's and Fick's Law<br>• Convective Heat and Mass Transfer: Applications in Process Engineering<br>• Unsteady State Transport Processes: Cooling & Drying<br>• Transport at fluidic Interfaces: Two Film, Penetration, Surface Renewal<br>• Transport Laws & Balance Equations with turbulence, sinks and sources<br>• Experimental Determination of Transport Coefficients<br>• Design and Scale Up of Reactors for Heat- and Mass Transfer<br>• Reactive Mass Transfer<br>• Processes with Phase Changes – Evaporization and Condensation<br>• Radiative Heat Transfer - Fundamentals<br>• Radiative Heat Transfer - Solar Energy |
| **Literature** | 1. Baehr, Stephan: Heat and Mass Transfer, Wiley 2002.<br>2. Bird, Stewart, Lightfood: Transport Phenomena, Springer, 2000.<br>3. John H. Lienhard: A Heat Transfer Textbook, Phlogiston Press, Cambridge Massachusetts, 2008.<br>4. Myers: Analytical Methods in Conduction Heat Transfer, McGraw-Hill, 1971.<br>5. Incropera, De Witt: Fundamentals of Heat and Mass Transfer, Wiley, 2002.<br>6. Beek, Muttzall: Transport Phenomena, Wiley, 1983.<br>7. Crank: The Mathematics of Diffusion, Oxford, 1995.<br>8. Madhusudana: Thermal Contact Conductance, Springer, 1996.<br>9. Treybal: Mass-Transfer-Operation, McGraw-Hill, 1987. |

## Module M0541: Process and Plant Engineering II

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Process and Plant Engineering II (L0097) | Lecture | 2 | 2 |
| Process and Plant Engineering II (L0098) | Recitation Section (large) | 1 | 2 |
| Process and Plant Engineering II (L1215) | Recitation Section (small) | 1 | 2 |

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|---|---|
| **Module Responsible** | Prof. Georg Fieg |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | unit operation of thermal and mechanical separation<br>chemical reactor engineering |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | students can:<br>-present process control concepts of apparatus and complex process plants<br>- classifyprocess models and model equations<br>- explain numerical methods and their use in simulation tasks<br>- explain the solving strategy of flowsheet simulation<br>- explain, present and discuss projects phases within the planning of processes<br>- present and explain the critical path method |
| *Skills* | students are capable of:<br>- formulation of targets of process control concepts and the translation into industrial practice<br>- design and evaluation of process control concepts and structures<br>- analyse the model structure ans parameters from the process simulation<br>- optimization of calculation sequence with respect to flowsheet simulation |
| **Personal Competence** | |
| *Social Competence* | students are capable of:<br>• develop solutions in heterogeneous small groups |
| *Autonomy* | students are capable of:<br>• taping new knowledge on a special subject by literature research |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 120 Min. |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Core qualification: Compulsory<br>International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory |

| Course L0097: Process and Plant Engineering II | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Georg Fieg, Dr. Thomas Waluga |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | 1. **Process optimization**<br>Application areas<br>Formulation of constrained optimization<br>Solving strategy<br>Classes of optimization tasks<br>2. **Process control**<br>Typical control functions of equipment and apparatus in process engineering<br>Structures of control systems<br>Plantwide control<br>3. **Process Modeling**<br>Process models (steady state and dynamic behaviour)<br>Degrees of freedom<br>Examples from industrial practice<br>4. **Process simulation**<br>Structured approach<br>Numerical methods<br>Flowsheeting<br>Solution methods<br>Examples for experimental validation in industrial practice<br>Application of flowsheet simulation<br>5. **Plant design and construction**<br>Introduction<br>Industrial project implementation<br>Project execution: Applied aspects in industrial use<br>critical path method |
| **Literature** | Literatur (Planung und Bau von Produktionsanlagen):<br>G. Barnecker, Planung und Bau verfahrenstechnischer Anlagen, Springer Verlag, 2001<br>F.P. Helmus, Anlagenplanung, Wiley-VCH Verlag, Weinheim, 2003<br>E. Klapp, Apparate- und Anlagentechnik, Springer -Verlag, Berlin, 1980<br>P. Rinza, Projektmanagement: Planung, Überwachung und Steuerung von technischen<br>und nichttechnischen Vorhaben, Düsseldorf,VDI-Verlag, 1994<br>K. Sattler, W. Kasper, Verfahrentechnische Anlagen, Wiley-VCH Verlag, Weinheim, 2000<br>G.H. Vogel, Verfahrensentwicklung, Wiley-VCH, Weinheim, 2002<br>K.H. Weber, Inbetriebnahme verfahrenstechnischer Anlagen, VDI Verlag, Düsseldorf, 1996<br>E. Wegener, Montagegerechte Anlagenplanung, Wiley-VCH Verlag, Weinheim, 2003 |

| Course L0098: Process and Plant Engineering II | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Georg Fieg, Dr. Thomas Waluga |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L1215: Process and Plant Engineering II | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Georg Fieg, Dr. Thomas Waluga |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0542: Fluid Mechanics in Process Engineering

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Applications of Fluid Mechanics in Process Engineering (L0106) | Recitation Section (large) | 2 | 2 |
| Fluid Mechanics II (L0001) | Lecture | 2 | 4 |

| | |
|---|---|
| **Module Responsible** | Prof. Michael Schlüter |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Mathematics I-III<br>• Fundamentals in Fluid Mechanics<br>• Technical Thermodynamics I-II<br>• Heat- and Mass Transfer |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students are able to describe different applications of fluid mechanics in Process Engineering, Bioprocess Engineering, Energy- and Environmental Process Engineering and Renewable Energies. They are able to use the fundamentals of fluid mechanics for calculations of certain engineering problems. The students are able to estimate if a problem can be solved with an analytical solution and what kind of alternative possibilities are available (e.g. self-similarity in an example of free jets, empirical solutions in an example with the Forchheimer equation, numerical methods in an example of Large Eddy Simulation. |
| *Skills* | Students are able to use the governing equations of Fluid Dynamics for the design of technical processes. Especially they are able to formulate momentum and mass balances to optimize the hydrodynamics of technical processes. They are able to transform a verbal formulated message into an abstract formal procedure. |
| **Personal Competence** | |
| *Social Competence* | The students are able to discuss a given problem in small groups and to develop an approach. |
| *Autonomy* | Students are able to define independently tasks for problems related to fluid mechanics. They are able to work out the knowledge that is necessary to solve the problem by themselves on the basis of the existing knowledge from the lecture. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 180 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Core qualification: Compulsory<br>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory |

| Course L0106: Applications of Fluid Mechanics in Process Engineering | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Michael Schlüter |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | The Exercise-Lecture will bridge the gap between the theoretical content from the lecture and practical calculations. For this aim a special exercise is calculated at the blackboard that shows how the theoretical knowledge from the lecture can be used to solve real problems in Process Engineering. |
| **Literature** | 1. Brauer, H.: Grundlagen der Einphasen- und Mehrphasenströmungen. Verlag Sauerländer, Aarau, Frankfurt (M), 1971.<br>2. Brauer, H.; Mewes, D.: Stoffaustausch einschließlich chemischer Reaktion. Frankfurt: Sauerländer 1972.<br>3. Crowe, C. T.: Engineering fluid mechanics. Wiley, New York, 2009.<br>4. Durst, F.: Strömungsmechanik: Einführung in die Theorie der Strömungen von Fluiden. Springer-Verlag, Berlin, Heidelberg, 2006.<br>5. Fox, R.W.; et al.: Introduction to Fluid Mechanics. J. Wiley & Sons, 1994.<br>6. Herwig, H.: Strömungsmechanik: Eine Einführung in die Physik und die mathematische Modellierung von Strömungen. Springer Verlag, Berlin, Heidelberg, New York, 2006.<br>7. Herwig, H.: Strömungsmechanik: Einführung in die Physik von technischen Strömungen: Vieweg+Teubner Verlag / GWV Fachverlage GmbH, Wiesbaden, 2008.<br>8. Kuhlmann, H.C.: Strömungsmechanik. München, Pearson Studium, 2007<br>9. Oertl, H.: Strömungsmechanik: Grundlagen, Grundgleichungen, Lösungsmethoden, Softwarebeispiele. Vieweg+ Teubner / GWV Fachverlage GmbH, Wiesbaden, 2009.<br>10. Schade, H.; Kunz, E.: Strömungslehre. Verlag de Gruyter, Berlin, New York, 2007.<br>11. Truckenbrodt, E.: Fluidmechanik 1: Grundlagen und elementare Strömungsvorgänge dichtebeständiger Fluide. Springer-Verlag, Berlin, Heidelberg, 2008.<br>12. Schlichting, H. : Grenzschicht-Theorie. Springer-Verlag, Berlin, 2006.<br>13. van Dyke, M.: An Album of Fluid Motion. The Parabolic Press, Stanford California, 1882.<br>14. White, F.: Fluid Mechanics, Mcgraw-Hill, ISBN-10: 0071311211, ISBN-13: 978-0071311212, 2011. |

| Course L0001: Fluid Mechanics II | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 92, Study Time in Lecture 28 |
| **Lecturer** | Prof. Michael Schlüter |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | • Differential equations for momentum-, heat and mass transfer<br>• Examples for simplifications of the Navier-Stokes Equations<br>• Unsteady momentum transfer<br>• Free shear layer, turbulence and free jets<br>• Flow around particles - Solids Process Engineering<br>• Coupling of momentum and heat transfer - Thermal Process Engineering<br>• Rheology – Bioprocess Engineering<br>• Coupling of momentum- and mass transfer – Reactive mixing, Chemical Process Engineering<br>• Flow threw porous structures - heterogeneous catalysis<br>• Pumps and turbines - Energy- and Environmental Process Engineering<br>• Wind- and Wave-Turbines - Renewable Energy<br>• Introduction into Computational Fluid Dynamics |
| **Literature** | 1. Brauer, H.: Grundlagen der Einphasen- und Mehrphasenströmungen. Verlag Sauerländer, Aarau, Frankfurt (M), 1971.<br>2. Brauer, H.; Mewes, D.: Stoffaustausch einschließlich chemischer Reaktion. Frankfurt: Sauerländer 1972.<br>3. Crowe, C. T.: Engineering fluid mechanics. Wiley, New York, 2009.<br>4. Durst, F.: Strömungsmechanik: Einführung in die Theorie der Strömungen von Fluiden. Springer-Verlag, Berlin, Heidelberg, 2006.<br>5. Fox, R.W.; et al.: Introduction to Fluid Mechanics. J. Wiley & Sons, 1994.<br>6. Herwig, H.: Strömungsmechanik: Eine Einführung in die Physik und die mathematische Modellierung von Strömungen. Springer Verlag, Berlin, Heidelberg, New York, 2006.<br>7. Herwig, H.: Strömungsmechanik: Einführung in die Physik von technischen Strömungen: Vieweg+Teubner Verlag / GWV Fachverlage GmbH, Wiesbaden, 2008.<br>8. Kuhlmann, H.C.: Strömungsmechanik. München, Pearson Studium, 2007<br>9. Oertl, H.: Strömungsmechanik: Grundlagen, Grundgleichungen, Lösungsmethoden, Softwarebeispiele. Vieweg+ Teubner / GWV Fachverlage GmbH, Wiesbaden, 2009.<br>10. Schade, H.; Kunz, E.: Strömungslehre. Verlag de Gruyter, Berlin, New York, 2007.<br>11. Truckenbrodt, E.: Fluidmechanik 1: Grundlagen und elementare Strömungsvorgänge dichtebeständiger Fluide. Springer-Verlag, Berlin, Heidelberg, 2008.<br>12. Schlichting, H. : Grenzschicht-Theorie. Springer-Verlag, Berlin, 2006.<br>13. van Dyke, M.: An Album of Fluid Motion. The Parabolic Press, Stanford California, 1882. |

## Module M0895: Advanced Chemical Reaction Engineering

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Chemical Reaction Engineering (Advanced Topics) (L0222) | Lecture | 2 | 2 |
| Chemical Reaction Engineering (Advanced Topics) (L0245) | Recitation Section (large) | 2 | 2 |
| Experimental Course Chemical Engineering (Advanced Topics) (L0287) | Practical Course | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Raimund Horn |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Content of the bachelor-lecture "basics of chemical reaction engineering". |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After completition of the module, students are able to:<br>- identify differences between ideal and non-ideal rectors,<br>- infer fundamental differences in kinetic models for catalyzed reactions,<br>- name modelling algorithms for non-ideal reactors. |
| *Skills* | After successfull completition of the module the students are able to<br>-evaluate properties of non-ideal reactors<br>-compare kinetic modells of heterogeneous-catalyzed reactions and develop measuring techniques thereof<br>-choose instruments for temperature, pressure- concentration and mass-flow measurements regarding process conditions<br>-develop a concept for design of experiments |
| **Personal Competence** | |
| *Social Competence* | The students are able to analyze scientific challenges and elaborate suitable solutions in small groups. Moreover they are able to document these approaches according to scientific guidelines.<br>After successful completition of the lab-course the students have a strong ability to organize themselfes in small groups to solve issues in chemical reaction engineering. The students can discuss their subject related knowledge among each other and with their teachers. |
| *Autonomy* | The students are able to obtain further information for experimental planning and assess their relevance autonomously. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | **Compulsory** **Bonus** **Form** **Description**<br>Yes None Subject theoretical and practical work |
| **Examination** | Written exam |
| **Examination duration and scale** | 120 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Core qualification: Compulsory<br>Process Engineering: Core qualification: Compulsory |

| Course L0222: Chemical Reaction Engineering (Advanced Topics) | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Raimund Horn |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | 1. Real reactors (residence time distribution E(t), F(t)-curve, measurement of E(t) or F(t), residence time distribution of ideal reactors, modeling of real reactors, segregated flow model, tanks in series model, dispersion model, compartment models)<br><br>2. Heterogeneous catalysis (what is a catalyst, operation principle of a catalyst, volcano plot, homogeneous catalysis, heterogeneous catalysis, biocatalysis, physisorption and chemisorption, turn-over frequency (TOF), Sabatier's principle, Bronstedt-Evans-Polyani-relationship, Adsorption isotherms of single and multi-component systems, kinetic models of heterogeneous catalytic reactions, Langmuir-Hinshelwood kinetics, Eley-Rideal kinetics, power law rate equations, kinetic measurements on heterogeneously catalyzed reactions in the laboratory , microkinetic modeling, catalyst characterization)<br><br>3. Diffusion in heterogeneous catalysis (diffusion regimes, Knudsen-diffusion, molecular diffusion, surface diffusion, single-file diffusion, reference systems, Stefan-Maxwell-Equations, Fick's law, pore effectiveness factor, impact of diffusion limitations in heterogeneous catalysis, Damköhler-relation, mass- and energy balance of heterogeneous catalytic reactors)<br><br>4. Laboratory measurements in heterogeneous catalysis (temperature, pressure, concentration, mass flow controllers, laboratory reactors, experimental design) |
| **Literature** | 1. Vorlesungsfolien R. Horn<br><br>2. Skript zur Vorlesung F. Keil<br><br>3. M. Baerns, A. Behr, A. Brehm, J. Gmehling, H. Hofmann, U. Onken, A. Renken, Technische Chemie, Wiley-VCH<br><br>4. G. Emig, E. Klemm, Technische Chemie, Springer<br><br>5. A. Behr, D. W. Agar, J. Jörissen, Einführung in die Technische Chemie<br><br>6. E. Müller-Erlwein, Chemische Reaktionstechnik 2012, 2. Auflage, Teubner Verlag<br><br>7. J. Hagen, Chemiereaktoren: Auslegung und Simulation, 2004, Wiley-VCH<br><br>8. H. S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall B<br><br>9. H. S. Fogler, Essentials of Chemical Reaction Engineering, Prentice Hall<br><br>10. O. Levenspiel, Chemical Reaction Engineering, John Wiley & Sons, 1998<br><br>11. L. D. Schmidt, The Engineering of Chemical Reactions, Oxford Univ. Press, 2009<br><br>12. J. B. Butt, Reaction Kinetics and Reactor Design, 2000, Marcel Dekker<br><br>13. R. Aris, Elementary Chemical Reactor Analysis, Dover Pubn. Inc., 2000<br><br>14. M. E. Davis, R. J. Davis, Fundamentals of Chemical Reaction Engineering, McGraw Hill 15. G. F. Froment, K. B. Bischoff, J. De Wilde, Chemical Reactor Analysis and Design, John Wiley & Sons, 2010<br><br>16. A. Jess, P. Wasserscheid, Chemical Technology An Integrated Textbook, WILEY-VCH<br><br>17. C. G. Hill, An Introduction to Chemical Engineering Kinetics & Reactor Design, John Wiley & Sons |

| Course L0245: Chemical Reaction Engineering (Advanced Topics) | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Raimund Horn, Dr. Oliver Korup |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | 1. Real reactors (residence time distribution E(t), F(t)-curve, measurement of E(t) or F(t), residence time distribution of ideal reactors, modeling of real reactors, segregated flow model, tanks in series model, dispersion model, compartment models)<br><br>2. Heterogeneous catalysis (what is a catalyst, operation principle of a catalyst, volcano plot, homogeneous catalysis, heterogeneous catalysis, biocatalysis, physisorption and chemisorption, turn-over frequency (TOF), Sabatier's principle, Bronstedt-Evans-Polyani-relationship, Adsorption isotherms of single and multi-component systems, kinetic models of heterogeneous catalytic reactions, Langmuir-Hinshelwood kinetics, Eley-Rideal kinetics, power law rate equations, kinetic measurements on heterogeneously catalyzed reactions in the laboratory , microkinetic modeling, catalyst characterization)<br><br>3. Diffusion in heterogeneous catalysis (diffusion regimes, Knudsen-diffusion, molecular diffusion, surface diffusion, single-file diffusion, reference systems, Stefan-Maxwell-Equations, Fick's law, pore effectiveness factor, impact of diffusion limitations in heterogeneous catalysis, Damköhler-relation, mass- and energy balance of heterogeneous catalytic reactors)<br><br>4. Laboratory measurements in heterogeneous catalysis (temperature, pressure, concentration, mass flow controllers, laboratory reactors, experimental design) |
| **Literature** | 1. Vorlesungsfolien R. Horn<br><br>2. Skript zur Vorlesung F. Keil<br><br>3. M. Baerns, A. Behr, A. Brehm, J. Gmehling, H. Hofmann, U. Onken, A. Renken, Technische Chemie, Wiley-VCH<br><br>4. G. Emig, E. Klemm, Technische Chemie, Springer<br><br>5. A. Behr, D. W. Agar, J. Jörissen, Einführung in die Technische Chemie<br><br>6. E. Müller-Erlwein, Chemische Reaktionstechnik 2012, 2. Auflage, Teubner Verlag<br><br>7. J. Hagen, Chemiereaktoren: Auslegung und Simulation, 2004, Wiley-VCH<br><br>8. H. S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall B<br><br>9. H. S. Fogler, Essentials of Chemical Reaction Engineering, Prentice Hall<br><br>10. O. Levenspiel, Chemical Reaction Engineering, John Wiley & Sons, 1998<br><br>11. L. D. Schmidt, The Engineering of Chemical Reactions, Oxford Univ. Press, 2009<br><br>12. J. B. Butt, Reaction Kinetics and Reactor Design, 2000, Marcel Dekker<br><br>13. R. Aris, Elementary Chemical Reactor Analysis, Dover Pubn. Inc., 2000<br><br>14. M. E. Davis, R. J. Davis, Fundamentals of Chemical Reaction Engineering, McGraw Hill 15. G. F. Froment, K. B. Bischoff, J. De Wilde, Chemical Reactor Analysis and Design, John Wiley & Sons, 2010<br><br>16. A. Jess, P. Wasserscheid, Chemical Technology An Integrated Textbook, WILEY-VCH<br><br>17. C. G. Hill, An Introduction to Chemical Engineering Kinetics & Reactor Design, John Wiley & Sons |

| Course L0287: Experimental Course Chemical Engineering (Advanced Topics) | |
|---|---|
| **Typ** | Practical Course |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Raimund Horn, Dr. Achim Bartsch |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | Execution and evaluation of several experiments in chemical reaction engineering.<br><br>* Calculation of error propagation and error analysis<br>* Steady state Wicke-Kallenbach measurements of diffusivities in a catalyst pellet<br>* Interaction of reaction and diffusion in a catalyst particle, dissociation of methanol on zinc oxide<br>* Mass transfer in gas/liquid system<br>* Stability of a CSTR (hydrolysis of acetic anhydride) |
| **Literature** | Skript zur Vorlesung, als Buch in der TU-Bibliothek<br><br>Praktikumsskript<br><br>Levenspiel, O.: Chemical reaction engineering; John Wiley & Sons, New York, 3. Ed., 1999 VTM 309(LB)<br><br>Smith, J. M.: Chemical Engineering Kinetics, McGraw Hill, New York, 1981.<br><br>Hill, C.: Chemical Engineering Kinetics & Reactor Design, John Wiley, New York, 1977.<br><br>Fogler, H. S. : Elements of Chemical Reaction Engineering , Prentice Hall, 2006<br><br>M. Baerns, A. Behr, A. Brehm, J. Gmehling, H. Hofmann, U. Onken, A. Renken: Technische Chemie, VCH , 2006<br><br>G. F. Froment, K. B. Bischoff: Chemical Reactor Analysis and Design, Wiley, 1990 |

## Module M0896: Bioprocess and Biosystems Engineering

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Bioreactor Design and Operation (L1034) | Lecture | 2 | 2 |
| Bioreactors and Biosystems Engineering (L1037) | Project-/problem-based Learning | 1 | 2 |
| Biosystems Engineering (L1036) | Lecture | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. An-Ping Zeng |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Knowledge of bioprocess engineering and process engineering at bachelor level |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After completion of this module, participants will be able to:<br>• differentiate between different kinds of bioreactors and describe their key features<br>• identify and characterize the peripheral and control systems of bioreactors<br>• depict integrated biosystems (bioprocesses including up- and downstream processing)<br>• name different sterilization methods and evaluate those in terms of different applications<br>• recall and define the advanced methods of modern systems-biological approaches<br>• connect the multiple "omics"-methods and evaluate their application for biological questions<br>• recall the fundamentals of modeling and simulation of biological networks and biotechnological processes and to discuss their methods<br>• assess and apply methods and theories of genomics, transcriptomics, proteomics and metabolomics in order to quantify and optimize biological processes at molecular and process levels. |
| *Skills* | After completion of this module, participants will be able to:<br>• describe different process control strategies for bioreactors and chose them after analysis of characteristics of a given bioprocess<br>• plan and construct a bioreactor system including peripherals from lab to pilot plant scale<br>• adapt a present bioreactor system to a new process and optimize it<br>• develop concepts for integration of bioreactors into bioproduction processes<br>• combine the different modeling methods into an overall modeling approach, to apply these methods to specific problems and to evaluate the achieved results critically<br>• connect all process components of biotechnological processes for a holistic system view. |
| **Personal Competence** | |
| *Social Competence* | After completion of this module, participants will be able to debate technical questions in small teams to enhance the ability to take position to their own opinions and increase their capacity for teamwork.<br>The students can reflect their specific knowledge orally and discuss it with other students and teachers. |
| *Autonomy* | After completion of this module, participants will be able to solve a technical problem in teams of approx. 8-12 persons independently including a presentation of the results.<br>• |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Credit points** | 6 |

| Course achievement | Compulsory | Bonus | Form | Description |
|---|---|---|---|---|
| | Yes | 20 % | Presentation | |

| | |
|---|---|
| **Examination** | Written exam |
| **Examination duration and scale** | 120 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Core qualification: Compulsory<br>Chemical and Bioprocess Engineering: Core qualification: Compulsory<br>Environmental Engineering: Specialisation Biotechnology: Elective Compulsory<br>International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory |

| **Course L1034: Bioreactor Design and Operation** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. An-Ping Zeng |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | **Design of bioreactors and peripheries:**<br>• reactor types and geometry<br>• materials and surface treatment<br>• agitation system design<br>• insertion of stirrer<br>• sealings<br>• fittings and valves<br>• peripherals<br>• materials<br>• standardization<br>• demonstration in laboratory and pilot plant<br>**Sterile operation:**<br>• theory of sterilisation processes<br>• different sterilisation methods<br>• sterilisation of reactor and probes<br>• industrial sterile test, automated sterilisation<br>• introduction of biological material<br>• autoclaves<br>• continuous sterilisation of fluids<br>• deep bed filters, tangential flow filters<br>• demonstration and practice in pilot plant<br>**Instrumentation and control:**<br>• temperature control and heat exchange<br>• dissolved oxygen control and mass transfer<br>• aeration and mixing<br>• used gassing units and gassing strategies<br>• control of agitation and power input<br>• pH and reactor volume, foaming, membrane gassing<br>**Bioreactor selection and scale-up:**<br>• selection criteria<br>• scale-up and scale-down<br>• reactors for mammalian cell culture<br>**Integrated biosystem:**<br>• interactions and integration of microorganisms, bioreactor and downstream processing<br>• Miniplant technologies<br>**Team work with presentation:**<br>• Operation mode of selected bioprocesses (e.g. fundamentals of batch, fed-batch and continuous cultivation) |
| **Literature** | • Storhas, Winfried, Bioreaktoren und periphere Einrichtungen, Braunschweig: Vieweg, 1994<br>• Chmiel, Horst, Bioprozeßtechnik; Springer 2011<br>• Krahe, Martin, Biochemical Engineering, Ullmann‘s Encyclopedia of Industrial Chemistry<br>• Pauline M. Doran, Bioprocess Engineering Principles, Second Edition, Academic Press, 2013<br>• Other lecture materials to be distributed |

| Course L1037: Bioreactors and Biosystems Engineering | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. An-Ping Zeng |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | **Introduction to Biosystems Engineering (Exercise)**<br><br>**Experimental basis and methods for biosystems analysis**<br>• Introduction to genomics, transcriptomics and proteomics<br>• More detailed treatment of metabolomics<br>• Determination of in-vivo kinetics<br>• Techniques for rapid sampling<br>• Quenching and extraction<br>• Analytical methods for determination of metabolite concentrations<br><br>**Analysis, modelling and simulation of biological networks**<br>• Metabolic flux analysis<br>• Introduction<br>• Isotope labelling<br>• Elementary flux modes<br>• Mechanistic and structural network models<br>• Regulatory networks<br>• Systems analysis<br>• Structural network analysis<br>• Linear and non-linear dynamic systems<br>• Sensitivity analysis (metabolic control analysis)<br><br>**Modelling and simulation for bioprocess engineering**<br>• Modelling of bioreactors<br>• Dynamic behaviour of bioprocesses<br>**Selected projects for biosystems engineering**<br>• Miniaturisation of bioreaction systems<br>• Miniplant technology for the integration of biosynthesis and downstream processin<br>• Technical and economic overall assessment of bioproduction processes |
| **Literature** | E. Klipp et al. Systems Biology in Practice, Wiley-VCH, 2006<br><br>R. Dohrn: Miniplant-Technik, Wiley-VCH, 2006<br><br>G.N. Stephanopoulos et. al.: Metabolic Engineering, Academic Press, 1998<br><br>I.J. Dunn et. al.: Biological Reaction Engineering, Wiley-VCH, 2003<br><br>Lecture materials to be distributed |

| **Course L1036: Biosystems Engineering** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. An-Ping Zeng |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | **Introduction to Biosystems Engineering**<br><br>**Experimental basis and methods for biosystems analysis**<br>• Introduction to genomics, transcriptomics and proteomics<br>• More detailed treatment of metabolomics<br>• Determination of in-vivo kinetics<br>• Techniques for rapid sampling<br>• Quenching and extraction<br>• Analytical methods for determination of metabolite concentrations<br><br>**Analysis, modelling and simulation of biological networks**<br>• Metabolic flux analysis<br>• Introduction<br>• Isotope labelling<br>• Elementary flux modes<br>• Mechanistic and structural network models<br>• Regulatory networks<br>• Systems analysis<br>• Structural network analysis<br>• Linear and non-linear dynamic systems<br>• Sensitivity analysis (metabolic control analysis)<br><br>**Modelling and simulation for bioprocess engineering**<br>• Modelling of bioreactors<br>• Dynamic behaviour of bioprocesses<br><br>**Selected projects for biosystems engineering**<br>• Miniaturisation of bioreaction systems<br>• Miniplant technology for the integration of biosynthesis and downstream processin<br>• Technical and economic overall assessment of bioproduction processes |
| **Literature** | E. Klipp et al. Systems Biology in Practice, Wiley-VCH, 2006<br><br>R. Dohrn: Miniplant-Technik, Wiley-VCH, 2006<br><br>G.N. Stephanopoulos et. al.: Metabolic Engineering, Academic Press, 1998<br><br>I.J. Dunn et. al.: Biological Reaction Engineering, Wiley-VCH, 2003<br><br>Lecture materials to be distributed |

## Module M0904: Process Design Project

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Process Design Project (L1050) | Projection Course | 6 | 6 |

| | |
|---|---|
| **Module Responsible** | Dozenten des SD V |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Particle Technology and Solid Process Engineering<br>• Transport Processes<br>• Process- and Plant Design II<br>• Fluid Mechanics for Process Engineering<br>• Chemical Reaction Engineering<br>• Bioprocess- and Biosystems-Engineering |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After the students passed the project course successfully they know:<br>• how a team is working together so solve a complex task in process engineering<br>• what kind of tools are necessary to design a process<br>• what kind of drawbacks and difficulties are coming up by designing a process |
| *Skills* | After passing the Module successfully the students are able to:<br>• utilize tools for process design for a specific given process engineering task,<br>• choose and connect apparatusses for a complete process,<br>• collecting all relevant data for an economical and ecological evaluation,<br>• optimization of calculation sequence with respect to flowsheet simulation. |
| **Personal Competence** | |
| *Social Competence* | The students are able to discuss in international teams in english and develop an approach under pressure of time. |
| *Autonomy* | Students are able to define independently tasks, to get new knowledge from existing knowledge as well as to find ways to use the knowledge in practice. They are able to organize their own team and to define priorities. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Subject theoretical and practical work |
| **Examination duration and scale** | . |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Core qualification: Compulsory<br>Chemical and Bioprocess Engineering: Core qualification: Compulsory<br>Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory |

### Course L1050: Process Design Project

| | |
|---|---|
| **Typ** | Projection Course |
| **Hrs/wk** | 6 |
| **CP** | 6 |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Lecturer** | NN |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | In the Process Design Project the students have to design in teams an energy or process engineering plant by calculating and designing single plant components. The calculation of costs as well as the process safety is another important aspect of this course. Furthermore the approval procedures have to be taken into account. |
| **Literature** | |

# Specialization Process Engineering

## Module M0513: System Aspects of Renewable Energies

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Fuel Cells, Batteries, and Gas Storage: New Materials for Energy Production and Storage (L0021) | Lecture | 2 | 2 |
| Energy Trading (L0019) | Lecture | 1 | 1 |
| Energy Trading (L0020) | Recitation Section (small) | 1 | 1 |
| Deep Geothermal Energy (L0025) | Lecture | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Martin Kaltschmitt |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Module: Technical Thermodynamics I<br>Module: Technical Thermodynamics II |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to describe the processes in energy trading and the design of energy markets and can critically evaluate them in relation to current subject specific problems. Furthermore, they are able to explain the basics of thermodynamics of electrochemical energy conversion in fuel cells and can establish and explain the relationship to different types of fuel cells and their respective structure. Students can compare this technology with other energy storage options. In addition, students can give an overview of the procedure and the energetic involvement of deep geothermal energy. |
| *Skills* | Students can apply the learned knowledge of storage systems for excessive energy to explain for various energy systems different approaches to ensure a secure energy supply. In particular, they can plan and calculate domestic, commercial and industrial heating equipment using energy storage systems in an energy-efficient way and can assess them in relation to complex power systems. In this context, students can assess the potential and limits of geothermal power plants and explain their operating mode.<br><br>Furthermore, the students are able to explain the procedures and strategies for marketing of energy and apply it in the context of other modules on renewable energy projects. In this context they can unassistedly carry out analysis and evaluations of energie markets and energy trades. |
| **Personal Competence** | |
| *Social Competence* | Students are able to discuss issues in the thematic fields in the renewable energy sector addressed within the module. |
| *Autonomy* | Students can independently exploit sources , acquire the particular knowledge about the subject area and transform it to new questions. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 3 hours written exam |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory<br>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory<br>Renewable Energies: Core qualification: Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Water: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Elective Compulsory |

| Course L0021: Fuel Cells, Batteries, and Gas Storage: New Materials for Energy Production and Storage | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Michael Fröba |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | 1. Introduction to electrochemical energy conversion<br>2. Function and structure of electrolyte<br>3. Low-temperature fuel cell<br>  ◦ Types<br>  ◦ Thermodynamics of the PEM fuel cell<br>  ◦ Cooling and humidification strategy<br>4. High-temperature fuel cell<br>  ◦ The MCFC<br>  ◦ The SOFC<br>  ◦ Integration Strategies and partial reforming<br>5. Fuels<br>  ◦ Supply of fuel<br>  ◦ Reforming of natural gas and biogas<br>  ◦ Reforming of liquid hydrocarbons<br>6. Energetic Integration and control of fuel cell systems |
| **Literature** | • Hamann, C.; Vielstich, W.: Elektrochemie 3. Aufl.; Weinheim: Wiley - VCH, 2003 |

| Course L0019: Energy Trading | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Michael Sagorje, Dr. Sven Orlowski |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | • Basic concepts and tradable products in energy markets<br>• Primary energy markets<br>• Electricity Markets<br>• European Emissions Trading Scheme<br>• Influence of renewable energy<br>• Real options<br>• Risk management<br><br>Within the exercise the various tasks are actively discussed and applied to various cases of application. |
| **Literature** | |

| Course L0020: Energy Trading | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Michael Sagorje, Dr. Sven Orlowski |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L0025: Deep Geothermal Energy | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Ben Norden |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | 1. Introduction to the deep geothermal use<br>2. Geological Basics I<br>3. Geological Basics II<br>4. Geology and thermal aspects<br>5. Rock Physical Aspects<br>6. Geochemical aspects<br>7. Exploration of deep geothermal reservoirs<br>8. Drilling technologies, piping and expansion<br>9. Borehole Geophysics<br>10. Underground system characterization and reservoir engineering<br>11. Microbiology and Upper-day system components<br>12. Adapted investment concepts, cost and environmental aspect |
| **Literature** | • Dipippo, R.: Geothermal Power Plants: Principles, Applications, Case Studies and Environmental Impact. Butterworth Heinemann; 3rd revised edition. (29. Mai 2012)<br>• www.geo-energy.org<br>• Edenhofer et al. (eds): Renewable Energy Sources and Climate Change Mitigation; Special Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 2012.<br>• Kaltschmitt et al. (eds): Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte. Springer, 5. Aufl. 2013.<br>• Kaltschmitt et al. (eds): Energie aus Erdwärme. Spektrum Akademischer Verlag; Auflage: 1999 (3. September 2001)<br>• Huenges, E. (ed.): Geothermal Energy Systems: Exploration, Development, and Utilization. Wiley-VCH Verlag GmbH & Co. KGaA; Auflage: 1. Auflage (19. April 2010) |

## Module M0874: Wastewater Systems

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Wastewater Systems - Collection, Treatment and Reuse (L0934) | Lecture | 2 | 2 |
| Wastewater Systems - Collection, Treatment and Reuse (L0943) | Recitation Section (large) | 1 | 1 |
| Advanced Wastewater Treatment (L0357) | Lecture | 2 | 2 |
| Advanced Wastewater Treatment (L0358) | Recitation Section (large) | 1 | 1 |

| | |
|---|---|
| **Module Responsible** | Prof. Ralf Otterpohl |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Knowledge of wastewater management and the key processes involved in wastewater treatment. |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to outline key areas of the full range of treatment systems in waste water management, as well as their mutual dependence for sustainable water protection. They can describe relevant economic, environmental and social factors. |
| *Skills* | Students are able to pre-design and explain the available wastewater treatment processes and the scope of their application in municipal and for some industrial treatment plants. |
| **Personal Competence** | |
| *Social Competence* | Social skills are not targeted in this module. |
| *Autonomy* | Students are in a position to work on a subject and to organize their work flow independently. They can also present on this subject. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 120 min |
| **Assignment for the Following Curricula** | Civil Engineering: Specialisation Structural Engineering: Elective Compulsory<br>Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory<br>Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory<br>Civil Engineering: Specialisation Water and Traffic: Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Environmental Engineering: Elective Compulsory<br>Environmental Engineering: Specialisation Water: Elective Compulsory<br>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Water: Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Compulsory |

| Course L0934: Wastewater Systems - Collection, Treatment and Reuse | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Ralf Otterpohl |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | •Understanding the global situation with water and wastewater<br>•Regional planning and decentralised systems<br>•Overview on innovative approaches<br>•In depth knowledge on advanced wastewater treatment options for different situations, for end-of-pipe and reuse<br>•Mathematical Modelling of Nitrogen Removal<br>•Exercises with calculations and design |
| **Literature** | Henze, Mogens:<br>Wastewater Treatment: Biological and Chemical Processes, Springer 2002, 430 pages<br><br>George Tchobanoglous, Franklin L. Burton, H. David Stensel:<br>Wastewater Engineering: Treatment and Reuse, Metcalf & Eddy<br>McGraw-Hill, 2004 - 1819 pages |

| Course L0943: Wastewater Systems - Collection, Treatment and Reuse | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Ralf Otterpohl |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L0357: Advanced Wastewater Treatment | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Joachim Behrendt |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | Survey on advanced wastewater treatment<br>reuse of reclaimed municipal wastewater<br>Precipitation<br>Flocculation<br>Depth filtration<br>Membrane Processes<br>Activated carbon adsorption<br>Ozonation<br>"Advanced Oxidation Processes"<br>Disinfection |
| **Literature** | Metcalf & Eddy, Wastewater Engineering: Treatment and Reuse, McGraw-Hill, Boston 2003<br><br>Wassertechnologie, H.H. Hahn, Springer-Verlag, Berlin 1987<br><br>Membranverfahren: Grundlagen der Modul- und Anlagenauslegung, T. Melin und R. Rautenbach, Springer-Verlag, Berlin 2007<br><br>Trinkwasserdesinfektion: Grundlagen, Verfahren, Anlagen, Geräte, Mikrobiologie, Chlorung, Ozonung, UV-Bestrahlung, Membranfiltration, Qualitätssicherung, W. Roeske, Oldenbourg-Verlag, München 2006<br><br>Organische Problemstoffe in Abwässern, H. Gulyas, GFEU, Hamburg 2003 |

| Course L0358: Advanced Wastewater Treatment | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Dr. Joachim Behrendt |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | Aggregate organic compounds (sum parameters)<br>Industrial wastewater<br>Processes for industrial wastewater treatment<br>Precipitation<br>Flocculation<br>Activated carbon adsorption<br>Recalcitrant organic compounds |
| **Literature** | Metcalf & Eddy, Wastewater Engineering: Treatment and Reuse, McGraw-Hill, Boston 2003<br>Wassertechnologie, H.H. Hahn, Springer-Verlag, Berlin 1987<br>Membranverfahren: Grundlagen der Modul- und Anlagenauslegung, T. Melin und R. Rautenbach, Springer-Verlag, Berlin 2007<br>Trinkwasserdesinfektion: Grundlagen, Verfahren, Anlagen, Geräte, Mikrobiologie, Chlorung, Ozonung, UV-Bestrahlung, Membranfiltration, Qualitätssicherung, W. Roeske, Oldenbourg-Verlag, München 2006<br>Organische Problemstoffe in Abwässern, H. Gulyas, GFEU, Hamburg 2003 |

## Module M0617: High Pressure Chemical Engineering

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| High Pressure Technique for Apparatus Engineering (L1278) | Lecture | 2 | 2 |
| Industrial Processes Under High Pressure (L0116) | Lecture | 2 | 2 |
| Advanced Separation Processes (L0094) | Lecture | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Dr. Monika Johannsen |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Fundamentals of Chemistry, Chemical Engineering, Fluid Process Engineering, Thermal Separation Processes, Thermodynamics, Heterogeneous Equilibria |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After a successful completion of this module, students can:<br>• explain the influence of pressure on the properties of compounds, phase equilibria, and production processes,<br>• describe the thermodynamic fundamentals of separation processes with supercritical fluids,<br>• exemplify models for the description of solid extraction and countercurrent extraction,<br>• discuss parameters for optimization of processes with supercritical fluids. |
| *Skills* | After successful completion of this module, students are able to:<br>• compare separation processes with supercritical fluids and conventional solvents,<br>• assess the application potential of high-pressure processes at a given separation task,<br>• include high pressure methods in a given multistep industrial application,<br>• estimate economics of high-pressure processes in terms of investment and operating costs,<br>• perform an experiment with a high pressure apparatus under guidance,<br>• evaluate experimental results,<br>• prepare an experimental protocol. |
| **Personal Competence** | |
| *Social Competence* | After successful completion of this module, students are able to:<br>• present a scientific topic from an original publication in teams of 2 and defend the contents together. |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | **Compulsory** **Bonus** **Form** **Description**<br>Yes 15 % Presentation |
| **Examination** | Written exam |
| **Examination duration and scale** | 120 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L1278: High Pressure Technique for Apparatus Engineering | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Arne Pietsch |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | 1. Basic laws and certification standards<br>2. Basics for calculations of pressurized vessels<br>3. Stress hypothesis<br>4. Selection of materials and fabrication processes<br>5. vessels with thin walls<br>6. vessels with thick walls<br>7. Safety installations<br>8. Safety analysis<br><br>Applications:<br><br>- subsea technology (manned and unmanned vessels)<br>- steam vessels<br>- heat exchangers<br>- LPG, LEG transport vessels |
| **Literature** | Apparate und Armaturen in der chemischen Hochdrucktechnik, Springer Verlag<br>Spain and Paauwe: High Pressure Technology, Vol. I und II, M. Dekker Verlag<br>AD-Merkblätter, Heumanns Verlag<br>Bertucco; Vetter: High Pressure Process Technology, Elsevier Verlag<br>Sherman; Stadtmuller: Experimental Techniques in High-Pressure Research, Wiley & Sons Verlag<br>Klapp: Apparate- und Anlagentechnik, Springer Verlag |

| **Course L0116: Industrial Processes Under High Pressure** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Carsten Zetzl |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | Part I : Physical Chemistry and Thermodynamics<br>1. Introduction: Overview, achieving high pressure, range of parameters.<br><br>2. Influence of pressure on properties of fluids: P,v,T-behaviour, enthalpy, internal energy, entropy, heat capacity, viscosity, thermal conductivity, diffusion coefficients, interfacial tension.<br><br>3. Influence of pressure on heterogeneous equilibria: Phenomenology of phase equilibria<br><br>4. Overview on calculation methods for (high pressure) phase equilibria).<br>Influence of pressure on transport processes, heat and mass transfer.<br><br>Part II : High Pressure Processes<br>5. Separation processes at elevated pressures: Absorption, adsorption (pressure swing adsorption), distillation (distillation of air), condensation (liquefaction of gases)<br><br>6. Supercritical fluids as solvents: Gas extraction, cleaning, solvents in reacting systems, dyeing, impregnation, particle formation (formulation)<br><br>7. Reactions at elevated pressures. Influence of elevated pressure on biochemical systems: Resistance against pressure<br><br>**Part III : Industrial production**<br><br>8. Reaction : Haber-Bosch-process, methanol-synthesis, polymerizations; Hydrations, pyrolysis, hydrocracking; Wet air oxidation, supercritical water oxidation (SCWO)<br><br>9. Separation : Linde Process, De-Caffeination, Petrol and Bio-Refinery<br><br>10. Industrial High Pressure Applications in Biofuel and Biodiesel Production<br><br>11. Sterilization and Enzyme Catalysis<br><br>12. Solids handling in high pressure processes, feeding and removal of solids, transport within the reactor.<br><br>13. Supercritical fluids for materials processing.<br><br>14. Cost Engineering<br><br>Learning Outcomes:<br>After a successful completion of this module, the student should be able to<br><br>- understand of the influences of pressure on properties of compounds, phase equilibria, and production processes.<br><br>- Apply high pressure approches in the complex process design tasks<br><br>- Estimate Efficiency of high pressure alternatives with respect to investment and operational costs<br><br>Performance Record:<br>1. Presence (28 h)<br><br>2. Oral presentation of original scientific article (15 min) with written summary<br><br>3. Written examination and Case study<br><br>( 2+3 : 32 h Workload)<br><br>Workload:<br>60 hours total |
| **Literature** | Literatur:<br><br>Script: High Pressure Chemical Engineering.<br>G. Brunner: Gas Extraction. An Introduction to Fundamentals of Supercritical Fluids and the Application to Separation Processes. Steinkopff, Darmstadt, Springer, New York, 1994. |

| Course L0094: Advanced Separation Processes | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Monika Johannsen |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Introduction/Overview on Properties of Supercritical Fluids (SCF)and their Application in Gas Extraction Processes<br>• Solubility of Compounds in Supercritical Fluids and Phase Equilibrium with SCF<br>• Extraction from Solid Substrates: Fundamentals, Hydrodynamics and Mass Transfer<br>• Extraction from Solid Substrates: Applications and Processes (including Supercritical Water)<br>• Countercurrent Multistage Extraction: Fundamentals and Methods, Hydrodynamics and Mass Transfer<br>• Countercurrent Multistage Extraction: Applications and Processes<br>• Solvent Cycle, Methods for Precipitation<br>• Supercritical Fluid Chromatography (SFC): Fundamentals and Application<br>• Simulated Moving Bed Chromatography (SMB)<br>• Membrane Separation of Gases at High Pressures<br>• Separation by Reactions in Supercritical Fluids (Enzymes) |
| **Literature** | G. Brunner: Gas Extraction. An Introduction to Fundamentals of Supercritical Fluids and the Application to Separation Processes. Steinkopff, Darmstadt, Springer, New York, 1994. |

## Module M0875: Nexus Engineering - Water, Soil, Food and Energy

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Ecological Town Design - Water, Energy, Soil and Food Nexus (L1229) | Seminar | 2 | 2 |
| Water & Wastewater Systems in a Global Context (L0939) | Lecture | 2 | 4 |

| | |
|---|---|
| **Module Responsible** | Prof. Ralf Otterpohl |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basic knowledge of the global situation with rising poverty, soil degradation, migration to cities, lack of water resources and sanitation |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can describe the facets of the global water situation. Students can judge the enormous potential of the implementation of synergistic systems in Water, Soil, Food and Energy supply. |
| *Skills* | Students are able to design ecological settlements for different geographic and socio-economic conditions for the main climates around the world. |
| **Personal Competence** | |
| *Social Competence* | The students are able to develop a specific topic in a team and to work out milestones according to a given plan. |
| *Autonomy* | Students are in a position to work on a subject and to organize their work flow independently. They can also present on this subject. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Subject theoretical and practical work |
| **Examination duration and scale** | During the course of the semester, the students work towards mile stones. The work includes presentations and papers. Detailed information can be found at the beginning of the smester in the StudIP course module handbook. |
| **Assignment for the Following Curricula** | Civil Engineering: Specialisation Water and Traffic: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Environmental Engineering: Core qualification: Elective Compulsory<br>Joint European Master in Environmental Studies - Cities and Sustainability: Core qualification: Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Water: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Elective Compulsory |

| Course L1229: Ecological Town Design - Water, Energy, Soil and Food Nexus | |
|---|---|
| **Typ** | Seminar |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Ralf Otterpohl |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Participants Workshop: Design of the most attractive productive Town<br>• Keynote lecture and video<br>• The limits of Urbanization / Green Cities<br>• The tragedy of the Rural: Soil degradation, agro chemical toxification, migration to cities<br>• Global Ecovillage Network: Upsides and Downsides around the World<br>• Visit of an Ecovillage<br>• Participants Workshop: Resources for thriving rural areas, Short presentations by participants, video competion<br>• TUHH Rural Development Toolbox<br>• Integrated New Town Development<br>• Participants workshop: Design of New Towns: Northern, Arid and Tropical cases<br>• Outreach: Participants campaign<br>• City with the Rural: Resilience, quality of live and productive biodiversity |
| **Literature** | • Ralf Otterpohl 2013: Gründer-Gruppen als Lebensentwurf: "Synergistische Wertschöpfung in erweiterten Kleinstadt- und Dorfstrukturen", in „Regionales Zukunftsmanagement Band 7: Existenzgründung unter regionalökonomischer Perspektive, Pabst Publisher, Lengerich<br>• http://youtu.be/9hmkgn0nBgk (Miracle Water Village, India, Integrated Rainwater Harvesting, Water Efficiency, Reforestation and Sanitation)<br>• TEDx New Town Ralf Otterpohl: http://youtu.be/_M0J2u9BrbU |

| Course L0939: Water & Wastewater Systems in a Global Context | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 92, Study Time in Lecture 28 |
| **Lecturer** | Prof. Ralf Otterpohl |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Keynote lecture and video<br>• Water & Soil: Water availability as a consequence of healthy soils<br>• Water and it's utilization, Integrated Urban Water Management<br>• Water & Energy, lecture and panel discussion pro and con for a specific big dam project<br>• Rainwater Harvesting on Catchment level, Holistic Planned Grazing, Multi-Use-Reforestation<br>• Sanitation and Reuse of water, nutrients and soil conditioners, Conventional and Innovative Approaches<br>• Why are there excreta in water? Public Health, Awareness Campaigns<br>• Rehearsal session, Q&A |
| **Literature** | • Montgomery, David R. 2007: Dirt: The Erosion of Civilizations, University of California Press<br>• Liu, John D.: http://eempc.org/hope-in-a-changing_climate/ (Integrated regeneration of the Loess Plateau, China, and sites in Ethiopia and Rwanda)<br>• http://youtu.be/9hmkgn0nBgk (Miracle Water Village, India, Integrated Rainwater Harvesting, Water Efficiency, Reforestation and Sanitation) |

## Module M0636: Cell and Tissue Engineering

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Fundamentals of Cell and Tissue Engineering (L0355) | Lecture | 2 | 3 |
| Bioprocess Engineering for Medical Applications (L0356) | Lecture | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Ralf Pörtner |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Knowledge of bioprocess engineering and process engineering at bachelor level |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After successful completion of the module the students<br>- know the basic principles of cell and tissue culture<br>- know the relevant metabolic and physiological properties of animal and human cells<br>- are able to explain and describe the basic underlying principles of bioreactors for cell and tissue cultures, in contrast to microbial fermentations<br>- are able to explain the essential steps (unit operations) in downstream<br>- are able to explain, analyze and describe the kinetic relationships and significant litigation strategies for cell culture reactors |
| *Skills* | The students are able<br>- to analyze and perform mathematical modeling to cellular metabolism at a higher level<br>- are able to to develop process control strategies for cell culture systems |
| **Personal Competence** | |
| *Social Competence* | After completion of this module, participants will be able to debate technical questions in small teams to enhance the ability to take position to their own opinions and increase their capacity for teamwork.<br>The students can reflect their specific knowledge orally and discuss it with other students and teachers. |
| *Autonomy* | After completion of this module, participants will be able to solve a technical problem in teams of approx. 8-12 persons independently including a presentation of the results. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 120 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0355: Fundamentals of Cell and Tissue Engineering | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Ralf Pörtner, Prof. An-Ping Zeng |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | Overview of cell culture technology and tissue engineering (cell culture product manufacturing, complexity of protein therapeutics, examples of tissue engineering) (Pörtner, Zeng) Fundamentals of cell biology for process engineering (cells: source, composition and structure. interactions with environment, growth and death - cell cycle, protein glycolysation) (Pörtner) Cell physiology for process engineering (Overview of central metabolism, genomics etc.) (Zeng) Medium design (impact of media on the overall cell culture process, basic components of culture medium, serum and protein-free media) (Pörtner) Stochiometry and kinetics of cell growth and product formation (growth of mammalian cells, quantitative description of cell growth & product formation, kinetics of growth) |
| **Literature** | Butler, M (2004) Animal Cell Culture Technology - The basics, 2nd ed. Oxford University Press<br><br>Ozturk SS, Hu WS (eds) (2006) Cell Culture Technology For Pharmaceutical and Cell-Based Therapies. Taylor & Francis Group, New York<br><br>Eibl, R.; D. Eibl; R. Pörtner; G. Catapano and P. Czermak: Cell and Tissue Reaction Engineering, Springer (2008). ISBN 978-3-540-68175-5<br><br>Pörtner R (ed) (2013) Animal Cell Biotechnology - Methods and Protocols. Humana Press |

| Course L0356: Bioprocess Engineering for Medical Applications | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Ralf Pörtner |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | Requirements for cell culture processess, shear effects, microcarrier technology Reactor systems for mammalian cell culture (production systems) (design, layout, scale-up: suspension reactors (stirrer, aeration, cell retention), fixed bed, fluidized bed (carrier), hollow fiber reactors (membranes), dialysis reactors, Reactor systems for Tissue Engineering, Prozess strategies (batch, fed-batch, continuous, perfusion, mathematical modelling), control (oxygen, substrate etc.) • Downstream |
| **Literature** | Butler, M (2004) Animal Cell Culture Technology - The basics, 2nd ed. Oxford University Press<br><br>Ozturk SS, Hu WS (eds) (2006) Cell Culture Technology For Pharmaceutical and Cell-Based Therapies. Taylor & Francis Group, New York<br><br>Eibl, R.; D. Eibl; R. Pörtner; G. Catapano and P. Czermak: Cell and Tissue Reaction Engineering, Springer (2008). ISBN 978-3-540-68175-5<br><br>Pörtner R (ed) (2013) Animal Cell Biotechnology - Methods and Protocols. Humana Press |

## Module M0914: Technical Microbiology

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Applied Molecular Biology (L0877) | Lecture | 2 | 3 |
| Technical Microbiology (L0999) | Lecture | 2 | 2 |
| Technical Microbiology (L1000) | Recitation Section (large) | 1 | 1 |

| | |
|---|---|
| **Module Responsible** | Dr. Anna Krüger |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Bachelor with basic knowledge in microbiology and genetics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After successfully finishing this module, students are able<br>• to give an overview of genetic processes in the cell<br>• to explain the application of industrial relevant biocatalysts<br>• to explain and prove genetic differences between pro- and eukaryotes |
| *Skills* | After successfully finishing this module, students are able<br>• to explain and use advanced molecularbiological methods<br>• to recognize problems in interdisciplinary fields |
| **Personal Competence** | |
| *Social Competence* | Students are able to<br>• write protocols and PBL-summaries in teams<br>• to lead and advise members within a PBL-unit in a group<br>• develop and distribute work assignments for given problems |
| *Autonomy* | Students are able to<br>• search information for a given problem by themselves<br>• prepare summaries of their search results for the team<br>• make themselves familiar with new topics |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Credit points** | 6 |

**Course achievement**

| Compulsory | Bonus | Form | Description |
|---|---|---|---|
| No | 10 % | Group discussion | PBL Diskussionen |
| No | 10 % | Excercises | Multiple Choice Aufgaben |

| | |
|---|---|
| **Examination** | Written exam |
| **Examination duration and scale** | 60 min exam |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Core qualification: Compulsory<br>Chemical and Bioprocess Engineering: Core qualification: Compulsory<br>Environmental Engineering: Core qualification: Elective Compulsory<br>International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0877: Applied Molecular Biology | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Garabed Antranikian |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | Lecture and PBL<br>- Methods in genetics / molecular cloning<br>- Industrial relevance of microbes and their biocatalysts<br>- Biotransformation at extreme conditions<br>- Genomics<br>- Protein engineering techniques<br>- Synthetic biology |
| **Literature** | Relevante Literatur wird im Kurs zur Verfügung gestellt.<br>Grundwissen in Molekularbiologie, Genetik, Mikrobiologie und Biotechnologie erforderlich.<br>Lehrbuch: Brock - Mikrobiologie / Microbiology (Madigan et al.) |

| Course L0999: Technical Microbiology | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Anna Krüger |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • History of microbiology and biotechnology<br>• Enzymes<br>• Molecular biology<br>• Fermentation<br>• Downstream Processing<br>• Industrial microbiological processes<br>• Technical enzyme application<br>• Biological Waste Water treatment |
| **Literature** | **Microbiology**, 2013, Madigan, M., Martinko, J. M., Stahl, D. A., Clark, D. P. (eds.), formerly „Brock“, Pearson<br>**Industrielle Mikrobiologie**, 2012, Sahm, H., Antranikian, G., Stahmann, K.-P., Takors, R. (eds.) Springer Berlin, Heidelberg, New York, Tokyo.<br>**Angewandte Mikrobiologie**, 2005, Antranikian, G. (ed.), Springer, Berlin, Heidelberg, New York, Tokyo. |

| Course L1000: Technical Microbiology | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Dr. Christin Burkhardt |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0714: Numerical Treatment of Ordinary Differential Equations

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Numerical Treatment of Ordinary Differential Equations (L0576) | Lecture | 2 | 3 |
| Numerical Treatment of Ordinary Differential Equations (L0582) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Sabine Le Borne |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Mathematik I, II, III für Ingenieurstudierende (deutsch oder englisch) oder Analysis & Lineare Algebra I + II sowie Analysis III für Technomathematiker<br>• Basic MATLAB knowledge |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to<br>• list numerical methods for the solution of ordinary differential equations and explain their core ideas,<br>• repeat convergence statements for the treated numerical methods (including the prerequisites tied to the underlying problem),<br>• explain aspects regarding the practical execution of a method.<br>• select the appropriate numerical method for concrete problems, implement the numerical algorithms efficiently and interpret the numerical results |
| *Skills* | Students are able to<br>• implement (MATLAB), apply and compare numerical methods for the solution of ordinary differential equations,<br>• to justify the convergence behaviour of numerical methods with respect to the posed problem and selected algorithm,<br>• for a given problem, develop a suitable solution approach, if necessary by the composition of several algorithms, to execute this approach and to critically evaluate the results. |
| **Personal Competence** | |
| *Social Competence* | Students are able to<br>• work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge), explain theoretical foundations and support each other with practical aspects regarding the implementation of algorithms. |
| *Autonomy* | Students are capable<br>• to assess whether the supporting theoretical and practical excercises are better solved individually or in a team,<br>• to assess their individual progress and, if necessary, to ask questions and seek help. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory<br>Energy Systems: Core qualification: Elective Compulsory<br>Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory<br>Mathematical Modelling in Engineering: Theory, Numerics, Applications: Specialisation I. Numerics (TUHH): Compulsory<br>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory<br>Technomathematics: Specialisation I. Mathematics: Elective Compulsory<br>Theoretical Mechanical Engineering: Core qualification: Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0576: Numerical Treatment of Ordinary Differential Equations | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Sabine Le Borne, Dr. Christian Seifert |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | Numerical methods for Initial Value Problems<br>• single step methods<br>• multistep methods<br>• stiff problems<br>• differential algebraic equations (DAE) of index 1<br>Numerical methods for Boundary Value Problems<br>• multiple shooting method<br>• difference methods<br>• variational methods |
| **Literature** | • E. Hairer, S. Noersett, G. Wanner: Solving Ordinary Differential Equations I: Nonstiff Problems<br>• E. Hairer, G. Wanner: Solving Ordinary Differential Equations II: Stiff and Differential-Algebraic Problems |

| Course L0582: Numerical Treatment of Ordinary Differential Equations | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Sabine Le Borne, Dr. Christian Seifert |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M1033: Special Areas of Process Engineering and Bioprocess Engineering

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Chemical Kinetics (L0508) | Lecture | 2 | 2 |
| Solid Matter Process in chemical Industry (L2021) | Lecture | 2 | 2 |
| Interfaces and Colloids (L0194) | Lecture | 2 | 2 |
| Industrial Inorganic and Organic Processes (L0531) | Lecture | 2 | 2 |
| Industrial biotechnology in Chemical Industriy (L2276) | Lecture | 2 | 3 |
| Optics for Engineers (L2437) | Lecture | 2 | 2 |
| Optics for Engineers (L2438) | Project-/problem-based Learning | 2 | 2 |
| Polymer Reaction Engineering (L1244) | Lecture | 2 | 2 |
| Practice in bioprocess engineering (L2275) | Lecture | 2 | 3 |
| Safety of Chemical Reactions (L1321) | Lecture | 2 | 2 |
| Ceramics Technology (L0379) | Lecture | 2 | 3 |
| Environmental Analysis (L0354) | Lecture | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Michael Schlüter |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | The students should have passed the Bachelor modules "Process Engineering" successfully. |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to find their way around selected special areas of Process Engineering within the scope of Process Engineering.<br>Students are able to explain technical dependencies and models in selected special areas of Process Engineering. |
| *Skills* | Students are able to apply basic methods in selected areas of process engineering. |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | Students can chose independently, in which field the want to deepen their knowledge and skills through the election of courses. |
| **Workload in Hours** | Depends on choice of courses |
| **Credit points** | 6 |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0508: Chemical Kinetics | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Klausur |
| **Examination duration and scale** | 120 Minuten |
| **Lecturer** | Prof. Raimund Horn |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | - Micro kinetics, formal kinetics, molecularity, reaction order, integrated rate laws<br><br>- Complex reactions, reversible reactions, consecutive reactions, parallel reactions, approximation methods: steady-state, pseudo-first order, numerical solution of rate equations , example : Belousov-Zhabotinskii reaction<br><br>- Experimental methods of kinetics, integral approach, differential approach, initial rate method, method of half-life, relaxation methods<br><br>- Collision theory, Maxwell velocity distribution, collision numbers, line of centers model<br><br>- Transition state theory, partition functions of atoms and molecules, examples, calculating reaction equilibria on the basis of molecular data only, heats of reaction, calculating rates of reaction by means of statistical thermodynamics<br><br>- Kinetics of heterogeneous reactions, peculiarities of heterogeneous reactions, mean-field approximation, Langmuir adsorption isotherm, reaction mechanisms, Langmuir-Hinshelwood Mechanism, Eley-Rideal Mechanism, steady-state approximation, quasi-equilibrium approximation, most abundant reaction intermediate (MARI), reaction order, apparent activation energy, example: CO oxidation, transition state theory of surface reactions, Sabatier´s principle, sticking coefficient, parameter fitting<br><br>- Explosions, cold flames |
| **Literature** | J. I. Steinfeld, J. S. Francisco, W. L . Hase: Chemical Kinetics & Dynamics, Prentice Hall<br><br>K. J. Laidler: Chemical Kinetics, Harper & Row Publishers<br><br>R. K. Masel. Chemical Kinetics & Catalysis , Wiley<br><br>I. Chorkendorff,, J. W. Niemantsverdriet: Concepts of modern Catalysis and Kinetics, Wiley |

| Course L2021: Solid Matter Process in chemical Industry | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Schriftliche Ausarbeitung |
| **Examination duration and scale** | 12 Seiten |
| **Lecturer** | Prof. Frank Kleine Jäger |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | |
| **Literature** | |

| Course L0194: Interfaces and Colloids | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Schriftliche Ausarbeitung |
| **Examination duration and scale** | 1 Stunde |
| **Lecturer** | Dr. Philip Jaeger |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | 1.Fundamentals, definitions 1.1 Thermodynamics of interfaces 1.2 Surfactants 1.3 Interfacial tension (Principles, Methods, Examples) 1.4 Wetting, adhesion 2.Dispersions 2.1 Droplet formation 2.2 Stabilization 2.3 Physical Properties 2.4 Rheology 2.5 Microemulsions 3. Transport Phenomena 3.1 Mass transport across phase boundaries 3.2 Interfacial convection - Marangoni flow 3.3 Influence of surfactants on interfacial area and transport resistance (bubbles, droplets, falling films) 4. Applications 4.1 Food Emulsification 4.2 Crude oil recovery (EOR) 4.3 Coating 4.4 Separation technology (Spray towers, packed columns) 4.5 Nucleation (Polymer foams, evaporation) 4.6 Recent developments (Surfactant aided extraction) |
| **Literature** | A.W. Adamson: Physical Chemistry of Surfaces, 5th ed., J. Wiley & Sons New York, 1990. P. Becher : Emulsions - Theory and Practice, 1965. P. Becher : Encyclopedia of Emulsion Technology, Vol. 1, Dekker New York, 1983. S.S. Dukhin, G. Kretzschmar, R. Miller: Dynamics of Adsorption at Liquid Interfaces, Elsevier Amsterdam, 1995. D.J. McClements: Food Emulsions - Principle, Practices and Techniques, 2nd ed., CRC Press Boca Raton, 2005. D. Myers: Surfaces, Interfaces and Colloids, VCH-Verlagsgesellschaft Weinheim, 1991. P. Sherman: Emulsion Science, 1968. J. Lyklema: Fundamentals of Interface and Colloid Science, Vol. III, Academic Press London, 2000. A.I. Rusanov: Phasengleichgewichte und Grenzflächenerscheinungen, Akademie Verlag, Berlin 1978. P. C. Hiemenz, R. Rajagopalan: Principles of Colloid and Surface Chemistry, 3rd ed. Marcel Dekker, New York 1997. P. Grassmann: Physikalische Grundlagen der Verfahrenstechnik, Verlag Salle und Sauerländer, 1983. M.J. Schwuger: Lehrbuch der Grenzflächenchemie, Thieme Verlag, 1996. |

| Course L0531: Industrial Inorganic and Organic Processes | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Klausur |
| **Examination duration and scale** | 45 Minuten |
| **Lecturer** | Dr. Achim Bartsch |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | The occupational area of chemical engineers is principally the chemical industry.<br><br>This survey course will focus on history, economic significance, technical applications, and main production processes in detail of major primary bulk inorganic and organic chemicals. Disposition of raw materials as well as ecological problems are discussed.<br><br>Inorganic Products<br><br>* inorganic raw materials (hydrogen and compounds, nitrogen and compounds...)<br><br>* inorganic fertilizers<br><br>* metals and their compounds<br><br>* semiconductors<br><br>* inorganic solids (building materials, ceramics, fibers, pigments ...)<br><br>...<br><br>Organic Products<br><br>* bulk products for organic synthesis (synthesis gas, C1-compounds)<br><br>* Production and processing of olefines, alcohols, hydrocarbons, aromatics<br><br>* Petroleum and Petrochemicals<br><br>* Surfactants and Detergents<br><br>* Production and processing of oleochemicals<br><br>* Synthetic Polymers<br><br>... |
| **Literature** | Ullmann's Encyclopedia of Industrial Chemistry, Wiley online library 2014<br><br>M. Bertau, A. Müller, P. Fröhlich und M. Katzberg: Industrielle Anorganische Chemie, Wiley-VCH 2013<br><br>Hans-Jürgen Arpe: Industrielle Organische Chemie, Wiley-VCH 2007 |

| Course L2276: Industrial biotechnology in Chemical Industriy | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Examination Form** | Referat |
| **Examination duration and scale** | 45 min |
| **Lecturer** | Prof. Andreas Liese, Dr. Stephan Freyer |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | This course gives an insight into the applications, processes, structures and boundary conditions in industrial practice. Various concrete applications of the technology, markets and other questions that will significantly influence the plant and process design will be shown. |
| **Literature** | Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen]<br><br>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.<br><br>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract<br><br>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003<br><br>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage<br><br>Krahe M (2003) Biochemical Engineering. Ullmann´s Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html<br><br>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts |

| Course L2437: Optics for Engineers | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Fachtheoretisch-fachpraktische Arbeit |
| **Examination duration and scale** | Vorstellung eines eigenen Optikentwurfs mit anschließender Diskussion, 10 Minuten Vorstellung + maximal 20 Minuten Diskussion |
| **Lecturer** | Prof. Thorsten Kern |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Basic values for optical systems and lighting technology<br>• Spectrum, black-bodies, color-perception<br>• Light-Sources und their characterization<br>• Photometrics<br>• Ray-Optics<br>• Matrix-Optics<br>• Stops, Pupils and Windows<br>• Light-field Technology<br>• Introduction to Wave-Optics<br>• Introduction to Holography |
| **Literature** | |

| Course L2438: Optics for Engineers | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Fachtheoretisch-fachpraktische Arbeit |
| **Examination duration and scale** | Vorstellung eines eigenen Optikentwurfs mit anschließender Diskussion, 10 Minuten Vorstellung + maximal 20 Minuten Diskussion |
| **Lecturer** | Prof. Thorsten Kern |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L1244: Polymer Reaction Engineering | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Schriftliche Ausarbeitung |
| **Examination duration and scale** | 1 Stunde |
| **Lecturer** | Prof. Hans-Ulrich Moritz |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | Introduction into polymer reaction engineering, free and controlled radical polymerization, coordination polymerization of olefins, ionic “living” polymerization, step polymerization (polyaddition, polycondensation), copolymerization, emulsion polymerization, specific challenges of the industrial implementation of polymerization reactions (viscosity increase, heat removal, scale-up, reactor safety, modelling of polymerization reactions and reactors), key competitive factors in polymer industry in Germany, EU and worldwide. |
| **Literature** | W. Keim: Kunststoffe - Synthese, Herstellungsverfahren, Apparaturen, 1. Auflage, Wiley-VCH, 2006<br>T. Meyer, J. Keurentjes: Handbook of Polymer Reaction Engineering, 2 Vol., 1. Ed., Wiley-VCH, 2005<br>A. Echte: Handbuch der technischen Polymerchemie, 1. Auflage, VCH-Verlagsgesellschaft, 1993<br>G. Odian: Principles of Polymerization, 4. Ed., Wiley-Interscience, 2004<br>J. Asua: Polymer Reaction Engineering, 1. Ed., Blackwell Publishing, 2007 |

| Course L2275: Practice in bioprocess engineering | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Examination Form** | Referat |
| **Examination duration and scale** | 45 min |
| **Lecturer** | Prof. An-Ping Zeng, Prof. Ralf Pörtner, Dr. Willfried Blümke |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | Content of this course is a concrete insight into the principles, processes and structures of an industrial biotechnology company. In addition to practical illustrative examples, aspects beyond the actual process engineering area are also addressed, such as e.g. Sustainability and engineering. |
| **Literature** | Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen]<br>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.<br>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract<br>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003<br>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage<br>Krahe M (2003) Biochemical Engineering. Ullmann´s Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html<br>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts |

| Course L1321: Safety of Chemical Reactions | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Klausur |
| **Examination duration and scale** | |
| **Lecturer** | Prof. Hans-Ulrich Moritz |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | |
| **Literature** | |

| Course L0379: Ceramics Technology | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Examination Form** | Klausur |
| **Examination duration and scale** | 90 Minuten |
| **Lecturer** | Dr. Rolf Janßen |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | Introduction to ceramic processing with emphasis on advanced structural ceramics. The course focus predominatly on powder-based processing, e.g. “powder-metauurgical techniques and sintering (soild state and liquid phase). Also, some aspects of glass and cement science as well as new developments in powderless forming techniques of ceramics and ceramic composites will be addressed Examples will be discussed in order to give engineering students an understanding of technology development and specific applications of ceramic components.<br>**Content:** 1. Introduction<br>Inhalt: 2. Raw materials<br>3. Powder fabrication<br>4. Powder processing<br>5. Shape-forming processes<br>6. Densification, sintering<br>7. Glass and Cement technology<br>8. Ceramic-metal joining techniques |
| **Literature** | W.D. Kingery, „Introduction to Ceramics“, John Wiley & Sons, New York, 1975<br>ASM Engineering Materials Handbook Vol.4 „Ceramics and Glasses“, 1991<br>D.W. Richerson, „Modern Ceramic Engineering“, Marcel Decker, New York, 1992<br>Skript zur Vorlesung |

| Course L0354: Environmental Analysis | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Examination Form** | Klausur |
| **Examination duration and scale** | 45 Minuten |
| **Lecturer** | Dr. Dorothea Rechtenbach, Dr. Henning Mangels |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | Introduction<br>Sampling in different environmental compartments, sample transportation, sample storage<br>Sample preparation<br>Photometry<br>Wastewater analysis<br>Introduction into chromatography<br>Gas chromatography<br>HPLC<br>Mass spectrometry<br>Optical emission spectrometry<br>Atom absorption spectrometry<br>Quality assurance in environmental analysis |
| **Literature** | Roger Reeve, Introduction to Environmental Analysis, John Wiley & Sons Ltd., 2002 (TUB: USD-728)<br>Pradyot Patnaik, Handbook of environmental analysis: chemical pollutants in air, water, soil, and solid wastes, CRC Press, Boca Raton, 2010 (TUB: USD-716)<br>Chunlong Zhang, Fundamentals of Environmental Sampling and Analysis, John Wiley & Sons Ltd., Hoboken, New Jersey, 2007 (TUB: USD-741)<br>Miroslav Radojević, Vladimir N. Bashkin, Practical Environmental Analysis<br>RSC Publ., Cambridge, 2006 (TUB: USD-720)<br>Werner Funk, Vera Dammann, Gerhild Donnevert, Sarah Iannelli (Translator), Eric Iannelli (Translator), Quality Assurance in Analytical Chemistry: Applications in Environmental, Food and Materials Analysis, Biotechnology, and Medical Engineering, 2nd Edition, WILEY-VCH Verlag GmbH & Co. KGaA,Weinheim, 2007 (TUB: CHF-350)<br>STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER, 21st Edition, Andrew D. Eaton, Leonore S. Clesceri, Eugene W. Rice, and Arnold E. Greenberg, editors, 2005 (TUB:CHF-428)<br>K. Robards, P. R. Haddad, P. E. Jackson, Principles and Practice of<br>Modern Chromatographic Methods, Academic Press<br>G. Schwedt, Chromatographische Trennmethoden, Thieme Verlag<br>H. M. McNair, J. M. Miller, Basic Gas Chromatography, Wiley<br>W. Gottwald, GC für Anwender, VCH<br>B. A. Bidlingmeyer, Practical HPLC Methodology and Applications, Wiley<br>K. K. Unger, Handbuch der HPLC, GIT Verlag<br>G. Aced, H. J. Möckel, Liquidchromatographie, VCH<br>Charles B. Boss and Kenneth J. Fredeen, Concepts, Instrumentation and Techniques in Inductively Coupled Plasma Optical Emission Spectrometry<br>Perkin-Elmer Corporation 1997, On-line available at:<br>http://files.instrument.com.cn/bbs/upfile/2006291448.pdf<br>Atomic absorption spectrometry: theory, design and applications, ed. by S. J. Haswell 1991 (TUB: 2727-5614)<br>Royal Society of Chemistry, Atomic absorption spectometry (http://www.kau.edu.sa/Files/130002/Files/6785_AAs.pdf) |

## Module M0721: Air Conditioning

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Air Conditioning (L0594) | Lecture | 3 | 5 |
| Air Conditioning (L0595) | Recitation Section (large) | 1 | 1 |

| | |
|---|---|
| **Module Responsible** | Prof. Gerhard Schmitz |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Technical Thermodynamics I, II, Fluid Dynamics, Heat Transfer |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students know the different kinds of air conditioning systems for buildings and mobile applications and how these systems are controlled. They are familiar with the change of state of humid air and are able to draw the state changes in a h1+x,x-diagram. They are able to calculate the minimum airflow needed for hygienic conditions in rooms and can choose suitable filters. They know the basic flow pattern in rooms and are able to calculate the air velocity in rooms with the help of simple methods. They know the principles to calculate an air duct network. They know the different possibilities to produce cold and are able to draw these processes into suitable thermodynamic diagrams. They know the criteria for the assessment of refrigerants. |
| *Skills* | Students are able to configure air condition systems for buildings and mobile applications. They are able to calculate an air duct network and have the ability to perform simple planning tasks, regarding natural heat sources and heat sinks. They can transfer research knowledge into practice. They are able to perform scientific work in the field of air conditioning. |
| **Personal Competence** | |
| *Social Competence* | The students are able to discuss in small groups and develop an approach. |
| *Autonomy* | Students are able to define independently tasks, to get new knowledge from existing knowledge as well as to find ways to use the knowledge in practice. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 60 min |
| **Assignment for the Following Curricula** | Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory<br>Energy Systems: Specialisation Energy Systems: Elective Compulsory<br>Energy Systems: Specialisation Marine Engineering: Elective Compulsory<br>Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory<br>Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory<br>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0594: Air Conditioning | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 3 |
| **CP** | 5 |
| **Workload in Hours** | Independent Study Time 108, Study Time in Lecture 42 |
| **Lecturer** | Prof. Gerhard Schmitz |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | 1. Overview<br>1.1 Kinds of air conditioning systems<br>1.2 Ventilating<br>1.3 Function of an air condition system<br>2. Thermodynamic processes<br>2.1 Psychrometric chart<br>2.2 Mixer preheater, heater<br>2.3 Cooler<br>2.4 Humidifier<br>2.5 Air conditioning process in a Psychrometric chart<br>2.6 Desiccant assisted air conditioning<br>3. Calculation of heating and cooling loads<br>3.1 Heating loads<br>3.2 Cooling loads<br>3.3 Calculation of inner cooling load<br>3.4 Calculation of outer cooling load<br>4. Ventilating systems<br>4.1 Fresh air demand<br>4.2 Air flow in rooms<br>4.3 Calculation of duct systems<br>4.4 Fans<br>4.5 Filters<br>5. Refrigeration systems<br>5.1. compression chillers<br>5.2Absorption chillers |
| **Literature** | • Schmitz, G.: Klimaanlagen, Skript zur Vorlesung<br>• VDI Wärmeatlas, 11. Auflage, Springer Verlag, Düsseldorf 2013<br>• Herwig, H.; Moschallski, A.: Wärmeübertragung, Vieweg+Teubner Verlag, Wiesbaden 2009<br>• Recknagel, H.; Sprenger, E.; Schrammek, E.-R.: Taschenbuch für Heizung- und Klimatechnik 2013/2014, 76. Auflage, Deutscher Industrieverlag, 2013 |

| Course L0595: Air Conditioning | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Gerhard Schmitz |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0657: Computational Fluid Dynamics II

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Computational Fluid Dynamics II (L0237) | Lecture | 2 | 3 |
| Computational Fluid Dynamics II (L0421) | Recitation Section (large) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Thomas Rung |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basics of computational and general thermo/fluid dynamics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Establish a thorough understanding of Finite-Volume approaches. Familiarise with details of the theoretical background of complex CFD algorithms. |
| *Skills* | Ability to manage of interface problems and build-up of coding skills. Ability to evaluate, assess and benchmark different solution options. |
| **Personal Competence** | |
| *Social Competence* | Practice of team working during team exercises. |
| *Autonomy* | Indenpendent analysis of specific solution approaches. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Oral exam |
| **Examination duration and scale** | 0.5h-0.75h |
| **Assignment for the Following Curricula** | Energy Systems: Core qualification: Elective Compulsory<br>Naval Architecture and Ocean Engineering: Core qualification: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Core qualification: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

### Course L0237: Computational Fluid Dynamics II

| | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Thomas Rung |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | Computational Modelling of complex single- and multiphase flows using higher-order approximations for unstructured grids and mehsless particle-based methods. |
| **Literature** | 1)<br>Vorlesungsmanuskript und Übungsunterlagen<br><br>2)<br>J.H. Ferziger, M. Peric:<br>Computational Methods for Fluid Dynamics,<br>Springer |

### Course L0421: Computational Fluid Dynamics II

| | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Thomas Rung |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0749: Waste Treatment and Solid Matter Process Technology

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Solid Matter Process Technology for Biomass (L0052) | Lecture | 2 | 2 |
| Thermal Waste Treatment (L0320) | Lecture | 2 | 2 |
| Thermal Waste Treatment (L1177) | Recitation Section (large) | 1 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Kerstin Kuchta |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basics of<br>• thermo dynamics<br>• fluid dynamics<br>• chemistry |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students can name, describe current issue and problems in the field of thermal waste treatment and particle process engineering and contemplate them in the context of their field.<br><br>The industrial application of unit operations as part of process engineering is explained by actual examples of waste incineration technologies and solid biomass processes. Compostion, particle sizes, transportation and dosing, drying and agglomeration of renewable resources and wastes are described as important unit operations when producing solid fuels and bioethanol, producing and refining edible oils, electricity , heat and mineral recyclables. |
| *Skills* | The students are able to select suitable processes for the treatment of wastes or raw material with respect to their characteristics and the process aims. They can evaluate the efforts and costs for processes and select economically feasible treatment concepts. |
| **Personal Competence** | |
| *Social Competence* | Students can<br>• respectfully work together as a team and discuss technical tasks<br>• participate in subject-specific and interdisciplinary discussions,<br>• develop cooperated solutions<br>• promote the scientific development and accept professional constructive criticism. |
| *Autonomy* | Students can independently tap knowledge of the subject area and transform it to new questions. They are capable, in consultation with supervisors, to assess their learning level and define further steps on this basis. Furthermore, they can define targets for new application-or research-oriented duties in accordance with the potential social, economic and cultural impact. |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 120 min |
| **Assignment for the Following Curricula** | Civil Engineering: Specialisation Water and Traffic: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory<br>International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Elective Compulsory |

| Course L0052: Solid Matter Process Technology for Biomass | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Werner Sitzmann |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | The industrial application of unit operations as part of process engineering is explained by actual examples of solid biomass processes. Size reduction, transportation and dosing, drying and agglomeration of renewable resources are described as important unit operations when producing solid fuels and bioethanol, producing and refining edible oils, when making Btl - and WPC - products. Aspects of explosion protection and plant design complete the lecture. |
| **Literature** | Kaltschmitt M., Hartmann H. (Hrsg.): Energie aus Bioamsse, Springer Verlag, 2001, ISBN 3-540-64853-4<br><br>Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz, Schriftenreihe Nachwachsende Rohstoffe,<br><br>Fachagentur Nachwachsende Rohstoffe e.V. www.nachwachsende-rohstoffe.de<br><br>Bockisch M.: Nahrungsfette und -öle, Ulmer Verlag, 1993, ISBN 380000158175 |

| Course L0320: Thermal Waste Treatment | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Kerstin Kuchta |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Introduction, actual state-of-the-art of waste incineration, aims. legal background, reaction principals<br>• basics of incineration processes: waste composition, calorific value, calculation of air demand and flue gas composition<br>• Incineration techniques: grate firing, ash transfer, boiler<br>• Flue gas cleaning: Volume, composition, legal frame work and emission limits, dry treatment, scrubber, de-nox techniques, dioxin elimination, Mercury elimination<br>• Ash treatment: Mass, quality, treatment concepts, recycling, disposal |
| **Literature** | Thomé-Kozmiensky, K. J. (Hrsg.): Thermische Abfallbehandlung Bande 1-7. EF-Verlag für Energie- und Umwelttechnik, Berlin, 196 - 2013. |

| Course L1177: Thermal Waste Treatment | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Kerstin Kuchta |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0897: Computer Aided Process Engineering (CAPE)

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| CAPE with Computer Exercises (L1039) | Lecture | 2 | 3 |
| Methods of Process Safety and Dangerous Substances (L1040) | Lecture | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Georg Fieg |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | thermal separation processes<br>heat and mass transport processes |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | students can:<br>- outline types of simulation tools<br>- describe principles of flowsheet and equation oriented simulation tools<br>- describe the setting of flowsheet simulation tools<br>- explain the main differences between steady state and dynamic simulations<br>- present the fundamentals of toxicology and hazardous materials<br>- explain the main methods of safety engineering<br>- present the importance of safety analysis with respect to plant design<br>- describe the definitions within the legal accident insurance<br>accident insurance |
| *Skills* | students can:<br>- conduct steady state and dynamic simulations<br>- evaluate simulation results and transform them in the practice<br>- choose and combine suitable simulation models into a production plant<br>- evaluate the achieved simulation results regarding practical importance<br>- evaluate the results of many experimental methods regarding safety aspects<br>- review, compare and use results of safety considerations for a plant design |
| **Personal Competence** | |
| *Social Competence* | students are able to:<br>- work together in teams in order to simulate process elements and develop an integral process<br>- develop in teams a safety concept for a process and present it to the audience |
| *Autonomy* | students are able to<br>- act responsible with respect to environment and needs of the society |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |

| Course achievement | Compulsory | Bonus | Form | Description |
|---|---|---|---|---|
| | Yes | None | Group discussion | Gruppendiskussionen finden im Rahmen der PC-Übungen statt |

| | |
|---|---|
| **Examination** | Written exam |
| **Examination duration and scale** | 180 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L1039: CAPE with Computer Exercises | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Georg Fieg |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | I. Introduction<br><br>1. Fundamentals of steady state process simulation<br><br>1.1. Classes of simulation tools<br>1.2. Sequential-modularer approach<br>1.3. Operating mode of ASPEN PLUS<br>2. Introduction in ASPEN PLUS<br>2.1. GUI<br>2.2. Estimation methods of physical properties<br>2.3. Aspen tools (z.B. Designspecification)<br>2.4. Convergence methods<br><br>II. Exercices using ASPEN PLUS and ACM<br><br>Performance and constraints of ASPEN PLUS<br>ASPEN datenbank using<br>Estimation methods of physical properties<br>Application of model databank, process synthesis<br><br>Design specifications<br><br>Sensitivity analysis<br>Optimization tasks<br>Industrial cases |
| **Literature** | - G. Fieg: Lecture notes<br>- Seider, W.D.; Seader, J.D.; Lewin, D.R.: Product and Process Design Principles: Synthesis, Analysis, and Evaluation; Hoboken, J. Wiley & Sons, 2010 |

| Course L1040: Methods of Process Safety and Dangerous Substances | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Georg Fieg, Dr. Thomas Waluga |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | |
| **Literature** | Bender, H.: Sicherer Umgang mit Gefahrstoffen; Weinheim (2005)<br>Bender, H.: Das Gefahrstoffbuch. Sicherer Umgang mit Gefahrstoffen in der Praxis; Weinheim (2002)<br>Birett, K.: Umgang mit Gefahrstoffen; Heidelberg (2011)<br>Birgersson, B.; Sterner, O.; Zimerson, E.: Chemie und Gesundheit; Weinheim (1988)<br><br>O. Antelmann, Diss. an der TU Berlin, 2001<br>R. Dittmeyer, W. Keim, G. Kreysa, A. Oberholz, Chemische Technik, Prozesse und Produkte, Band 1<br><br>Methodische Grundlagen, VCH, 2004-2006, S. 719<br><br>H. Pohle, Chemische Industrie, Umweltschutz, Arbeitsschutz, Anlagensicherheit, VCH, Weinheim, 1991<br><br>J. Steinbach, Chemische Sicherheitstechnik, VCH, Weinheim, 1995<br><br>G. Suter, Identifikation sicherheitskritischer Prozesse, P&A Kompendium, 2004 |

## Module M0898: Heterogeneous Catalysis

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Analysis and Design of Heterogeneous Catalytic Reactors (L0223) | Lecture | 2 | 2 |
| Modern Methods in Heterogeneous Catalysis (L0533) | Lecture | 2 | 2 |
| Modern Methods in Heterogeneous Catalysis (L0534) | Practical Course | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Raimund Horn |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Content of the bachelor-modules "process technology", as well as particle technology, fluidmechanics in process-technology and transport processes. |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students are able to apply their knowledge to explain industrial catalytic processes as well as indicate different synthesis routes of established catalyst systems. They are capable to outline dis-/advantages of supported and full-catalysts with respect to their application. Students are able to identify anayltical tools for specific catalytic applications. |
| *Skills* | After successfull completition of the module, students are able to use their knowledge to identify suitable analytical tools for specific catalytic applications and to explain their choice. Moreover the students are able to choose and formulate suitable reactor systems for the current synthesis process. Students can apply their knowldege discretely to develop and conduct experiments. They are able to appraise achieved results into a more general context and draw conclusions out of them. |
| **Personal Competence** | |
| *Social Competence* | The students are able to plan, prepare, conduct and document experiments according to scientific guidelines in small groups.<br>The students can discuss their subject related knowledge among each other and with their teachers. |
| *Autonomy* | The students are able to obtain further information for experimental planning and assess their relevance autonomously. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | **Compulsory** / **Bonus** / **Form** / **Description**<br>Yes / None / Presentation |
| **Examination** | Written exam |
| **Examination duration and scale** | 120 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Core qualification: Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0223: Analysis and Design of Heterogeneous Catalytic Reactors | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Raimund Horn |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | 1. Material- and Energybalance of the two-dimensionsal zweidimensionalen pseudo-homogeneous reactor model<br><br>2. Numerical solution of ordinary differential equations (Euler, Runge-Kutta, solvers for stiff problems, step controlled solvers)<br><br>3. Reactor design with one-dimensional models (ethane cracker, catalyst deactivation, tubular reactor with deactivating catalyst, moving bed reactor with regenerating catalyst, riser reactor, fluidized bed reactor)<br><br>4. Partial differential equations (classification, numerical solution Lösung, finite difference method, method of lines)<br><br>5. Examples of reactor design (isothermal tubular reactor with axial dispersion, dehydrogenation of ethyl benzene, wrong-way behaviour)<br><br>6. Boundary value problems (numerical solution, shooting method, concentration- and temperature profiles in a catalyst pellet, multiphase reactors, trickle bed reactor) |
| **Literature** | 1. Lecture notes R. Horn<br><br>2. Lecture notes F. Keil<br><br>3. G. F. Froment, K. B. Bischoff, J. De Wilde, Chemical Reactor Analysis and Design, John Wiley & Sons, 2010<br><br>4. R. Aris, Elementary Chemical Reactor Analysis, Dover Pubn. Inc., 2000 |

| Course L0533: Modern Methods in Heterogeneous Catalysis | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Raimund Horn |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | Heterogeneous Catalysis and Chemical Reaction Engineering are inextricably linked. About 90% of all chemical intermediates and consumer products (fuels, plastics, fertilizers etc.) are produced with the aid of catalysts. Most of them, in particular large scale products, are produced by heterogeneous catalysis viz. gaseous or liquid reactants react on solid catalysts. In multiphase reactors gases, liquids and a solid catalyst are present.<br><br>Heterogeneous catalysis plays also a key role in any future energy scenario (fuel cells, electrocatalytic splitting of water) and in environmental engineering (automotive catalysis, photocatalyic abatement of water pollutants).<br><br>Heterogeneous catalysis is an interdisciplinary science requiring knowledge of different scientific disciplines such as<br><br>• Materials Science (synthesis and characterization of solid catalysts)<br>• Physics (structure and electronic properties of solids, defects)<br>• Physical Chemistry (thermodynamics, reaction mechanisms, chemical kinetics, adsorption, desorption, spectroscopy, surface chemistry, theory)<br>• Reaction Engineering (catalytic reactors, mass- and heat transport in catalytic reactors, multi-scale modeling, application of heterogeneous catalysis)<br><br>The class „Modern Methods in Heterogeneous Catalysis“ will deal with the above listed aspects of heterogeneous catalysis beyond the material presented in the normal curriculum of chemical reaction engineering classes. In the corresponding laboratory will have the opportunity to apply their aquired theoretical knowledge by synthesizing a solid catalyst, characterizing it with a variety of modern instrumental methods (e.g. BET, chemisorption, pore analysis, XRD, Raman-Spectroscopy, Electron Microscopy) and measuring its kinetics. Class and laboratory „Modern Methods in Heterogeneous Catalysis“ in combination with the lecture „Analysis and Design of Heterogeneous Catalytic Reactors“ will give interested students the opportunity to specialize in this vibrant, multifaceted and application oriented field of research. |
| **Literature** | • J.M. Thomas, W.J. Thomas: Principles and Practice of Heterogeneous Catalysis, VCH<br>• I. Chorkendorff, J. W. Niemantsverdriet, Concepts of Modern Catalysis and Kinetics, WILEY-VCH<br>• B.C. Gates: Catalytic Chemistry, John Wiley<br>• R.A. van Santen, P.W.N.M. van Leeuwen, J.A. Moulijn, B.A. Averill (Eds.): Catalysis: an integrated approach, Elsevier<br>• D.P. Woodruff, T.A. Delchar: Modern Techniques of Surface Science, Cambridge Univ. Press<br>• J.W. Niemantsverdriet: Spectrocopy in Catalysis, VCH<br>• F. Delannay (Ed.): Characterization of heterogeneous catalysts, Marcel Dekker<br>• C.H. Bartholomew, R.J. Farrauto: Fundamentals of Industrial Catalytic Processes (2nd Ed.),Wiley |

| Course L0534: Modern Methods in Heterogeneous Catalysis | |
|---|---|
| **Typ** | Practical Course |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Raimund Horn |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0906: Numerical Simulation and Lagrangian Transport

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Lagrangian transport in turbulent flows (L2301) | Lecture | 2 | 3 |
| Computational Fluid Dynamics - Exercises in OpenFoam (L1375) | Recitation Section (small) | 1 | 1 |
| Computational Fluid Dynamics in Process Engineering (L1052) | Lecture | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Michael Schlüter |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Mathematics I-IV<br>• Basic knowledge in Fluid Mechanics<br>• Basic knowledge in chemical thermodynamics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After successful completion of the module the students are able to<br>• explain the the basic principles of statistical thermodynamics (ensembles, simple systems)<br>• describe the main approaches in classical Molecular Modeling (Monte Carlo, Molecular Dynamics) in various ensembles<br>• discuss examples of computer programs in detail,<br>• evaluate the application of numerical simulations,<br>• list the possible start and boundary conditions for a numerical simulation. |
| *Skills* | The students are able to:<br>• set up computer programs for solving simple problems by Monte Carlo or molecular dynamics,<br>• solve problems by molecular modeling,<br>• set up a numerical grid,<br>• perform a simple numerical simulation with OpenFoam,<br>• evaluate the result of a numerical simulation. |
| **Personal Competence** | |
| *Social Competence* | The students are able to<br>• develop joint solutions in mixed teams and present them in front of the other students,<br>• to collaborate in a team and to reflect their own contribution toward it. |
| *Autonomy* | The students are able to:<br>• evaluate their learning progress and to define the following steps of learning on that basis,<br>• evaluate possible consequences for their profession. |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Oral exam |
| **Examination duration and scale** | 30 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L2301: Lagrangian transport in turbulent flows | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Alexandra von Kameke |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | |
| **Literature** | |

| Course L1375: Computational Fluid Dynamics - Exercises in OpenFoam | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Michael Schlüter |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • generation of numerical grids with a common grid generator<br>• selection of models and boundary conditions<br>• basic numerical simulation with OpenFoam within the TUHH CIP-Pool |
| **Literature** | OpenFoam Tutorials (StudIP) |

| Course L1052: Computational Fluid Dynamics in Process Engineering | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Michael Schlüter |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Introduction into partial differential equations<br>• Basic equations<br>• Boundary conditions and grids<br>• Numerical methods<br>• Finite difference method<br>• Finite volume method<br>• Time discretisation and stability<br>• Population balance<br>• Multiphase Systems<br>• Modeling of Turbulent Flows<br>• Exercises: Stability Analysis<br>• Exercises: Example on CFD - analytically/numerically |
| **Literature** | Paschedag A.R.: CFD in der Verfahrenstechnik: Allgemeine Grundlagen und mehrphasige Anwendungen, Wiley-VCH, 2004 ISBN 3-527-30994-2.<br><br>Ferziger, J.H.; Peric, M.: Numerische Strömungsmechanik. Springer-Verlag, Berlin, 2008, ISBN: 3540675868.<br><br>Ferziger, J.H.; Peric, M.: Computational Methods for Fluid Dynamics. Springer, 2002, ISBN 3-540-42074-6 |

## Module M0633: Industrial Process Automation

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Industrial Process Automation (L0344) | Lecture | 2 | 3 |
| Industrial Process Automation (L0345) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Alexander Schlaefer |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | mathematics and optimization methods<br>principles of automata<br>principles of algorithms and data structures<br>programming skills |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students can evaluate and assess discrete event systems. They can evaluate properties of processes and explain methods for process analysis. The students can compare methods for process modelling and select an appropriate method for actual problems. They can discuss scheduling methods in the context of actual problems and give a detailed explanation of advantages and disadvantages of different programming methods. The students can relate process automation to methods from robotics and sensor systems as well as to recent topics like 'cyberphysical systems' and 'industry 4.0'. |
| *Skills* | The students are able to develop and model processes and evaluate them accordingly. This involves taking into account optimal scheduling, understanding algorithmic complexity, and implementation using PLCs. |
| **Personal Competence** | |
| *Social Competence* | The students work in teams to solve problems. |
| *Autonomy* | The students can reflect their knowledge and document the results of their work. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |

**Course achievement**

| Compulsory | Bonus | Form | Description |
|---|---|---|---|
| No | 10 % | Excercises | |

| | |
|---|---|
| **Examination** | Written exam |
| **Examination duration and scale** | 90 minutes |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory<br>Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory<br>International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory<br>International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory<br>Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory<br>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0344: Industrial Process Automation | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Alexander Schlaefer |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | - foundations of problem solving and system modeling, discrete event systems<br>- properties of processes, modeling using automata and Petri-nets<br>- design considerations for processes (mutex, deadlock avoidance, liveness)<br>- optimal scheduling for processes<br>- optimal decisions when planning manufacturing systems, decisions under uncertainty<br>- software design and software architectures for automation, PLCs |
| **Literature** | J. Lunze: „Automatisierungstechnik“, Oldenbourg Verlag, 2012<br>Reisig: Petrinetze: Modellierungstechnik, Analysemethoden, Fallstudien; Vieweg+Teubner 2010<br>Hrúz, Zhou: Modeling and Control of Discrete-event Dynamic Systems; Springer 2007<br>Li, Zhou: Deadlock Resolution in Automated Manufacturing Systems, Springer 2009<br>Pinedo: Planning and Scheduling in Manufacturing and Services, Springer 2009 |

| Course L0345: Industrial Process Automation | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Alexander Schlaefer |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0705: Groundwater

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Geohydraulic and Solute Transport (L0539) | Lecture | 2 | 2 |
| Geohydraulic and Solute Transport (L0540) | Recitation Section (small) | 1 | 1 |
| Simulation in Groundwater Hydrology (L0541) | Lecture | 1 | 1 |
| Simulation in Groundwater Hydrology (L0542) | Recitation Section (small) | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | NN |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Ground water hydrology<br>• Hydromechanics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students are able to describe the fate of solutes in the subsurface along the path between soil and water body quantitatively and qualitatively. They are able to do this with simulation models. |
| *Skills* | The students are able to describe conceptually movement and storage of water in the unsaturated zone. They are able to analyse pF- functions and Ku functions. They can model transport of solutes in the unsaturated and saturated zoned. They are able to determine dispersiities, sorption coefficients, decay rates and dissolution rates for organic and inorganic substances. |
| **Personal Competence** | |
| *Social Competence* | The students can help to each other. |
| *Autonomy* | none |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 60 min written exam and written papers |
| **Assignment for the Following Curricula** | Civil Engineering: Specialisation Structural Engineering: Elective Compulsory<br>Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory<br>Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory<br>Civil Engineering: Specialisation Water and Traffic: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Water: Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Elective Compulsory |

### Course L0539: Geohydraulic and Solute Transport

| | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Wilfried Schneider |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | Pump test analysis, water content-water suction functions, unsaturated hydraulic conductivity function, Brooks-Corey relation, van Genuchten relation, solute transport in unsaturated zone, solute transport and reactions in groundwater |
| **Literature** | Todd; K. (2005): Groundwater Hydrology<br>Fetter, C.W. (2001): Applied Hydrogeology<br>Hölting & Coldewey (2005): Hydrogeologie<br>Charbeneau, R.J. (2000): Groundwater Hydraulics and pollutant Transport |

| Course L0540: Geohydraulic and Solute Transport | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Wilfried Schneider |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L0541: Simulation in Groundwater Hydrology | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Sonja Götz (geb. Schröter) |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | Basics and theoretical background of simulation models frequently used in science and practise for pumping test analysis, water movement in vadose zone, solute transport in vadose zone, groundwater recharge, solute transport in groundwater |
| **Literature** | Handbücher der verwendeten Slumationsmodelle werden bereitgestellt. |

| Course L0542: Simulation in Groundwater Hydrology | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Sonja Götz (geb. Schröter) |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0876: Aquatic Chemistry

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Chemistry of Drinking Water Treatment (L0311) | Lecture | 2 | 1 |
| Chemistry of Drinking Water Treatment (L0312) | Recitation Section (large) | 1 | 2 |
| Practical Course Aquatic Chemistry (L0965) | Practical Course | 4 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Kerstin Kuchta |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | none |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students are able to describe the solubility of gases, carbonic acid system and calcium carbonate, blending, softening and redox processes as well as materials and legal requirements on drinking water treatment. |
| *Skills* | The participants must take responsibility for partial aspects of the practical course within the group.<br><br>In addition, the participants are able to compile and evaluate designs and layouts of plants and test transcripts as well as the analysis and techniques, measurements and professional relevant methods. Out of the need to prepare laboratory transcripts on the experiments the students can communicate in a technical way and debate their own results in detail in a group. |
| **Personal Competence** | |
| *Social Competence* | Students can work together as a team of 2-5 persons, participate in subject-specific and interdisciplinary discussions, develop cooperated solutions and defend their own work results in front of others and promote the scientific development of colleagues. Furthermore, they can give and accept professional constructive criticisms. |
| *Autonomy* | Students can accumulate knowledge of the subject area and practice it in the lab. |
| **Workload in Hours** | Independent Study Time 82, Study Time in Lecture 98 |
| **Credit points** | 6 |
| **Course achievement** | **Compulsory** **Bonus** **Form** **Description**<br>Yes None Written elaboration |
| **Examination** | Written exam |
| **Examination duration and scale** | 1 hour |
| **Assignment for the Following Curricula** | Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0311: Chemistry of Drinking Water Treatment | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 2, Study Time in Lecture 28 |
| **Lecturer** | Dr. Klaus Johannsen |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | The topic of this course is water chemistry with respect to drinking water treatment and water distribution<br><br>Major topics are solubility of gases, carbonic acid system and calcium carbonate, blending, softening, redox processes, materials and legal requirements on drinking water treatment. Focus is put on generally accepted rules of technology (DVGW- and DIN-standards).<br><br>Special emphasis is put on calculations using realistic analysis data (e.g. calculation of pH or calcium carbonate dissolution potential) in exercises. Students can get a feedback and gain extra points for exam by solving problems for homework.<br><br>Knowledge of drinking water treatment processes is vital for this lecture. Therefore the most important processes are explained coordinated with the course " Water resources management" in the beginning of the semester. |
| **Literature** | **MHW (rev. by Crittenden, J. et al.):** Water treatment principles and design. John Wiley & Sons, Hoboken, 2005.<br><br>**Stumm, W., Morgan, J.J.**: Aquatic chemistry. John Wiley & Sons, New York, 1996.<br><br>**DVGW (Hrsg.):** Wasseraufbereitung - Grundlagen und Verfahren. Oldenbourg Industrie Verlag, München, 2004.<br><br>**Jensen, J. N.**: A Problem Solving Approach to Aquatic Chemistry. John Wiley & Sons, Inc., New York, 2003. |

| Course L0312: Chemistry of Drinking Water Treatment | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Dr. Klaus Johannsen |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L0965: Practical Course Aquatic Chemistry | |
|---|---|
| **Typ** | Practical Course |
| **Hrs/wk** | 4 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 34, Study Time in Lecture 56 |
| **Lecturer** | Prof. Kerstin Kuchta |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | The practical course is conducted as a block course and lasts for 1 week. There are simple but typical methods for chemical analysis for water, sewage, soil and waste taught, which serve the students as the basis for their later work in this area.<br><br>In this practical course for example the Institutes of Wastewater Management and Water Protection (IAG), Environmental Technology and Energy Economics(IUE), Water Resources and Water Supply (IWW) are involved.<br>In the following examples of experiments and methods taught in the course are summarized:<br><br>• Surface waters: sampling of water and sediment<br>• Determination of the pH-value<br>• Determination of the redox potential<br>• Determination of a heavy metal (Zn)<br>• Acid neutralizing capacity (sediment)<br>• Flocculation or co-precipitation of water-suspended titanium dioxide particles<br>• Precipitation of phosphate with Fe3 +<br>• determine the toxicity of wastewater componentsagainst bacteria<br>• denitrification<br>• Electrical conductivity<br>• Acid and base capacity (m-and p-value)<br>• Determination of permanent gases (H2, O2, N2, CO2, CH4) in Landfill Gas<br>• Determining a grading curve by screens<br>• Determination of volatile organic acids and the total content of inorganic carbonate (FOS / TAC) by means of pH titration in samples from biogas plants |
| **Literature** | |

## Module M0881: Mathematical Image Processing

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Mathematical Image Processing (L0991) | Lecture | 3 | 4 |
| Mathematical Image Processing (L0992) | Recitation Section (small) | 1 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Marko Lindner |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Analysis: partial derivatives, gradient, directional derivative<br>• Linear Algebra: eigenvalues, least squares solution of a linear system |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to<br>• characterize and compare diffusion equations<br>• explain elementary methods of image processing<br>• explain methods of image segmentation and registration<br>• sketch and interrelate basic concepts of functional analysis |
| *Skills* | Students are able to<br>• implement and apply elementary methods of image processing<br>• explain and apply modern methods of image processing |
| **Personal Competence** | |
| *Social Competence* | Students are able to work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge) and to explain theoretical foundations. |
| *Autonomy* | • Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them.<br>• Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Oral exam |
| **Examination duration and scale** | 20 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Computer Science: Specialisation III. Mathematics: Elective Compulsory<br>Computational Science and Engineering: Specialisation III. Mathematics: Elective Compulsory<br>Mechatronics: Technical Complementary Course: Elective Compulsory<br>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory<br>Mechatronics: Specialisation System Design: Elective Compulsory<br>Technomathematics: Specialisation I. Mathematics: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0991: Mathematical Image Processing | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 3 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 78, Study Time in Lecture 42 |
| **Lecturer** | Prof. Marko Lindner |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | • basic methods of image processing<br>• smoothing filters<br>• the diffusion / heat equation<br>• variational formulations in image processing<br>• edge detection<br>• de-convolution<br>• inpainting<br>• image segmentation<br>• image registration |
| **Literature** | Bredies/Lorenz: Mathematische Bildverarbeitung |

| Course L0992: Mathematical Image Processing | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Marko Lindner |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0537: Applied Thermodynamics: Thermodynamic Properties for Industrial Applications

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Applied Thermodynamics: Thermodynamic Properties for Industrial Applications (L0100) | Lecture | 4 | 3 |
| Applied Thermodynamics: Thermodynamic Properties for Industrial Applications (L0230) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Dr. Sven Jakobtorweihen |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Thermodynamics III |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students are capable to formulate thermodynamic problems and to specify possible solutions. Furthermore, they can describe the current state of research in thermodynamic property predictions. |
| *Skills* | The students are capable to apply modern thermodynamic calculation methods to multi-component mixtures and relevant biological systems. They can calculate phase equilibria and partition coefficients by applying equations of state, gE models, and COSMO-RS methods. They can provide a comparison and a critical assessment of these methods with regard to their industrial relevance. The students are capable to use the software COSMOtherm and relevant property tools of ASPEN and to write short programs for the specific calculation of different thermodynamic properties. They can judge and evaluate the results from thermodynamic calculations/predictions for industrial processes. |
| **Personal Competence** | |
| *Social Competence* | Students are capable to develop and discuss solutions in small groups; further they can translate these solutions into calculation algorithms. |
| *Autonomy* | Students can rank the field of “Applied Thermodynamics” within the scientific and social context. They are capable to define research projects within the field of thermodynamic data calculation. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | **Compulsory** **Bonus** **Form** **Description**<br>Yes None Written elaboration |
| **Examination** | Oral exam |
| **Examination duration and scale** | 1 Stunde Gruppenprüfung |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Core qualification: Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0100: Applied Thermodynamics: Thermodynamic Properties for Industrial Applications | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 4 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 34, Study Time in Lecture 56 |
| **Lecturer** | Dr. Sven Jakobtorweihen, Prof. Ralf Dohrn |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Phase equilibria in multicomponent systems<br>• Partioning in biorelevant systems<br>• Calculation of phase equilibria in colloidal systems: UNIFAC, COSMO-RS (exercises in computer pool)<br>• Calculation of partitioning coefficients in biological membranes: COSMO-RS (exercises in computer pool)<br>• Application of equations of state (vapour pressure, phase equilibria, etc.) (exercises in computer pool)<br>• Intermolecular forces, interaction Potenitials<br>• Introduction in statistical thermodynamics |
| **Literature** | |

| Course L0230: Applied Thermodynamics: Thermodynamic Properties for Industrial Applications | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Sven Jakobtorweihen, Prof. Ralf Dohrn |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | exercises in computer pool, see lecture description for more details |
| **Literature** | - |

## Module M0899: Synthesis and Design of Industrial Processes

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Synthesis and Design of Industrial Facilities (L1048) | Lecture | 1 | 2 |
| Industrial Plant Design and Economics (L1977) | Project-/problem-based Learning | 3 | 4 |

| | |
|---|---|
| **Module Responsible** | Prof. Mirko Skiborowski |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | process and plant engineering I and II<br>thermal separation processes<br>heat and mass transport processes<br>CAPE (absolut necessarily!) |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | students can:<br>- reproduce the main elements of design of industrial processes<br>- give an overview and explain the phases of design<br>- describe and explain energy, mass balances, cost estimation methods and economic evaluation of invest projects<br>- justify and discuss process control concepts and fundamentals of process optimization |
| *Skills* | students are capable of:<br>-conduction and evaluation of design of unit operations<br>- combination of unit operation to a complex process plant<br>- use of cost estimation methods for the prediction of production costs<br>- carry out the pfd-diagram |
| **Personal Competence** | |
| *Social Competence* | students are able to discuss and develop in groups the design of an industrial process |
| *Autonomy* | students are able to reflect the consequences of their professional activity |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Subject theoretical and practical work |
| **Examination duration and scale** | Engineering Handbook and oral exam (20 min) |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L1048: Synthesis and Design of Industrial Facilities | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Mirko Skiborowski, Dr. Thomas Waluga |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | Presentation of the task<br>Introduction to design and analysis of a chemical processing plant (example chemical processing plants)<br>Discussion of the process, preparation of process flow diagram<br>Calculation of material balance<br>Calculation of energy balance<br>Designing/Sizing of the equipment<br>Capital cost estimation<br>Production cost estimation<br>Process control & HAZOP Study<br>Lecture 11 = Process optimization<br>Lecture 12 = Final Project Presentation |
| **Literature** | Richard Turton; Analysis, Synthesis and Design of Chemical Processes:International Edition<br>Harry Silla; Chemical Process Engineering: Design And Economics<br>Coulson and Richardson's Chemical Engineering, Volume 6, Second Edition: Chemical Engineering Design<br>Lorenz T. Biegler;Systematic Methods of Chemical Process Design<br>Max S. Peters, Klaus Timmerhaus; Plant Design and Economics for Chemical Engineers<br>James Douglas; Conceptual Design of Chemical Processes<br>Robin Smith; Chemical Process: Design and Integration<br>Warren D. Seider; Process design principles, synthesis analysis and evaluation |

| Course L1977: Industrial Plant Design and Economics | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 3 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 78, Study Time in Lecture 42 |
| **Lecturer** | Prof. Mirko Skiborowski, Dr. Thomas Waluga |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | Introduction<br>Flowsheet (Discussion)<br>Mass and Energy Balances<br>Economics<br>Process Safety |
| **Literature** | Richard Turton; Analysis, Synthesis and Design of Chemical Processes:International Edition<br>Harry Silla; Chemical Process Engineering: Design And Economics<br>Coulson and Richardson's Chemical Engineering, Volume 6, Second Edition: Chemical Engineering Design<br>Lorenz T. Biegler;Systematic Methods of Chemical Process Design<br>Max S. Peters, Klaus Timmerhaus; Plant Design and Economics for Chemical Engineers<br>James Douglas; Conceptual Design of Chemical Processes<br>Robin Smith; Chemical Process: Design and Integration<br>Warren D. Seider; Process design principles, synthesis analysis and evaluation |

## Module M0545: Separation Technologies for Life Sciences

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Chromatographic Separation Processes (L0093) | Lecture | 2 | 2 |
| Unit Operations for Bio-Related Systems (L0112) | Lecture | 2 | 2 |
| Unit Operations for Bio-Related Systems (L0113) | Project-/problem-based Learning | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Irina Smirnova |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Fundamentals of Chemistry, Fluid Process Engineering, Thermal Separation Processes, Chemical Engineering, Chemical Engineering, Bioprocess Engineering<br><br>Basic knowledge in thermodynamics and in unit operations related to thermal separation processes |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | On completion of the module, students are able to present an overview of the basic thermal process technology operations that are used, in particular, in the separation and purification of biochemically manufactured products. Students can describe chromatographic separation techniques and classic and new basic operations in thermal process technology and their areas of use. In their choice of separation operation students are able to take the specific properties and limitations of biomolecules into consideration. Using different phase diagrams they can explain the principle behind the basic operation and its suitability for bioseparation problems. |
| *Skills* | On completion of the module, students are able to assess the separation processes for bio- and pharmaceutical products that have been dealt with for their suitability for a specific separation problem. They can use simulation software to establish the productivity and economic efficiency of bioseparation processes. In small groups they are able to jointly design a downstream process and to present their findings in plenary and summarize them in a joint report. |
| **Personal Competence** | |
| *Social Competence* | Students are able in small heterogeneous groups to jointly devise a solution to a technical problem by using project management methods such as keeping minutes and sharing tasks and information. |
| *Autonomy* | Students are able to prepare for a group assignment by working their way into a given problem on their own. They can procure the necessary information from suitable literature sources and assess its quality themselves. They are also capable of independently preparing the information gained in a way that all participants can understand (by means of reports, minutes, and presentations). |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | **Compulsory** Yes; **Bonus** None; **Form** Presentation; **Description** |
| **Examination** | Written exam |
| **Examination duration and scale** | 120 minutes; theoretical questions and calculations |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Core qualification: Compulsory<br>Chemical and Bioprocess Engineering: Core qualification: Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0093: Chromatographic Separation Processes | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Monika Johannsen |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Introduction: overview, history of chromatography, LC (HPLC), GC, SFC<br>• Fundamentals of linear (analytical) chromatography, retention time/factor, separation factor, peak resolution, band broadening, Van-Deemter equation<br>• Fundamentals of nonlinear chromatography, discontinuous and continuous preparative chromatography (annular, true moving bed - TMB, simulated moving bed - SMB)<br>• Adsorption equilibrium: experimental determination of adsorption isotherms and modeling<br>• Equipment for chromatography, production and characterization of chromatographic adsorbents<br>• Method development, scale up methods, process design, modeling of chromatographic processes, economic aspects<br>• Applications: e.g. normal phase chromatography, reversed phase chromatography, hydrophobic interaction chromatography, chiral chromatography, bioaffinity chromatography, ion exchange chromatography |
| **Literature** | • Schmidt-Traub, H.: Preparative Chromatography of Fine Chemicals and Pharmaceutical Agents. Weinheim: Wiley-VCH (2005) - eBook<br>• Carta, G.: Protein chromatography: process development and scale-up. Weinheim: Wiley-VCH (2010)<br>• Guiochon, G.; Lin, B.: Modeling for Preparative Chromatography. Amsterdam: Elsevier (2003)<br>• Hagel, L.: Handbook of process chromatography: development, manufacturing, validation and economics. London ;Burlington, MA Academic (2008) - eBook |

| Course L0112: Unit Operations for Bio-Related Systems | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Irina Smirnova |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | Contents:<br>• Introduction: overview about the separation process in biotechnology and pharmacy<br>• Handling of multicomponent systems<br>• Adsorption of biologic molecules<br>• Crystallization of biologic molecules<br>• Reactive extraction<br>• Aqueous two-phase systems<br>• Micellar systems: micellar extraction and micellar chromatographie<br>• Electrophoresis<br>• Choice of the separation process for the specific systems<br>Learning Outcomes:<br>• Basic knowledge of separation processes for biotechnological and pharmaceutical processes<br>• Identification of specific features and limitations in bio-related systems<br>• Proof of economical value of the process |
| **Literature** | "Handbook of Bioseparations", Ed. S. Ahuja<br>http://www.elsevier.com/books/handbook-of-bioseparations-2/ahuja/978-0-12-045540-9<br>"Bioseparations Engineering" M. R. Ladish<br>http://eu.wiley.com/WileyCDA/WileyTitle/productCd-0471244767.html |

| Course L0113: Unit Operations for Bio-Related Systems | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Irina Smirnova |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0662: Numerical Mathematics I

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Numerical Mathematics I (L0417) | Lecture | 2 | 3 |
| Numerical Mathematics I (L0418) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Sabine Le Borne |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Mathematik I + II for Engineering Students (german or english) **or** Analysis & Linear Algebra I + II for Technomathematicians<br>• basic MATLAB knowledge |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to<br>• name numerical methods for interpolation, integration, least squares problems, eigenvalue problems, nonlinear root finding problems and to explain their core ideas,<br>• repeat convergence statements for the numerical methods,<br>• explain aspects for the practical execution of numerical methods with respect to computational and storage complexitx. |
| *Skills* | Students are able to<br>• implement, apply and compare numerical methods using MATLAB,<br>• justify the convergence behaviour of numerical methods with respect to the problem and solution algorithm,<br>• select and execute a suitable solution approach for a given problem. |
| **Personal Competence** | |
| *Social Competence* | Students are able to<br>• work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge), explain theoretical foundations and support each other with practical aspects regarding the implementation of algorithms. |
| *Autonomy* | Students are capable<br>• to assess whether the supporting theoretical and practical excercises are better solved individually or in a team,<br>• to assess their individual progess and, if necessary, to ask questions and seek help. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 minutes |
| **Assignment for the Following Curricula** | General Engineering Science (German program, 7 semester): Specialisation Computer Science: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Biomedical Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Computer Science: Specialisation Computational Mathematics: Elective Compulsory<br>Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory<br>Data Science: Core qualification: Compulsory<br>Electrical Engineering: Core qualification: Elective Compulsory<br>Engineering Science: Core qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Elective Compulsory<br>General Engineering Science (English program, 7 semester): Core qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Computer Science: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: |

| | |
|---|---|
| | Compulsory<br>Computational Science and Engineering: Core qualification: Compulsory<br>Mechanical Engineering: Specialisation Theoretical Mechanical Engineering: Elective Compulsory<br>Mechanical Engineering: Specialisation Theoretical Mechanical Engineering: Compulsory<br>Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course Core Studies: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| **Course L0417: Numerical Mathematics I** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Sabine Le Borne |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | 1. Error analysis: Number representation, error types, conditioning and stability<br>2. Interpolation: polynomial and spline interpolation<br>3. Numerical integration and differentiation: order, Newton-Cotes formula, error estimates, Gaussian quadrature, adaptive quadrature, difference formulas<br>4. Linear systems: LU and Cholesky factorization, matrix norms, conditioning<br>5. Linear least squares problems: normal equations, Gram.Schmidt and Householder orthogonalization, singular value decomposition, regularization<br>6. Eigenvalue problems: power iteration, inverse iteration, QR algorithm<br>7. Nonlinear systems of equations: Fixed point iteration, root-finding algorithms for real-valued functions, Newton and Quasi-Newton methods for systems |
| **Literature** | • Stoer/Bulirsch: Numerische Mathematik 1, Springer<br>• Dahmen, Reusken: Numerik für Ingenieure und Naturwissenschaftler, Springer |

| **Course L0418: Numerical Mathematics I** | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Sabine Le Borne, Dr. Jens-Peter Zemke |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0900: Examples in Solid Process Engineering

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Fluidization Technology (L0431) | Lecture | 2 | 2 |
| Practical Course Fluidization Technology (L1369) | Practical Course | 1 | 1 |
| Technical Applications of Particle Technology (L0955) | Lecture | 2 | 2 |
| Exercises in Fluidization Technology (L1372) | Recitation Section (small) | 1 | 1 |

| | |
|---|---|
| **Module Responsible** | Prof. Stefan Heinrich |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Knowledge from the module particle technology |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After completion of the module the students will be able to describe based on examples the assembly of solids engineering processes consisting of multiple apparatuses and subprocesses. They are able to describe the coaction and interrelation of subprocesses. |
| *Skills* | Students are able to analyze tasks in the field of solids process engineering and to combine suitable subprocesses in a process chain. |
| **Personal Competence** | |
| *Social Competence* | Students are able to discuss technical problems in a scientific manner. |
| *Autonomy* | Students are able to acquire scientific knowledge independently and discuss technical problems in a scientific manner. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |

**Course achievement**

| Compulsory | Bonus | Form | Description |
|---|---|---|---|
| Yes | None | Written elaboration | drei Berichte (pro Versuch ein Bericht) à 5-10 Seiten |

| | |
|---|---|
| **Examination** | Written exam |
| **Examination duration and scale** | 120 minutes |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

### Course L0431: Fluidization Technology

| | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Stefan Heinrich |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | Introduction: definition, fluidization regimes, comparison with other types of gas/solids reactors<br>Typical fluidized bed applications<br>Fluidmechanical principle<br>Local fluid mechanics of gas/solid fluidization<br>Fast fluidization (circulating fluidized bed)<br>Entrainment<br>Solids mixing in fluidized beds<br>Application of fluidized beds to granulation and drying processes |
| **Literature** | Kunii, D.; Levenspiel, O.: Fluidization Engineering. Butterworth Heinemann, Boston, 1991. |

| Course L1369: Practical Course Fluidization Technology | |
|---|---|
| **Typ** | Practical Course |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Stefan Heinrich |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | Experiments:<br>• Determination of the minimum fluidization velocity<br>• heat transfer<br>• granulation<br>• drying |
| **Literature** | Kunii, D.; Levenspiel, O.: Fluidization Engineering. Butterworth Heinemann, Boston, 1991. |

| Course L0955: Technical Applications of Particle Technology | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Werner Sitzmann |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | Unit operations like mixing, separation, agglomeration and size reduction are discussed concerning their technical applicability from the perspective of the practician. Machines and apparatuses are presented, their designs and modes of action are explained and their application in production processes for chemicals, food and feed and in recycling processes are illustrated. |
| **Literature** | Stieß M: Mechanische Verfahrenstechnik I und II, Springer - Verlag, 1997 |

| Course L1372: Exercises in Fluidization Technology | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Stefan Heinrich |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | Exercises and calculation examples for the lecture Fluidization Technology |
| **Literature** | Kunii, D.; Levenspiel, O.: Fluidization Engineering. Butterworth Heinemann, Boston, 1991. |

## Module M0802: Membrane Technology

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Membrane Technology (L0399) | Lecture | 2 | 3 |
| Membrane Technology (L0400) | Recitation Section (small) | 1 | 2 |
| Membrane Technology (L0401) | Practical Course | 1 | 1 |

| | |
|---|---|
| **Module Responsible** | Prof. Mathias Ernst |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basic knowledge of water chemistry. Knowledge of the core processes involved in water, gas and steam treatment |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students will be able to rank the technical applications of industrially important membrane processes. They will be able to explain the different driving forces behind existing membrane separation processes. Students will be able to name materials used in membrane filtration and their advantages and disadvantages. Students will be able to explain the key differences in the use of membranes in water, other liquid media, gases and in liquid/gas mixtures. |
| *Skills* | Students will be able to prepare mathematical equations for material transport in porous and solution-diffusion membranes and calculate key parameters in the membrane separation process. They will be able to handle technical membrane processes using available boundary data and provide recommendations for the sequence of different treatment processes. Through their own experiments, students will be able to classify the separation efficiency, filtration characteristics and application of different membrane materials. Students will be able to characterise the formation of the fouling layer in different waters and apply technical measures to control this. |
| **Personal Competence** | |
| *Social Competence* | Students will be able to work in diverse teams on tasks in the field of membrane technology. They will be able to make decisions within their group on laboratory experiments to be undertaken jointly and present these to others. |
| *Autonomy* | Students will be in a position to solve homework on the topic of membrane technology independently. They will be capable of finding creative solutions to technical questions. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 min |
| **Assignment for the Following Curricula** | Civil Engineering: Specialisation Water and Traffic: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory<br>Environmental Engineering: Specialisation Water: Elective Compulsory<br>Joint European Master in Environmental Studies - Cities and Sustainability: Specialisation Water: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Water: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Elective Compulsory |

| Course L0399: Membrane Technology | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Mathias Ernst |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | The lecture on membrane technology supply provides students with a broad understanding of existing membrane treatment processes, encompassing pressure driven membrane processes, membrane application in electrodialyis, pervaporation as well as membrane distillation. The lectures main focus is the industrial production of drinking water like particle separation or desalination; however gas separation processes as well as specific wastewater oriented applications such as membrane bioreactor systems will be discussed as well.<br><br>Initially, basics in low pressure and high pressure membrane applications are presented (microfiltration, ultrafiltration, nanofiltration, reverse osmosis). Students learn about essential water quality parameter, transport equations and key parameter for pore membrane as well as solution diffusion membrane systems. The lecture sets a specific focus on fouling and scaling issues and provides knowledge on methods how to tackle with these phenomena in real water treatment application. A further part of the lecture deals with the character and manufacturing of different membrane materials and the characterization of membrane material by simple methods and advanced analysis.<br><br>The functions, advantages and drawbacks of different membrane housings and modules are explained. Students learn how an industrial membrane application is designed in the succession of treatment steps like pre-treatment, water conditioning, membrane integration and post-treatment of water. Besides theory, the students will be provided with knowledge on membrane demo-site examples and insights in industrial practice. |
| **Literature** | • T. Melin, R. Rautenbach: Membranverfahren: Grundlagen der Modul- und Anlagenauslegung (2., erweiterte Auflage), Springer-Verlag, Berlin 2004.<br>• Marcel Mulder, Basic Principles of Membrane Technology, Kluwer Academic Publishers, Dordrecht, The Netherlands<br>• Richard W. Baker, Membrane Technology and Applications, Second Edition, John Wiley & Sons, Ltd., 2004 |

| Course L0400: Membrane Technology | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Mathias Ernst |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L0401: Membrane Technology | |
|---|---|
| **Typ** | Practical Course |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Mathias Ernst |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0902: Wastewater Treatment and Air Pollution Abatement

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Biological Wastewater Treatment (L0517) | Lecture | 2 | 3 |
| Air Pollution Abatement (L0203) | Lecture | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Dr. Swantje Pietsch |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basic knowledge of biology and chemistry<br>basic knowledge of solids process engineering and separation technology |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After successful completion of the module students are able to<br>• name and explain biological processes for waste water treatment,<br>• characterize waste water and sewage sludge<br>• discuss legal regulations in the area of emissions and air quality<br>• classify off gas tretament processes and to define their area of application |
| *Skills* | Students are able to<br>• choose and design processs steps for the biological waste water treatment<br>• combine processes for cleaning of off-gases depending on the pollutants contained in the gases |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 min |
| **Assignment for the Following Curricula** | Civil Engineering: Specialisation Water and Traffic: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Environmental Engineering: Elective Compulsory<br>Environmental Engineering: Specialisation Waste and Energy: Elective Compulsory<br>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory<br>Joint European Master in Environmental Studies - Cities and Sustainability: Specialisation Water: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Water: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Compulsory |

| **Course L0517: Biological Wastewater Treatment** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Joachim Behrendt |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | Charaterisation of Wastewater<br>Metobolism of Microorganisms<br>Kinetic of mirobiotic processes<br>Calculation of bioreactor for wastewater treatment<br>Concepts of Wastewater treatment<br>Design of WWTP<br>Excursion to a WWTP<br>Biofilms<br>Biofim Reactors<br>Anaerobic Wastewater and sldge treatment<br>resources oriented sanitation technology<br>Future challenges of wastewater treatment |
| **Literature** | **Gujer, Willi**<br>Siedlungswasserwirtschaft : mit 84 Tabellen<br>ISBN: 3540343296 (Gb.) URL: http://www.gbv.de/dms/bs/toc/516261924.pdf URL: http://deposit.d-nb.de/cgi-bin/dokserv?id=2842122&prov=M&dok_var=1&dok_ext=htm<br>Berlin [u.a.] : Springer, 2007<br>TUB_HH_Katalog<br>**Henze, Mogens**<br>Wastewater treatment : biological and chemical processes<br>ISBN: 3540422285 (Pp.)<br>Berlin [u.a.] : Springer, 2002<br>TUB_HH_Katalog<br>**Imhoff, Karl** (Imhoff, Klaus R.;)<br>Taschenbuch der Stadtentwässerung : mit 10 Tafeln<br>ISBN: 3486263331 ((Gb.))<br>München [u.a.] : Oldenbourg, 1999<br>TUB_HH_Katalog<br>**Lange, Jörg** (Otterpohl, Ralf; Steger-Hartmann, Thomas;)<br>Abwasser : Handbuch zu einer zukunftsfähigen Wasserwirtschaft<br>ISBN: 3980350215 (kart.) URL: http://www.gbv.de/du/services/agi/52567E5D44DA0809C12570220050BF25/000000700334<br>Donaueschingen-Pfohren : Mall-Beton-Verl., 2000<br>TUB_HH_Katalog<br>**Mudrack, Klaus** (Kunst, Sabine;)<br>Biologie der Abwasserreinigung : 18 Tabellen<br>ISBN: 382741427X URL: http://www.gbv.de/du/services/agi/94B581161B6EC747C1256E3F005A8143/420000114903<br>Heidelberg [u.a.] : Spektrum, Akad. Verl., 2003<br>TUB_HH_Katalog<br>**Tchobanoglous, George** (Metcalf & Eddy, Inc., ;)<br>Wastewater engineering : treatment and reuse<br>ISBN: 0070418780 (alk. paper) ISBN: 0071122508 (ISE (*pbk))<br>Boston [u.a.] : McGraw-Hill, 2003<br>TUB_HH_Katalog<br>**Henze, Mogens**<br>Activated sludge models ASM1, ASM2, ASM2d and ASM3<br>ISBN: 1900222248<br>London : IWA Publ., 2002<br>TUB_HH_Katalog<br>**Kunz, Peter**<br>Umwelt-Bioverfahrenstechnik<br>Vieweg, 1992<br>**Bauhaus-Universität., Arbeitsgruppe Weiterbildendes Studium Wasser und Umwelt** (Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall, ;)<br>Abwasserbehandlung : Gewässerbelastung, Bemessungsgrundlagen, Mechanische Verfahren, Biologische Verfahren, Reststoffe aus der Abwasserbehandlung, Kleinkläranlagen<br>ISBN: 3860682725 URL: http://www.gbv.de/dms/weimar/toc/513989765_toc.pdf URL: http://www.gbv.de/dms/weimar/abs/513989765_abs.pdf<br>Weimar : Universitätsverl, 2006<br>TUB_HH_Katalog<br>**Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall**<br>DWA-Regelwerk<br>Hennef : DWA, 2004<br>TUB_HH_Katalog<br>**Wiesmann, Udo** (Choi, In Su; Dombrowski, Eva-Maria;)<br>Fundamentals of biological wastewater treatment<br>ISBN: 3527312196 (Gb.) URL: http://deposit.ddb.de/cgi-bin/dokserv?id=2774611&prov=M&dok_var=1&dok_ext=htm<br>Weinheim : WILEY-VCH, 2007<br>TUB_HH_Katalog |

| Course L0203: Air Pollution Abatement | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Swantje Pietsch |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | In the lecture methods for the reduction of emissions from industrial plants are treated. At the beginning a short survey of the different forms of air pollutants is given. In the second part physical principals for the removal of particulate and gaseous pollutants form flue gases are treated. Industrial applications of these principles are demonstrated with examples showing the removal of specific compounds, e.g. sulfur or mercury from flue gases of incinerators. |
| **Literature** | Handbook of air pollution prevention and control, Nicholas P. Cheremisinoff. - Amsterdam [u.a.] : Butterworth-Heinemann, 2002<br>Atmospheric pollution : history, science, and regulation, Mark Zachary Jacobson. - Cambridge [u.a.] : Cambridge Univ. Press, 2002<br>Air pollution control technology handbook, Karl B. Schnelle. - Boca Raton [u.a.] : CRC Press, c 2002<br>Air pollution, Jeremy Colls. - 2. ed. - London [u.a.] : Spon, 2002 |

## Module M0949: Rural Development and Resources Oriented Sanitation for different Climate Zones

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Rural Development and Resources Oriented Sanitation for different Climate Zones (L0942) | Seminar | 2 | 3 |
| Rural Development and Resources Oriented Sanitation for different Climate Zones (L0941) | Lecture | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Ralf Otterpohl |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basic knowledge of the global situation with rising poverty, soil degradation, lack of water resources and sanitation |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can describe resources oriented wastewater systems mainly based on source control in detail. They can comment on techniques designed for reuse of water, nutrients and soil conditioners.<br>Students are able to discuss a wide range of proven approaches in Rural Development from and for many regions of the world. |
| *Skills* | Students are able to design low-tech/low-cost sanitation, rural water supply, rainwater harvesting systems, measures for the rehabilitation of top soil quality combined with food and water security. Students can consult on the basics of soil building through “Holisitc Planned Grazing” as developed by Allan Savory. |
| **Personal Competence** | |
| *Social Competence* | The students are able to develop a specific topic in a team and to work out milestones according to a given plan. |
| *Autonomy* | Students are in a position to work on a subject and to organize their work flow independently. They can also present on this subject. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Subject theoretical and practical work |
| **Examination duration and scale** | During the course of the semester, the students work towards mile stones. The work includes presentations and papers. Detailed information will be provided at the beginning of the smester. |
| **Assignment for the Following Curricula** | Civil Engineering: Specialisation Water and Traffic: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory<br>Environmental Engineering: Specialisation Water: Elective Compulsory<br>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory<br>Joint European Master in Environmental Studies - Cities and Sustainability: Specialisation Water: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Water: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Elective Compulsory |

| Course L0942: Rural Development and Resources Oriented Sanitation for different Climate Zones | |
|---|---|
| **Typ** | Seminar |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Ralf Otterpohl |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Central part of this module is a group work on a subtopic of the lectures. The focus of these projects will be based on an interview with a target audience, practitioners or scientists.<br>• The group work is divided into several Milestones and Assignments. The outcome will be presented in a final presentation at the end of the semester. |
| **Literature** | • J. Lange, R. Otterpohl 2000: Abwasser - Handbuch zu einer zukunftsfähigen Abwasserwirtschaft. Mallbeton Verlag (TUHH Bibliothek)<br>• Winblad, Uno and Simpson-Hébert, Mayling 2004: Ecological Sanitation, EcoSanRes, Sweden (free download)<br>• Schober, Sabine: WTO/TUHH Award winning Terra Preta Toilet Design: http://youtu.be/w_R09cYq6ys |

| Course L0941: Rural Development and Resources Oriented Sanitation for different Climate Zones | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Ralf Otterpohl |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Living Soil - THE key element of Rural Development<br>• Participatory Approaches<br>• Rainwater Harvesting<br>• Ecological Sanitation Principles and practical examples<br>• Permaculture Principles of Rural Development<br>• Performance and Resilience of Organic Small Farms<br>• Going Further: The TUHH Toolbox for Rural Development<br>• EMAS Technologies, Low cost drinking water supply |
| **Literature** | • Miracle Water Village, India, Integrated Rainwater Harvesting, Water Efficiency, Reforestation and Sanitation: http://youtu.be/9hmkgn0nBgk<br>• Montgomery, David R. 2007: Dirt: The Erosion of Civilizations, University of California Press |

## Module M0952: Industrial Bioprocess Engineering

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Biotechnical Processes (L1065) | Project-/problem-based Learning | 2 | 3 |
| Development of bioprocess engineering processes in industrial practice (L1172) | Seminar | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. An-Ping Zeng |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Knowledge of bioprocess engineering and process engineering at bachelor level |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After successful completion of the module<br>• the students can outline the current status of research on the specific topics discussed<br>• the students can explain the basic underlying principles of the respective biotechnological production processes |
| *Skills* | After successful completion of the module students are able to<br>• analyzing and evaluate current research approaches<br>• Lay-out biotechnological production processes basically |
| **Personal Competence** | |
| *Social Competence* | Students are able to work together as a team with several students to solve given tasks and discuss their results in the plenary and to defend them. |
| *Autonomy* | After completion of this module, participants will be able to solve a technical problem in teams of approx. 8-12 persons independently including a presentation of the results. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Presentation |
| **Examination duration and scale** | oral presentation + discussion (45 min) + Written report (10 pages) |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L1065: Biotechnical Processes | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Willfried Blümke |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | This course gives an overview of the most important biotechnological production processes. In addition to the individual methods and their specific requirements, general aspects of industrial reality are also addressed, such as:<br>• Asset Lifecycle<br>• Digitization in the bioprocess industry<br>• Basic principles of industrial bioprocess development<br>• Sustainability aspects in the development of bioprocess engineering processes |
| **Literature** | Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1<br><br>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.<br><br>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract<br><br>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003<br><br>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage<br><br>Krahe M (2003) Biochemical Engineering. Ullmann´s Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html<br><br>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts |

| Course L1172: Development of bioprocess engineering processes in industrial practice | |
|---|---|
| **Typ** | Seminar |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Stephan Freyer |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | This course gives an insight into the methodology used in the development of industrial biotechnology processes. Important aspects of this are, for example, the development of the fermentation and the work-up steps for the respective target molecule, the integration of the partial steps into an overall process, and the cost-effectiveness of the process. |
| **Literature** | Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen]<br><br>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.<br><br>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract<br><br>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003<br><br>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage<br><br>Krahe M (2003) Biochemical Engineering. Ullmann´s Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html<br><br>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts |

## Module M0973: Biocatalysis

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Biocatalysis and Enzyme Technology (L1158) | Lecture | 2 | 3 |
| Technical Biocatalysis (L1157) | Lecture | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Andreas Liese |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Knowledge of bioprocess engineering and process engineering at bachelor level |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After successful completion of this course, students will be able to<br>• reflect a broad knowledge about enzymes and their applications in academia and industry<br>• have an overview of relevant biotransformations und name the general definitions |
| *Skills* | After successful completion of this course, students will be able to<br>• understand the fundamentals of biocatalysis and enzyme processes and transfer this to new tasks<br>• know the several enzyme reactors and the important parameters of enzyme processes<br>• use their gained knowledge about the realisation of processes. Transfer this to new tasks<br>• analyse and discuss special tasks of processes in plenum and give solutions<br>• communicate and discuss in English |
| **Personal Competence** | |
| *Social Competence* | After completion of this module, participants will be able to debate technical and biocatalytical questions in small teams to enhance the ability to take position to their own opinions and increase their capacity for teamwork. |
| *Autonomy* | After completion of this module, participants will be able to solve a technical problem independently including a presentation of the results. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Core qualification: Compulsory<br>Chemical and Bioprocess Engineering: Core qualification: Compulsory<br>Environmental Engineering: Specialisation Biotechnology: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L1158: Biocatalysis and Enzyme Technology | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Andreas Liese |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | 1. Introduction: Impact and potential of enzyme-catalysed processes in biotechnology.<br>2. History of microbial and enzymatic biotransformations.<br>3. Chirality - definition & measurement<br>4. Basic biochemical reactions, structure and function of enzymes.<br>5. Biocatalytic retrosynthesis of asymmetric molecules<br>6. Enzyme kinetics: mechanisms, calculations, multisubstrate reactions.<br>7. Reactors for biotransformations. |
| **Literature** | • K. Faber: Biotransformations in Organic Chemistry, Springer, 5th Ed., 2004<br>• A. Liese, K. Seelbach, C. Wandrey: Industrial Biotransformations, Wiley-VCH, 2006<br>• R. B. Silverman: The Organic Chemistry of Enzyme-Catalysed Reactions, Academic Press, 2000<br>• K. Buchholz, V. Kasche, U. Bornscheuer: Biocatalysts and Enzyme Technology. VCH, 2005.<br>• R. D. Schmidt: Pocket Guide to Biotechnology and Genetic Engineering, Woley-VCH, 2003 |

| Course L1157: Technical Biocatalysis | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Andreas Liese |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | 1. Introduction<br>2. Production and Down Stream Processing of Biocatalysts<br>3. Analytics (offline/online)<br>4. Reaction Engineering & Process Control<br>• Definitions<br>• Reactors<br>• Membrane Processes<br>• Immobilization<br>5. Process Optimization<br>• Simplex / DOE / GA<br>6. Examples of Industrial Processes<br>• food / feed<br>• fine chemicals<br>7. Non-Aqueous Solvents as Reaction Media<br>• ionic liquids<br>• scCO2<br>• solvent free |
| **Literature** | • A. Liese, K. Seelbach, C. Wandrey: Industrial Biotransformations, Wiley-VCH, 2006<br>• H. Chmiel: Bioprozeßtechnik, Elsevier, 2005<br>• K. Buchholz, V. Kasche, U. Bornscheuer: Biocatalysts and Enzyme Technology, VCH, 2005<br>• R. D. Schmidt: Pocket Guide to Biotechnology and Genetic Engineering, Woley-VCH, 2003 |

## Module M1017: Food Technology

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Food Technology (L1216) | Lecture | 2 | 3 |
| Experimental Course: Brewing Technology (L1242) | Practical Course | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Stefan Heinrich |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Basic knowledge of partice technology<br>• Separation Technique; Heat and Mass Transfer I |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After successful completion of the module students are able to<br>• discuss the material properties of food<br>• explain basic of production processes in food engineering<br>• describe some selected processes |
| *Skills* | Students are able to<br>• choose and design process chains for the processing of food<br>• asses the effect of the single process steps on the material properties of food |
| **Personal Competence** | |
| *Social Competence* | Students are enabled to discuss knowledge in a scientific environment. |
| *Autonomy* | Students are able to acquire scientific knowledge independently and knowledge in a scientific manner. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |

| Course achievement | Compulsory | Bonus | Form | Description |
|---|---|---|---|---|
| | Yes | None | Written elaboration | 10 - 15 Seiten |

| | |
|---|---|
| **Examination** | Written exam |
| **Examination duration and scale** | 120 minutes |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

### Course L1216: Food Technology

| | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Stefan Heinrich, Prof. Stefan Palzer |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | 1. Material properties: Rheology, Transport coefficients, Measuring devices, Quality aspects<br>2. Processes at ambient condition, at elevated temperature and pressure<br>3. energy analysis<br>4. Selected processes: Seed oil production; Roasted Coffee |
| **Literature** | M. Bockisch: Handbuch der Lebensmitteltechnologie , Stuttgart, 1993<br>R. Eggers: Vorlesungsmanuskript |

| Course L1242: Experimental Course: Brewing Technology | |
|---|---|
| **Typ** | Practical Course |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Stefan Heinrich, Prof. Stefan Palzer |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | In the frame of the course the basics of fermentation, fluid processing and process engineering will be repeated.<br><br>Following all aspects of manufacturing of beer will be explained: selection and processing of raw materials, different liquid and solid unit operations, packaging technology and final quality assurance/sensory evaluation.<br><br>The students will perform all unit operations in pilot scale. The objective is that student experience and adopt a holistic view of food manufacturing. |
| **Literature** | Ludwig Narziss: Abriss der Bierbrauerei, 7. Auflage, Wiley VCH |

## Module M0905: Research Project Process Engineering

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Research Project in Process Engineering (L1051) | Project-/problem-based Learning | 6 | 6 |

| | |
|---|---|
| **Module Responsible** | Dozenten des SD V |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Advanced state of knowledge in the master program of Process Engineering |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students know current research topics oft institutes engaged in their specialization. They can name the fundamental scientific methods used for doing related reserach. |
| *Skills* | Students are capable of completing a small, independent sub-project of currently ongoing research projects in the institutes engaged in their specialization. Students can justify and explain their approach for problem solving, they can draw conclusions from their results, and then can find new ways and methods for their work. Students are capable of comparing and assessing alterantive approaches with their own with regard to given criteria. |
| **Personal Competence** | |
| *Social Competence* | Students are able to discuss their work progress with research assistants of the supervising institute. They are capable of presenting their results in front of a professional audience. |
| *Autonomy* | Based on their competences gained so far students are capable of defining meaningful tasks within ongoing research project for themselves. They are able to develop the necessary understanding and problem solving methods. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Study work |
| **Examination duration and scale** | According to General Regulations |
| **Assignment for the Following Curricula** | Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory |

### Course L1051: Research Project in Process Engineering

| | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 6 |
| **CP** | 6 |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Lecturer** | Dozenten des SD V |
| **Language** | DE/EN |
| **Cycle** | WiSe/SoSe |
| **Content** | Working on current research topics of the chosen specialisation.<br><br>Research projects can be carried out at the institutes of process engineering, in industry or abroad. It is always necessary to have a university lecturer from the school of Process Engineering as a supervisor, who must be determined before the research project begins. |
| **Literature** | Aktuelle Literatur zu Forschungsthemen aus der gewählten Vertiefungsrichtung.<br><br>Current literature on research topics of the chosen specialization. |

## Module M0658: Innovative CFD Approaches

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Application of Innovative CFD Methods in Research and Development (L0239) | Lecture | 2 | 3 |
| Application of Innovative CFD Methods in Research and Development (L1685) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Thomas Rung |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Attendance of a computational fluid dynamics course (CFD1/CFD2)<br>Competent knowledge of numerical analysis in addition to general and computational thermo/fluid dynamics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Student can explain the theoretical background of different CFD strategies (e.g. Lattice-Boltzmann, Smoothed Particle-Hydrodynamics, Finite-Volume methods) and describe the fundamentals of simulation-based optimisation. |
| *Skills* | Student is able to identify an appropriate CFD-based solution strategy on a jusitfied basis. |
| **Personal Competence** | |
| *Social Competence* | Student should practice her/his team-working abilities, learn to lead team sessions and present solutions to experts. |
| *Autonomy* | Student should be able to structure and perform a simulation-based project independently, |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | **Compulsory** **Bonus** **Form** **Description**<br>Yes 20 % Written elaboration |
| **Examination** | Oral exam |
| **Examination duration and scale** | 30 min |
| **Assignment for the Following Curricula** | Energy Systems: Core qualification: Elective Compulsory<br>Naval Architecture and Ocean Engineering: Core qualification: Elective Compulsory<br>Ship and Offshore Technology: Core qualification: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

### Course L0239: Application of Innovative CFD Methods in Research and Development

| | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Thomas Rung |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | Computational Optimisation, Parallel Computing, Efficient CFD-Procedures for GPU Archtiectures, Alternative Approximations (Lattice-Boltzmann Methods, Particle Methods), Fluid/Structure-Interaction, Modelling of Hybrid Continua |
| **Literature** | Vorlesungsmaterialien /lecture notes |

### Course L1685: Application of Innovative CFD Methods in Research and Development

| | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Thomas Rung |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M1396: Hybrid Processes in Process Engineering

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Hybrid Processes in Process Engineering (L1715) | Project-/problem-based Learning | 2 | 4 |
| Hybrid Processes in Process Engineering (L1978) | Lecture | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Mirko Skiborowski |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Process and Plant Engineering 1<br>Process and Plant Engineering 2<br>Basics in Process Engineering |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to evaluate hybrid processes |
| *Skills* | Students are able to evaluate processes with regard to their suitability as hybrid processes and to interpret them accordingly. |
| **Personal Competence** | |
| *Social Competence* | Students are able to apply the principles of project management for small groups. |
| *Autonomy* | Students are able to acquire and discuss specialized knowledge about hybrid processes. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |

| **Course achievement** | **Compulsory** | **Bonus** | **Form** | **Description** |
|---|---|---|---|---|
| | Yes | 15 % | Midterm | |

| | |
|---|---|
| **Examination** | Written elaboration |
| **Examination duration and scale** | Project report incl. PM-documents |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory |

### Course L1715: Hybrid Processes in Process Engineering

| | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 2 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 92, Study Time in Lecture 28 |
| **Lecturer** | Dr. Thomas Waluga |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L1978: Hybrid Processes in Process Engineering | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Thomas Waluga |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | |
| **Literature** | - H. Schmidt-Traub; Integrated Reaction and Separation Operations: Modelling and Experimental Validation; Springer 2006<br>- K. Sundmacher, A. Kienle, A. Seidel-Morgenstern; Integrated Chemical Processes: Synthesis, Operation, Analysis, and Control; Wiley-VCH 2005<br>- Mexandre C. Dimian (Ed); Integrated Design and Simulation of Chemical Processes; in Computer Aided Chemical Engineering, Volume 13, Pages 1-698 (2003) |

## Module M0822: Process Modeling in Water Technology

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Process Modelling of Wastewater Treatment (L0522) | Project-/problem-based Learning | 2 | 3 |
| Process Modeling in Drinking Water Treatment (L0314) | Project-/problem-based Learning | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Dr. Klaus Johannsen |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Knowledge of the most important processes in drinking water and waste water treatment. |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to explain selected processes of drinking water and waste water treatment in detail. They are able to explain basics as well as possibilities and limitations of dynamic modeling. |
| *Skills* | Students are able to use the most important features Modelica offers. They are able to transpose selected processes in drinking water and waste water treatment into a mathematical model in Modelica with respect to equilibrium, kinetics and mass balances. They are able to set up and apply models and assess their possibilities and limitations. |
| **Personal Competence** | |
| *Social Competence* | Students are able to solve problems and document solutions in a group with members of different technical background. They are able to give appropriate feedback and can work constructively with feedback concerning their work. |
| *Autonomy* | Students are able to define a problem, gain the required knowledge and set up a model. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 1,5 hours |
| **Assignment for the Following Curricula** | Civil Engineering: Specialisation Water and Traffic: Elective Compulsory<br>Environmental Engineering: Specialisation Water: Elective Compulsory<br>Joint European Master in Environmental Studies - Cities and Sustainability: Specialisation Water: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Water: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Elective Compulsory |

| Course L0522: Process Modelling of Wastewater Treatment | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Joachim Behrendt |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | Mass and energy balances<br><br>Tracer modelling<br><br>Activated Sludge Model<br><br>Wastewater Treatment Plant Modelling (continously and SBR)<br><br>Sludge Treatment (ADM, aerobic autothermal)<br><br>Biofilm Modelling |
| **Literature** | **Henze, Mogens** (Seminar on Activated Sludge Modelling, ; Kollekolle Seminar on Activated Sludge Modelling, ;)<br>Activated sludge modelling : processes in theory and practice ; selected proceedings of the 5th Kollekolle Seminar on Activated Sludge Modelling, held in Kollekolle, Denmark, 10 - 12 September 2001<br>ISBN: 1843394146<br>[London] : IWA Publ., 2002<br>TUB_HH_Katalog<br>**Henze, Mogens**<br>Activated sludge models ASM1, ASM2, ASM2d and ASM3<br>ISBN: 1900222248<br>London : IWA Publ., 2002<br>TUB_HH_Katalog<br>**Henze, Mogens**<br>Wastewater treatment : biological and chemical processes<br>ISBN: 3540422285 (Pp.)<br>Berlin [u.a.] : Springer, 2002<br>TUB_HH_Katalog<br>**Wiesmann, Udo** (Choi, In Su; Dombrowski, Eva-Maria;)<br>Fundamentals of biological wastewater treatment<br>ISBN: 3527312196 (Gb.) URL: http://deposit.ddb.de/cgi-bin/dokserv?id=2774611&prov=M&dok_var=1&dok_ext=htm<br>Weinheim : WILEY-VCH, 2007<br>TUB_HH_Katalog |

| Course L0314: Process Modeling in Drinking Water Treatment | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Klaus Johannsen |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | In this course selected drinking water treatment processes (e.g. aeration or activated carbon adsorption) are modeled dynamically using the programming language Modelica, that is increasingly used in industry. In this course OpenModelica is used, an free access frontend of the programming language Modelica.<br><br>In the beginning of the course the use of OpenModelica is explainded by means of simple examples. Together required elements and structure of the model are developed. The implementation in OpenModelica and the application of the model is done individually or in groups respectively. Students get feedback and can gain extra points for the exam. |
| **Literature** | **OpenModelica:** https://openmodelica.org/index.php/download/download-windows<br><br>**OpenModelica - Modelica Tutorial:** https://openmodelica.org/index.php/useresresources/userdocumentation<br><br>**OpenModelica - Users Guide:** https://openmodelica.org/index.php/useresresources/userdocumentation<br><br>**Peter Fritzson:** Principles of Object-Oriented Modeling and Simulation with Modelica 2.1,Wiley-IEEE Press, ISBN 0-471-471631.<br><br>**MHW (rev. by Crittenden, J. et al.):** Water treatment principles and design. John Wiley & Sons, Hoboken, 2005.<br><br>**Stumm, W., Morgan, J.J.**: Aquatic chemistry. John Wiley & Sons, New York, 1996.<br><br>**DVGW (Hrsg.):** Wasseraufbereitung - Grundlagen und Verfahren. Oldenbourg Industrie Verlag, München, 2004. |

## Module M0742: Thermal Energy Systems

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Thermal Engergy Systems (L0023) | Lecture | 3 | 5 |
| Thermal Engergy Systems (L0024) | Recitation Section (large) | 1 | 1 |

| | |
|---|---|
| **Module Responsible** | Prof. Gerhard Schmitz |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Technical Thermodynamics I, II, Fluid Dynamics, Heat Transfer |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students know the different energy conversion stages and the difference between efficiency and annual efficiency. They have increased knowledge in heat and mass transfer, especially in regard to buildings and mobile applications. They are familiar with German energy saving code and other technical relevant rules. They know to differ different heating systems in the domestic and industrial area and how to control such heating systems. They are able to model a furnace and to calculate the transient temperatures in a furnace. They have the basic knowledge of emission formations in the flames of small burners and how to conduct the flue gases into the atmosphere. They are able to model thermodynamic systems with object oriented languages. |
| *Skills* | Students are able to calculate the heating demand for different heating systems and to choose the suitable components. They are able to calculate a pipeline network and have the ability to perform simple planning tasks, regarding solar energy. They can write Modelica programs and can transfer research knowledge into practice. They are able to perform scientific work in the field of thermal engineering. |
| **Personal Competence** | |
| *Social Competence* | The students are able to discuss in small groups and develop an approach. |
| *Autonomy* | Students are able to define independently tasks, to get new knowledge from existing knowledge as well as to find ways to use the knowledge in practice. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 60 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Energy Engineering: Elective Compulsory<br>Energy Systems: Specialisation Energy Systems: Compulsory<br>Energy Systems: Specialisation Marine Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory<br>Product Development, Materials and Production: Core qualification: Elective Compulsory<br>Renewable Energies: Core qualification: Compulsory<br>Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0023: Thermal Engergy Systems | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 3 |
| **CP** | 5 |
| **Workload in Hours** | Independent Study Time 108, Study Time in Lecture 42 |
| **Lecturer** | Prof. Gerhard Schmitz |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | 1. Introduction<br><br>2. Fundamentals of Thermal Engineering 2.1 Heat Conduction 2.2 Convection 2.3 Radiation 2.4 Heat transition 2.5 Combustion parameters 2.6 Electrical heating 2.7 Water vapor transport<br><br>3. Heating Systems 3.1 Warm water heating systems 3.2 Warm water supply 3.3 piping calculation 3.4 boilers, heat pumps, solar collectors 3.5 Air heating systems 3.6 radiative heating systems<br><br>4. Thermal traetment systems 4.1 Industrial furnaces 4.2 Melting furnaces 4.3 Drying plants 4.4 Emission control 4.5 Chimney calculation 4.6 Energy measuring<br><br>5. Laws and standards 5.1 Buildings 5.2 Industrial plants |
| **Literature** | • Schmitz, G.: Klimaanlagen, Skript zur Vorlesung<br>• VDI Wärmeatlas, 11. Auflage, Springer Verlag, Düsseldorf 2013<br>• Herwig, H.; Moschallski, A.: Wärmeübertragung, Vieweg+Teubner Verlag, Wiesbaden 2009<br>• Recknagel, H.; Sprenger, E.; Schrammek, E.-R.: Taschenbuch für Heizung- und Klimatechnik 2013/2014, 76. Auflage, Deutscher Industrieverlag, 2013 |

| Course L0024: Thermal Engergy Systems | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Gerhard Schmitz |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0975: Industrial Bioprocesses in Practice

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Industrial biotechnology in Chemical Industriy (L2276) | Seminar | 2 | 3 |
| Practice in bioprocess engineering (L2275) | Seminar | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Andreas Liese |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Knowledge of bioprocess engineering and process engineering at bachelor level |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After successful completion of the module<br>• the students can outline the current status of research on the specific topics discussed<br>• the students can explain the basic underlying principles of the respective industrial biotransformations |
| *Skills* | After successful completion of the module students are able to<br>• analyze and evaluate current research approaches<br>• plan industrial biotransformations basically |
| **Personal Competence** | |
| *Social Competence* | Students are able to work together as a team with several students to solve given tasks and discuss their results in the plenary and to defend them. |
| *Autonomy* | The students are able independently to present the results of their subtasks in a presentation |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Presentation |
| **Examination duration and scale** | each seminar 15 min lecture and 15 min discussion |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory<br>Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory<br>Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Management and Controlling: Elective Compulsory<br>Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Management and Controlling: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory |

| Course L2276: Industrial biotechnology in Chemical Industriy | |
|---|---|
| **Typ** | Seminar |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Stephan Freyer |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | This course gives an insight into the applications, processes, structures and boundary conditions in industrial practice. Various concrete applications of the technology, markets and other questions that will significantly influence the plant and process design will be shown. |
| **Literature** | Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen]<br><br>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.<br><br>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract<br><br>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003<br><br>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage<br><br>Krahe M (2003) Biochemical Engineering. Ullmann´s Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html<br><br>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts |

| Course L2275: Practice in bioprocess engineering | |
|---|---|
| **Typ** | Seminar |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Willfried Blümke |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | Content of this course is a concrete insight into the principles, processes and structures of an industrial biotechnology company. In addition to practical illustrative examples, aspects beyond the actual process engineering area are also addressed, such as e.g. Sustainability and engineering. |
| **Literature** | Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen]<br><br>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.<br><br>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract<br><br>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003<br><br>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage<br><br>Krahe M (2003) Biochemical Engineering. Ullmann´s Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html<br><br>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts |

# Specialization Chemical Process Engineering

## Module M0617: High Pressure Chemical Engineering

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| High Pressure Technique for Apparatus Engineering (L1278) | Lecture | 2 | 2 |
| Industrial Processes Under High Pressure (L0116) | Lecture | 2 | 2 |
| Advanced Separation Processes (L0094) | Lecture | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Dr. Monika Johannsen |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Fundamentals of Chemistry, Chemical Engineering, Fluid Process Engineering, Thermal Separation Processes, Thermodynamics, Heterogeneous Equilibria |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After a successful completion of this module, students can:<br>• explain the influence of pressure on the properties of compounds, phase equilibria, and production processes,<br>• describe the thermodynamic fundamentals of separation processes with supercritical fluids,<br>• exemplify models for the description of solid extraction and countercurrent extraction,<br>• discuss parameters for optimization of processes with supercritical fluids. |
| *Skills* | After successful completion of this module, students are able to:<br>• compare separation processes with supercritical fluids and conventional solvents,<br>• assess the application potential of high-pressure processes at a given separation task,<br>• include high pressure methods in a given multistep industrial application,<br>• estimate economics of high-pressure processes in terms of investment and operating costs,<br>• perform an experiment with a high pressure apparatus under guidance,<br>• evaluate experimental results,<br>• prepare an experimental protocol. |
| **Personal Competence** | |
| *Social Competence* | After successful completion of this module, students are able to:<br>• present a scientific topic from an original publication in teams of 2 and defend the contents together. |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | **Compulsory** **Bonus** **Form** **Description**<br>Yes 15 % Presentation |
| **Examination** | Written exam |
| **Examination duration and scale** | 120 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L1278: High Pressure Technique for Apparatus Engineering | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Arne Pietsch |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | 1. Basic laws and certification standards<br>2. Basics for calculations of pressurized vessels<br>3. Stress hypothesis<br>4. Selection of materials and fabrication processes<br>5. vessels with thin walls<br>6. vessels with thick walls<br>7. Safety installations<br>8. Safety analysis<br><br>Applications:<br><br>- subsea technology (manned and unmanned vessels)<br>- steam vessels<br>- heat exchangers<br>- LPG, LEG transport vessels |
| **Literature** | Apparate und Armaturen in der chemischen Hochdrucktechnik, Springer Verlag<br>Spain and Paauwe: High Pressure Technology, Vol. I und II, M. Dekker Verlag<br>AD-Merkblätter, Heumanns Verlag<br>Bertucco; Vetter: High Pressure Process Technology, Elsevier Verlag<br>Sherman; Stadtmuller: Experimental Techniques in High-Pressure Research, Wiley & Sons Verlag<br>Klapp: Apparate- und Anlagentechnik, Springer Verlag |

| **Course L0116: Industrial Processes Under High Pressure** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Carsten Zetzl |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | Part I : Physical Chemistry and Thermodynamics<br>1. Introduction: Overview, achieving high pressure, range of parameters.<br><br>2. Influence of pressure on properties of fluids: P,v,T-behaviour, enthalpy, internal energy, entropy, heat capacity, viscosity, thermal conductivity, diffusion coefficients, interfacial tension.<br><br>3. Influence of pressure on heterogeneous equilibria: Phenomenology of phase equilibria<br><br>4. Overview on calculation methods for (high pressure) phase equilibria).<br>Influence of pressure on transport processes, heat and mass transfer.<br><br>Part II : High Pressure Processes<br>5. Separation processes at elevated pressures: Absorption, adsorption (pressure swing adsorption), distillation (distillation of air), condensation (liquefaction of gases)<br><br>6. Supercritical fluids as solvents: Gas extraction, cleaning, solvents in reacting systems, dyeing, impregnation, particle formation (formulation)<br><br>7. Reactions at elevated pressures. Influence of elevated pressure on biochemical systems: Resistance against pressure<br><br>**Part III : Industrial production**<br><br>8. Reaction : Haber-Bosch-process, methanol-synthesis, polymerizations; Hydrations, pyrolysis, hydrocracking; Wet air oxidation, supercritical water oxidation (SCWO)<br><br>9. Separation : Linde Process, De-Caffeination, Petrol and Bio-Refinery<br><br>10. Industrial High Pressure Applications in Biofuel and Biodiesel Production<br><br>11. Sterilization and Enzyme Catalysis<br><br>12. Solids handling in high pressure processes, feeding and removal of solids, transport within the reactor.<br><br>13. Supercritical fluids for materials processing.<br><br>14. Cost Engineering<br><br>Learning Outcomes:<br>After a successful completion of this module, the student should be able to<br><br>- understand of the influences of pressure on properties of compounds, phase equilibria, and production processes.<br><br>- Apply high pressure approches in the complex process design tasks<br><br>- Estimate Efficiency of high pressure alternatives with respect to investment and operational costs<br><br>Performance Record:<br>1. Presence (28 h)<br><br>2. Oral presentation of original scientific article (15 min) with written summary<br><br>3. Written examination and Case study<br><br>( 2+3 : 32 h Workload)<br><br>Workload:<br>60 hours total |
| **Literature** | Literatur:<br><br>Script: High Pressure Chemical Engineering.<br>G. Brunner: Gas Extraction. An Introduction to Fundamentals of Supercritical Fluids and the Application to Separation Processes. Steinkopff, Darmstadt, Springer, New York, 1994. |

| Course L0094: Advanced Separation Processes | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Monika Johannsen |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Introduction/Overview on Properties of Supercritical Fluids (SCF)and their Application in Gas Extraction Processes<br>• Solubility of Compounds in Supercritical Fluids and Phase Equilibrium with SCF<br>• Extraction from Solid Substrates: Fundamentals, Hydrodynamics and Mass Transfer<br>• Extraction from Solid Substrates: Applications and Processes (including Supercritical Water)<br>• Countercurrent Multistage Extraction: Fundamentals and Methods, Hydrodynamics and Mass Transfer<br>• Countercurrent Multistage Extraction: Applications and Processes<br>• Solvent Cycle, Methods for Precipitation<br>• Supercritical Fluid Chromatography (SFC): Fundamentals and Application<br>• Simulated Moving Bed Chromatography (SMB)<br>• Membrane Separation of Gases at High Pressures<br>• Separation by Reactions in Supercritical Fluids (Enzymes) |
| **Literature** | G. Brunner: Gas Extraction. An Introduction to Fundamentals of Supercritical Fluids and the Application to Separation Processes. Steinkopff, Darmstadt, Springer, New York, 1994. |

## Module M0714: Numerical Treatment of Ordinary Differential Equations

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Numerical Treatment of Ordinary Differential Equations (L0576) | Lecture | 2 | 3 |
| Numerical Treatment of Ordinary Differential Equations (L0582) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Sabine Le Borne |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Mathematik I, II, III für Ingenieurstudierende (deutsch oder englisch) oder Analysis & Lineare Algebra I + II sowie Analysis III für Technomathematiker<br>• Basic MATLAB knowledge |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to<br>• list numerical methods for the solution of ordinary differential equations and explain their core ideas,<br>• repeat convergence statements for the treated numerical methods (including the prerequisites tied to the underlying problem),<br>• explain aspects regarding the practical execution of a method.<br>• select the appropriate numerical method for concrete problems, implement the numerical algorithms efficiently and interpret the numerical results |
| *Skills* | Students are able to<br>• implement (MATLAB), apply and compare numerical methods for the solution of ordinary differential equations,<br>• to justify the convergence behaviour of numerical methods with respect to the posed problem and selected algorithm,<br>• for a given problem, develop a suitable solution approach, if necessary by the composition of several algorithms, to execute this approach and to critically evaluate the results. |
| **Personal Competence** | |
| *Social Competence* | Students are able to<br>• work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge), explain theoretical foundations and support each other with practical aspects regarding the implementation of algorithms. |
| *Autonomy* | Students are capable<br>• to assess whether the supporting theoretical and practical excercises are better solved individually or in a team,<br>• to assess their individual progress and, if necessary, to ask questions and seek help. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory<br>Energy Systems: Core qualification: Elective Compulsory<br>Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory<br>Mathematical Modelling in Engineering: Theory, Numerics, Applications: Specialisation I. Numerics (TUHH): Compulsory<br>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory<br>Technomathematics: Specialisation I. Mathematics: Elective Compulsory<br>Theoretical Mechanical Engineering: Core qualification: Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0576: Numerical Treatment of Ordinary Differential Equations | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Sabine Le Borne, Dr. Christian Seifert |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | Numerical methods for Initial Value Problems<br>• single step methods<br>• multistep methods<br>• stiff problems<br>• differential algebraic equations (DAE) of index 1<br>Numerical methods for Boundary Value Problems<br>• multiple shooting method<br>• difference methods<br>• variational methods |
| **Literature** | • E. Hairer, S. Noersett, G. Wanner: Solving Ordinary Differential Equations I: Nonstiff Problems<br>• E. Hairer, G. Wanner: Solving Ordinary Differential Equations II: Stiff and Differential-Algebraic Problems |

| Course L0582: Numerical Treatment of Ordinary Differential Equations | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Sabine Le Borne, Dr. Christian Seifert |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0749: Waste Treatment and Solid Matter Process Technology

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Solid Matter Process Technology for Biomass (L0052) | Lecture | 2 | 2 |
| Thermal Waste Treatment (L0320) | Lecture | 2 | 2 |
| Thermal Waste Treatment (L1177) | Recitation Section (large) | 1 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Kerstin Kuchta |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basics of<br>• thermo dynamics<br>• fluid dynamics<br>• chemistry |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students can name, describe current issue and problems in the field of thermal waste treatment and particle process engineering and contemplate them in the context of their field.<br><br>The industrial application of unit operations as part of process engineering is explained by actual examples of waste incineration technologies and solid biomass processes. Compostion, particle sizes, transportation and dosing, drying and agglomeration of renewable resources and wastes are described as important unit operations when producing solid fuels and bioethanol, producing and refining edible oils, electricity , heat and mineral recyclables. |
| *Skills* | The students are able to select suitable processes for the treatment of wastes or raw material with respect to their characteristics and the process aims. They can evaluate the efforts and costs for processes and select economically feasible treatment concepts. |
| **Personal Competence** | |
| *Social Competence* | Students can<br>• respectfully work together as a team and discuss technical tasks<br>• participate in subject-specific and interdisciplinary discussions,<br>• develop cooperated solutions<br>• promote the scientific development and accept professional constructive criticism. |
| *Autonomy* | Students can independently tap knowledge of the subject area and transform it to new questions. They are capable, in consultation with supervisors, to assess their learning level and define further steps on this basis. Furthermore, they can define targets for new application-or research-oriented duties in accordance with the potential social, economic and cultural impact. |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 120 min |
| **Assignment for the Following Curricula** | Civil Engineering: Specialisation Water and Traffic: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory<br>International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Elective Compulsory |

| Course L0052: Solid Matter Process Technology for Biomass | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Werner Sitzmann |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | The industrial application of unit operations as part of process engineering is explained by actual examples of solid biomass processes. Size reduction, transportation and dosing, drying and agglomeration of renewable resources are described as important unit operations when producing solid fuels and bioethanol, producing and refining edible oils, when making Btl - and WPC - products. Aspects of explosion protection and plant design complete the lecture. |
| **Literature** | Kaltschmitt M., Hartmann H. (Hrsg.): Energie aus Bioamsse, Springer Verlag, 2001, ISBN 3-540-64853-4<br><br>Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz, Schriftenreihe Nachwachsende Rohstoffe,<br><br>Fachagentur Nachwachsende Rohstoffe e.V. www.nachwachsende-rohstoffe.de<br><br>Bockisch M.: Nahrungsfette und -öle, Ulmer Verlag, 1993, ISBN 380000158175 |

| Course L0320: Thermal Waste Treatment | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Kerstin Kuchta |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Introduction, actual state-of-the-art of waste incineration, aims. legal background, reaction principals<br>• basics of incineration processes: waste composition, calorific value, calculation of air demand and flue gas composition<br>• Incineration techniques: grate firing, ash transfer, boiler<br>• Flue gas cleaning: Volume, composition, legal frame work and emission limits, dry treatment, scrubber, de-nox techniques, dioxin elimination, Mercury elimination<br>• Ash treatment: Mass, quality, treatment concepts, recycling, disposal |
| **Literature** | Thomé-Kozmiensky, K. J. (Hrsg.): Thermische Abfallbehandlung Bande 1-7. EF-Verlag für Energie- und Umwelttechnik, Berlin, 196 - 2013. |

| Course L1177: Thermal Waste Treatment | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Kerstin Kuchta |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0897: Computer Aided Process Engineering (CAPE)

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| CAPE with Computer Exercises (L1039) | Lecture | 2 | 3 |
| Methods of Process Safety and Dangerous Substances (L1040) | Lecture | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Georg Fieg |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | thermal separation processes<br>heat and mass transport processes |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | students can:<br>- outline types of simulation tools<br>- describe principles of flowsheet and equation oriented simulation tools<br>- describe the setting of flowsheet simulation tools<br>- explain the main differences between steady state and dynamic simulations<br>- present the fundamentals of toxicology and hazardous materials<br>- explain the main methods of safety engineering<br>- present the importance of safety analysis with respect to plant design<br>- describe the definitions within the legal accident insurance<br>accident insurance |
| *Skills* | students can:<br>- conduct steady state and dynamic simulations<br>- evaluate simulation results and transform them in the practice<br>- choose and combine suitable simulation models into a production plant<br>- evaluate the achieved simulation results regarding practical importance<br>- evaluate the results of many experimental methods regarding safety aspects<br>- review, compare and use results of safety considerations for a plant design |
| **Personal Competence** | |
| *Social Competence* | students are able to:<br>- work together in teams in order to simulate process elements and develop an integral process<br>- develop in teams a safety concept for a process and present it to the audience |
| *Autonomy* | students are able to<br>- act responsible with respect to environment and needs of the society |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |

| **Course achievement** | **Compulsory** | **Bonus** | **Form** | **Description** |
|---|---|---|---|---|
| | Yes | None | Group discussion | Gruppendiskussionen finden im Rahmen der PC-Übungen statt |

| | |
|---|---|
| **Examination** | Written exam |
| **Examination duration and scale** | 180 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L1039: CAPE with Computer Exercises | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Georg Fieg |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | I. Introduction<br><br>1. Fundamentals of steady state process simulation<br><br>1.1. Classes of simulation tools<br>1.2. Sequential-modularer approach<br>1.3. Operating mode of ASPEN PLUS<br>2. Introduction in ASPEN PLUS<br>2.1. GUI<br>2.2. Estimation methods of physical properties<br>2.3. Aspen tools (z.B. Designspecification)<br>2.4. Convergence methods<br><br>II. Exercices using ASPEN PLUS and ACM<br><br>Performance and constraints of ASPEN PLUS<br>ASPEN datenbank using<br>Estimation methods of physical properties<br>Application of model databank, process synthesis<br><br>Design specifications<br><br>Sensitivity analysis<br>Optimization tasks<br>Industrial cases |
| **Literature** | - G. Fieg: Lecture notes<br>- Seider, W.D.; Seader, J.D.; Lewin, D.R.: Product and Process Design Principles: Synthesis, Analysis, and Evaluation; Hoboken, J. Wiley & Sons, 2010 |

| Course L1040: Methods of Process Safety and Dangerous Substances | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Georg Fieg, Dr. Thomas Waluga |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | |
| **Literature** | Bender, H.: Sicherer Umgang mit Gefahrstoffen; Weinheim (2005)<br>Bender, H.: Das Gefahrstoffbuch. Sicherer Umgang mit Gefahrstoffen in der Praxis; Weinheim (2002)<br>Birett, K.: Umgang mit Gefahrstoffen; Heidelberg (2011)<br>Birgersson, B.; Sterner, O.; Zimerson, E.: Chemie und Gesundheit; Weinheim (1988)<br><br>O. Antelmann, Diss. an der TU Berlin, 2001<br>R. Dittmeyer, W. Keim, G. Kreysa, A. Oberholz, Chemische Technik, Prozesse und Produkte, Band 1<br><br>Methodische Grundlagen, VCH, 2004-2006, S. 719<br><br>H. Pohle, Chemische Industrie, Umweltschutz, Arbeitsschutz, Anlagensicherheit, VCH, Weinheim, 1991<br><br>J. Steinbach, Chemische Sicherheitstechnik, VCH, Weinheim, 1995<br><br>G. Suter, Identifikation sicherheitskritischer Prozesse, P&A Kompendium, 2004 |

## Module M0898: Heterogeneous Catalysis

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Analysis and Design of Heterogeneous Catalytic Reactors (L0223) | Lecture | 2 | 2 |
| Modern Methods in Heterogeneous Catalysis (L0533) | Lecture | 2 | 2 |
| Modern Methods in Heterogeneous Catalysis (L0534) | Practical Course | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Raimund Horn |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Content of the bachelor-modules "process technology", as well as particle technology, fluidmechanics in process-technology and transport processes. |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students are able to apply their knowledge to explain industrial catalytic processes as well as indicate different synthesis routes of established catalyst systems. They are capable to outline dis-/advantages of supported and full-catalysts with respect to their application. Students are able to identify anayltical tools for specific catalytic applications. |
| *Skills* | After successfull completition of the module, students are able to use their knowledge to identify suitable analytical tools for specific catalytic applications and to explain their choice. Moreover the students are able to choose and formulate suitable reactor systems for the current synthesis process. Students can apply their knowldege discretely to develop and conduct experiments. They are able to appraise achieved results into a more general context and draw conclusions out of them. |
| **Personal Competence** | |
| *Social Competence* | The students are able to plan, prepare, conduct and document experiments according to scientific guidelines in small groups.<br>The students can discuss their subject related knowledge among each other and with their teachers. |
| *Autonomy* | The students are able to obtain further information for experimental planning and assess their relevance autonomously. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | **Compulsory** / **Bonus** / **Form** / **Description**<br>Yes / None / Presentation |
| **Examination** | Written exam |
| **Examination duration and scale** | 120 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Core qualification: Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0223: Analysis and Design of Heterogeneous Catalytic Reactors | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Raimund Horn |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | 1. Material- and Energybalance of the two-dimensionsal zweidimensionalen pseudo-homogeneous reactor model<br><br>2. Numerical solution of ordinary differential equations (Euler, Runge-Kutta, solvers for stiff problems, step controlled solvers)<br><br>3. Reactor design with one-dimensional models (ethane cracker, catalyst deactivation, tubular reactor with deactivating catalyst, moving bed reactor with regenerating catalyst, riser reactor, fluidized bed reactor)<br><br>4. Partial differential equations (classification, numerical solution Lösung, finite difference method, method of lines)<br><br>5. Examples of reactor design (isothermal tubular reactor with axial dispersion, dehydrogenation of ethyl benzene, wrong-way behaviour)<br><br>6. Boundary value problems (numerical solution, shooting method, concentration- and temperature profiles in a catalyst pellet, multiphase reactors, trickle bed reactor) |
| **Literature** | 1. Lecture notes R. Horn<br><br>2. Lecture notes F. Keil<br><br>3. G. F. Froment, K. B. Bischoff, J. De Wilde, Chemical Reactor Analysis and Design, John Wiley & Sons, 2010<br><br>4. R. Aris, Elementary Chemical Reactor Analysis, Dover Pubn. Inc., 2000 |

| Course L0533: Modern Methods in Heterogeneous Catalysis | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Raimund Horn |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | Heterogeneous Catalysis and Chemical Reaction Engineering are inextricably linked. About 90% of all chemical intermediates and consumer products (fuels, plastics, fertilizers etc.) are produced with the aid of catalysts. Most of them, in particular large scale products, are produced by heterogeneous catalysis viz. gaseous or liquid reactants react on solid catalysts. In multiphase reactors gases, liquids and a solid catalyst are present.<br><br>Heterogeneous catalysis plays also a key role in any future energy scenario (fuel cells, electrocatalytic splitting of water) and in environmental engineering (automotive catalysis, photocatalyic abatement of water pollutants).<br><br>Heterogeneous catalysis is an interdisciplinary science requiring knowledge of different scientific disciplines such as<br><br>• Materials Science (synthesis and characterization of solid catalysts)<br>• Physics (structure and electronic properties of solids, defects)<br>• Physical Chemistry (thermodynamics, reaction mechanisms, chemical kinetics, adsorption, desorption, spectroscopy, surface chemistry, theory)<br>• Reaction Engineering (catalytic reactors, mass- and heat transport in catalytic reactors, multi-scale modeling, application of heterogeneous catalysis)<br><br>The class „Modern Methods in Heterogeneous Catalysis“ will deal with the above listed aspects of heterogeneous catalysis beyond the material presented in the normal curriculum of chemical reaction engineering classes. In the corresponding laboratory will have the opportunity to apply their aquired theoretical knowledge by synthesizing a solid catalyst, characterizing it with a variety of modern instrumental methods (e.g. BET, chemisorption, pore analysis, XRD, Raman-Spectroscopy, Electron Microscopy) and measuring its kinetics. Class and laboratory „Modern Methods in Heterogeneous Catalysis“ in combination with the lecture „Analysis and Design of Heterogeneous Catalytic Reactors“ will give interested students the opportunity to specialize in this vibrant, multifaceted and application oriented field of research. |
| **Literature** | • J.M. Thomas, W.J. Thomas: Principles and Practice of Heterogeneous Catalysis, VCH<br>• I. Chorkendorff, J. W. Niemantsverdriet, Concepts of Modern Catalysis and Kinetics, WILEY-VCH<br>• B.C. Gates: Catalytic Chemistry, John Wiley<br>• R.A. van Santen, P.W.N.M. van Leeuwen, J.A. Moulijn, B.A. Averill (Eds.): Catalysis: an integrated approach, Elsevier<br>• D.P. Woodruff, T.A. Delchar: Modern Techniques of Surface Science, Cambridge Univ. Press<br>• J.W. Niemantsverdriet: Spectrocopy in Catalysis, VCH<br>• F. Delannay (Ed.): Characterization of heterogeneous catalysts, Marcel Dekker<br>• C.H. Bartholomew, R.J. Farrauto: Fundamentals of Industrial Catalytic Processes (2nd Ed.),Wiley |

| Course L0534: Modern Methods in Heterogeneous Catalysis | |
|---|---|
| **Typ** | Practical Course |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Raimund Horn |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0906: Numerical Simulation and Lagrangian Transport

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Lagrangian transport in turbulent flows (L2301) | Lecture | 2 | 3 |
| Computational Fluid Dynamics - Exercises in OpenFoam (L1375) | Recitation Section (small) | 1 | 1 |
| Computational Fluid Dynamics in Process Engineering (L1052) | Lecture | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Michael Schlüter |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Mathematics I-IV<br>• Basic knowledge in Fluid Mechanics<br>• Basic knowledge in chemical thermodynamics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After successful completion of the module the students are able to<br>• explain the the basic principles of statistical thermodynamics (ensembles, simple systems)<br>• describe the main approaches in classical Molecular Modeling (Monte Carlo, Molecular Dynamics) in various ensembles<br>• discuss examples of computer programs in detail,<br>• evaluate the application of numerical simulations,<br>• list the possible start and boundary conditions for a numerical simulation. |
| *Skills* | The students are able to:<br>• set up computer programs for solving simple problems by Monte Carlo or molecular dynamics,<br>• solve problems by molecular modeling,<br>• set up a numerical grid,<br>• perform a simple numerical simulation with OpenFoam,<br>• evaluate the result of a numerical simulation. |
| **Personal Competence** | |
| *Social Competence* | The students are able to<br>• develop joint solutions in mixed teams and present them in front of the other students,<br>• to collaborate in a team and to reflect their own contribution toward it. |
| *Autonomy* | The students are able to:<br>• evaluate their learning progress and to define the following steps of learning on that basis,<br>• evaluate possible consequences for their profession. |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Oral exam |
| **Examination duration and scale** | 30 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L2301: Lagrangian transport in turbulent flows | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Alexandra von Kameke |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | |
| **Literature** | |

| Course L1375: Computational Fluid Dynamics - Exercises in OpenFoam | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Michael Schlüter |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • generation of numerical grids with a common grid generator<br>• selection of models and boundary conditions<br>• basic numerical simulation with OpenFoam within the TUHH CIP-Pool |
| **Literature** | OpenFoam Tutorials (StudIP) |

| Course L1052: Computational Fluid Dynamics in Process Engineering | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Michael Schlüter |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Introduction into partial differential equations<br>• Basic equations<br>• Boundary conditions and grids<br>• Numerical methods<br>• Finite difference method<br>• Finite volume method<br>• Time discretisation and stability<br>• Population balance<br>• Multiphase Systems<br>• Modeling of Turbulent Flows<br>• Exercises: Stability Analysis<br>• Exercises: Example on CFD - analytically/numerically |
| **Literature** | Paschedag A.R.: CFD in der Verfahrenstechnik: Allgemeine Grundlagen und mehrphasige Anwendungen, Wiley-VCH, 2004 ISBN 3-527-30994-2.<br><br>Ferziger, J.H.; Peric, M.: Numerische Strömungsmechanik. Springer-Verlag, Berlin, 2008, ISBN: 3540675868.<br><br>Ferziger, J.H.; Peric, M.: Computational Methods for Fluid Dynamics. Springer, 2002, ISBN 3-540-42074-6 |

## Module M0633: Industrial Process Automation

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Industrial Process Automation (L0344) | Lecture | 2 | 3 |
| Industrial Process Automation (L0345) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Alexander Schlaefer |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | mathematics and optimization methods<br>principles of automata<br>principles of algorithms and data structures<br>programming skills |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students can evaluate and assess discrete event systems. They can evaluate properties of processes and explain methods for process analysis. The students can compare methods for process modelling and select an appropriate method for actual problems. They can discuss scheduling methods in the context of actual problems and give a detailed explanation of advantages and disadvantages of different programming methods. The students can relate process automation to methods from robotics and sensor systems as well as to recent topics like 'cyberphysical systems' and 'industry 4.0'. |
| *Skills* | The students are able to develop and model processes and evaluate them accordingly. This involves taking into account optimal scheduling, understanding algorithmic complexity, and implementation using PLCs. |
| **Personal Competence** | |
| *Social Competence* | The students work in teams to solve problems. |
| *Autonomy* | The students can reflect their knowledge and document the results of their work. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |

**Course achievement**

| Compulsory | Bonus | Form | Description |
|---|---|---|---|
| No | 10 % | Excercises | |

| | |
|---|---|
| **Examination** | Written exam |
| **Examination duration and scale** | 90 minutes |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory<br>Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory<br>International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory<br>International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory<br>Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory<br>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0344: Industrial Process Automation | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Alexander Schlaefer |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | - foundations of problem solving and system modeling, discrete event systems<br>- properties of processes, modeling using automata and Petri-nets<br>- design considerations for processes (mutex, deadlock avoidance, liveness)<br>- optimal scheduling for processes<br>- optimal decisions when planning manufacturing systems, decisions under uncertainty<br>- software design and software architectures for automation, PLCs |
| **Literature** | J. Lunze: „Automatisierungstechnik“, Oldenbourg Verlag, 2012<br>Reisig: Petrinetze: Modellierungstechnik, Analysemethoden, Fallstudien; Vieweg+Teubner 2010<br>Hrúz, Zhou: Modeling and Control of Discrete-event Dynamic Systems; Springer 2007<br>Li, Zhou: Deadlock Resolution in Automated Manufacturing Systems, Springer 2009<br>Pinedo: Planning and Scheduling in Manufacturing and Services, Springer 2009 |

| Course L0345: Industrial Process Automation | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Alexander Schlaefer |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0899: Synthesis and Design of Industrial Processes

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Synthesis and Design of Industrial Facilities (L1048) | Lecture | 1 | 2 |
| Industrial Plant Design and Economics (L1977) | Project-/problem-based Learning | 3 | 4 |

| | |
|---|---|
| **Module Responsible** | Prof. Mirko Skiborowski |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | process and plant engineering I and II<br>thermal separation processes<br>heat and mass transport processes<br>CAPE (absolut necessarily!) |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | students can:<br>- reproduce the main elements of design of industrial processes<br>- give an overview and explain the phases of design<br>- describe and explain energy, mass balances, cost estimation methods and economic evaluation of invest projects<br>- justify and discuss process control concepts and fundamentals of process optimization |
| *Skills* | students are capable of:<br>-conduction and evaluation of design of unit operations<br>- combination of unit operation to a complex process plant<br>- use of cost estimation methods for the prediction of production costs<br>- carry out the pfd-diagram |
| **Personal Competence** | |
| *Social Competence* | students are able to discuss and develop in groups the design of an industrial process |
| *Autonomy* | students are able to reflect the consequences of their professional activity |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Subject theoretical and practical work |
| **Examination duration and scale** | Engineering Handbook and oral exam (20 min) |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L1048: Synthesis and Design of Industrial Facilities | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Mirko Skiborowski, Dr. Thomas Waluga |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | Presentation of the task<br>Introduction to design and analysis of a chemical processing plant (example chemical processing plants)<br>Discussion of the process, preparation of process flow diagram<br>Calculation of material balance<br>Calculation of energy balance<br>Designing/Sizing of the equipment<br>Capital cost estimation<br>Production cost estimation<br>Process control & HAZOP Study<br>Lecture 11 = Process optimization<br>Lecture 12 = Final Project Presentation |
| **Literature** | Richard Turton; Analysis, Synthesis and Design of Chemical Processes:International Edition<br>Harry Silla; Chemical Process Engineering: Design And Economics<br>Coulson and Richardson's Chemical Engineering, Volume 6, Second Edition: Chemical Engineering Design<br>Lorenz T. Biegler;Systematic Methods of Chemical Process Design<br>Max S. Peters, Klaus Timmerhaus; Plant Design and Economics for Chemical Engineers<br>James Douglas; Conceptual Design of Chemical Processes<br>Robin Smith; Chemical Process: Design and Integration<br>Warren D. Seider; Process design principles, synthesis analysis and evaluation |

| Course L1977: Industrial Plant Design and Economics | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 3 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 78, Study Time in Lecture 42 |
| **Lecturer** | Prof. Mirko Skiborowski, Dr. Thomas Waluga |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | Introduction<br>Flowsheet (Discussion)<br>Mass and Energy Balances<br>Economics<br>Process Safety |
| **Literature** | Richard Turton; Analysis, Synthesis and Design of Chemical Processes:International Edition<br>Harry Silla; Chemical Process Engineering: Design And Economics<br>Coulson and Richardson's Chemical Engineering, Volume 6, Second Edition: Chemical Engineering Design<br>Lorenz T. Biegler;Systematic Methods of Chemical Process Design<br>Max S. Peters, Klaus Timmerhaus; Plant Design and Economics for Chemical Engineers<br>James Douglas; Conceptual Design of Chemical Processes<br>Robin Smith; Chemical Process: Design and Integration<br>Warren D. Seider; Process design principles, synthesis analysis and evaluation |

## Module M0900: Examples in Solid Process Engineering

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Fluidization Technology (L0431) | Lecture | 2 | 2 |
| Practical Course Fluidization Technology (L1369) | Practical Course | 1 | 1 |
| Technical Applications of Particle Technology (L0955) | Lecture | 2 | 2 |
| Exercises in Fluidization Technology (L1372) | Recitation Section (small) | 1 | 1 |

| | |
|---|---|
| **Module Responsible** | Prof. Stefan Heinrich |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Knowledge from the module particle technology |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After completion of the module the students will be able to describe based on examples the assembly of solids engineering processes consisting of multiple apparatuses and subprocesses. They are able to describe the coaction and interrelation of subprocesses. |
| *Skills* | Students are able to analyze tasks in the field of solids process engineering and to combine suitable subprocesses in a process chain. |
| **Personal Competence** | |
| *Social Competence* | Students are able to discuss technical problems in a scientific manner. |
| *Autonomy* | Students are able to acquire scientific knowledge independently and discuss technical problems in a scientific manner. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |

**Course achievement**

| Compulsory | Bonus | Form | Description |
|---|---|---|---|
| Yes | None | Written elaboration | drei Berichte (pro Versuch ein Bericht) à 5-10 Seiten |

| | |
|---|---|
| **Examination** | Written exam |
| **Examination duration and scale** | 120 minutes |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

### Course L0431: Fluidization Technology

| | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Stefan Heinrich |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | Introduction: definition, fluidization regimes, comparison with other types of gas/solids reactors<br>Typical fluidized bed applications<br>Fluidmechanical principle<br>Local fluid mechanics of gas/solid fluidization<br>Fast fluidization (circulating fluidized bed)<br>Entrainment<br>Solids mixing in fluidized beds<br>Application of fluidized beds to granulation and drying processes |
| **Literature** | Kunii, D.; Levenspiel, O.: Fluidization Engineering. Butterworth Heinemann, Boston, 1991. |

| Course L1369: Practical Course Fluidization Technology | |
|---|---|
| **Typ** | Practical Course |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Stefan Heinrich |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | Experiments:<br>• Determination of the minimum fluidization velocity<br>• heat transfer<br>• granulation<br>• drying |
| **Literature** | Kunii, D.; Levenspiel, O.: Fluidization Engineering. Butterworth Heinemann, Boston, 1991. |

| Course L0955: Technical Applications of Particle Technology | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Werner Sitzmann |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | Unit operations like mixing, separation, agglomeration and size reduction are discussed concerning their technical applicability from the perspective of the practician. Machines and apparatuses are presented, their designs and modes of action are explained and their application in production processes for chemicals, food and feed and in recycling processes are illustrated. |
| **Literature** | Stieß M: Mechanische Verfahrenstechnik I und II, Springer - Verlag, 1997 |

| Course L1372: Exercises in Fluidization Technology | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Stefan Heinrich |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | Exercises and calculation examples for the lecture Fluidization Technology |
| **Literature** | Kunii, D.; Levenspiel, O.: Fluidization Engineering. Butterworth Heinemann, Boston, 1991. |

## Module M1033: Special Areas of Process Engineering and Bioprocess Engineering

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Chemical Kinetics (L0508) | Lecture | 2 | 2 |
| Solid Matter Process in chemical Industry (L2021) | Lecture | 2 | 2 |
| Interfaces and Colloids (L0194) | Lecture | 2 | 2 |
| Industrial Inorganic and Organic Processes (L0531) | Lecture | 2 | 2 |
| Industrial biotechnology in Chemical Industriy (L2276) | Lecture | 2 | 3 |
| Optics for Engineers (L2437) | Lecture | 2 | 2 |
| Optics for Engineers (L2438) | Project-/problem-based Learning | 2 | 2 |
| Polymer Reaction Engineering (L1244) | Lecture | 2 | 2 |
| Practice in bioprocess engineering (L2275) | Lecture | 2 | 3 |
| Safety of Chemical Reactions (L1321) | Lecture | 2 | 2 |
| Ceramics Technology (L0379) | Lecture | 2 | 3 |
| Environmental Analysis (L0354) | Lecture | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Michael Schlüter |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | The students should have passed the Bachelor modules "Process Engineering" successfully. |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to find their way around selected special areas of Process Engineering within the scope of Process Engineering.<br>Students are able to explain technical dependencies and models in selected special areas of Process Engineering. |
| *Skills* | Students are able to apply basic methods in selected areas of process engineering. |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | Students can chose independently, in which field the want to deepen their knowledge and skills through the election of courses. |
| **Workload in Hours** | Depends on choice of courses |
| **Credit points** | 6 |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0508: Chemical Kinetics | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Klausur |
| **Examination duration and scale** | 120 Minuten |
| **Lecturer** | Prof. Raimund Horn |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | - Micro kinetics, formal kinetics, molecularity, reaction order, integrated rate laws<br><br>- Complex reactions, reversible reactions, consecutive reactions, parallel reactions, approximation methods: steady-state, pseudo-first order, numerical solution of rate equations , example : Belousov-Zhabotinskii reaction<br><br>- Experimental methods of kinetics, integral approach, differential approach, initial rate method, method of half-life, relaxation methods<br><br>- Collision theory, Maxwell velocity distribution, collision numbers, line of centers model<br><br>- Transition state theory, partition functions of atoms and molecules, examples, calculating reaction equilibria on the basis of molecular data only, heats of reaction, calculating rates of reaction by means of statistical thermodynamics<br><br>- Kinetics of heterogeneous reactions, peculiarities of heterogeneous reactions, mean-field approximation, Langmuir adsorption isotherm, reaction mechanisms, Langmuir-Hinshelwood Mechanism, Eley-Rideal Mechanism, steady-state approximation, quasi-equilibrium approximation, most abundant reaction intermediate (MARI), reaction order, apparent activation energy, example: CO oxidation, transition state theory of surface reactions, Sabatier´s principle, sticking coefficient, parameter fitting<br><br>- Explosions, cold flames |
| **Literature** | J. I. Steinfeld, J. S. Francisco, W. L . Hase: Chemical Kinetics & Dynamics, Prentice Hall<br><br>K. J. Laidler: Chemical Kinetics, Harper & Row Publishers<br><br>R. K. Masel. Chemical Kinetics & Catalysis , Wiley<br><br>I. Chorkendorff,, J. W. Niemantsverdriet: Concepts of modern Catalysis and Kinetics, Wiley |

| Course L2021: Solid Matter Process in chemical Industry | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Schriftliche Ausarbeitung |
| **Examination duration and scale** | 12 Seiten |
| **Lecturer** | Prof. Frank Kleine Jäger |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | |
| **Literature** | |

| Course L0194: Interfaces and Colloids | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Schriftliche Ausarbeitung |
| **Examination duration and scale** | 1 Stunde |
| **Lecturer** | Dr. Philip Jaeger |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | 1.Fundamentals, definitions 1.1 Thermodynamics of interfaces 1.2 Surfactants 1.3 Interfacial tension (Principles, Methods, Examples) 1.4 Wetting, adhesion 2.Dispersions 2.1 Droplet formation 2.2 Stabilization 2.3 Physical Properties 2.4 Rheology 2.5 Microemulsions 3. Transport Phenomena 3.1 Mass transport across phase boundaries 3.2 Interfacial convection - Marangoni flow 3.3 Influence of surfactants on interfacial area and transport resistance (bubbles, droplets, falling films) 4. Applications 4.1 Food Emulsification 4.2 Crude oil recovery (EOR) 4.3 Coating 4.4 Separation technology (Spray towers, packed columns) 4.5 Nucleation (Polymer foams, evaporation) 4.6 Recent developments (Surfactant aided extraction) |
| **Literature** | A.W. Adamson: Physical Chemistry of Surfaces, 5th ed., J. Wiley & Sons New York, 1990. P. Becher : Emulsions - Theory and Practice, 1965. P. Becher : Encyclopedia of Emulsion Technology, Vol. 1, Dekker New York, 1983. S.S. Dukhin, G. Kretzschmar, R. Miller: Dynamics of Adsorption at Liquid Interfaces, Elsevier Amsterdam, 1995. D.J. McClements: Food Emulsions - Principle, Practices and Techniques, 2nd ed., CRC Press Boca Raton, 2005. D. Myers: Surfaces, Interfaces and Colloids, VCH-Verlagsgesellschaft Weinheim, 1991. P. Sherman: Emulsion Science, 1968. J. Lyklema: Fundamentals of Interface and Colloid Science, Vol. III, Academic Press London, 2000. A.I. Rusanov: Phasengleichgewichte und Grenzflächenerscheinungen, Akademie Verlag, Berlin 1978. P. C. Hiemenz, R. Rajagopalan: Principles of Colloid and Surface Chemistry, 3rd ed. Marcel Dekker, New York 1997. P. Grassmann: Physikalische Grundlagen der Verfahrenstechnik, Verlag Salle und Sauerländer, 1983. M.J. Schwuger: Lehrbuch der Grenzflächenchemie, Thieme Verlag, 1996. |

| Course L0531: Industrial Inorganic and Organic Processes | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Klausur |
| **Examination duration and scale** | 45 Minuten |
| **Lecturer** | Dr. Achim Bartsch |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | The occupational area of chemical engineers is principally the chemical industry.<br><br>This survey course will focus on history, economic significance, technical applications, and main production processes in detail of major primary bulk inorganic and organic chemicals. Disposition of raw materials as well as ecological problems are discussed.<br><br>Inorganic Products<br><br>* inorganic raw materials (hydrogen and compounds, nitrogen and compounds...)<br><br>* inorganic fertilizers<br><br>* metals and their compounds<br><br>* semiconductors<br><br>* inorganic solids (building materials, ceramics, fibers, pigments ...)<br><br>...<br><br>Organic Products<br><br>* bulk products for organic synthesis (synthesis gas, C1-compounds)<br><br>* Production and processing of olefines, alcohols, hydrocarbons, aromatics<br><br>* Petroleum and Petrochemicals<br><br>* Surfactants and Detergents<br><br>* Production and processing of oleochemicals<br><br>* Synthetic Polymers<br><br>... |
| **Literature** | Ullmann's Encyclopedia of Industrial Chemistry, Wiley online library 2014<br><br>M. Bertau, A. Müller, P. Fröhlich und M. Katzberg: Industrielle Anorganische Chemie, Wiley-VCH 2013<br><br>Hans-Jürgen Arpe: Industrielle Organische Chemie, Wiley-VCH 2007 |

| Course L2276: Industrial biotechnology in Chemical Industriy | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Examination Form** | Referat |
| **Examination duration and scale** | 45 min |
| **Lecturer** | Prof. Andreas Liese, Dr. Stephan Freyer |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | This course gives an insight into the applications, processes, structures and boundary conditions in industrial practice. Various concrete applications of the technology, markets and other questions that will significantly influence the plant and process design will be shown. |
| **Literature** | Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen]<br><br>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.<br><br>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract<br><br>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003<br><br>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage<br><br>Krahe M (2003) Biochemical Engineering. Ullmann´s Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html<br><br>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts |

| Course L2437: Optics for Engineers | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Fachtheoretisch-fachpraktische Arbeit |
| **Examination duration and scale** | Vorstellung eines eigenen Optikentwurfs mit anschließender Diskussion, 10 Minuten Vorstellung + maximal 20 Minuten Diskussion |
| **Lecturer** | Prof. Thorsten Kern |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Basic values for optical systems and lighting technology<br>• Spectrum, black-bodies, color-perception<br>• Light-Sources und their characterization<br>• Photometrics<br>• Ray-Optics<br>• Matrix-Optics<br>• Stops, Pupils and Windows<br>• Light-field Technology<br>• Introduction to Wave-Optics<br>• Introduction to Holography |
| **Literature** | |

| Course L2438: Optics for Engineers | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Fachtheoretisch-fachpraktische Arbeit |
| **Examination duration and scale** | Vorstellung eines eigenen Optikentwurfs mit anschließender Diskussion, 10 Minuten Vorstellung + maximal 20 Minuten Diskussion |
| **Lecturer** | Prof. Thorsten Kern |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L1244: Polymer Reaction Engineering | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Schriftliche Ausarbeitung |
| **Examination duration and scale** | 1 Stunde |
| **Lecturer** | Prof. Hans-Ulrich Moritz |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | Introduction into polymer reaction engineering, free and controlled radical polymerization, coordination polymerization of olefins, ionic “living” polymerization, step polymerization (polyaddition, polycondensation), copolymerization, emulsion polymerization, specific challenges of the industrial implementation of polymerization reactions (viscosity increase, heat removal, scale-up, reactor safety, modelling of polymerization reactions and reactors), key competitive factors in polymer industry in Germany, EU and worldwide. |
| **Literature** | W. Keim: Kunststoffe - Synthese, Herstellungsverfahren, Apparaturen, 1. Auflage, Wiley-VCH, 2006<br>T. Meyer, J. Keurentjes: Handbook of Polymer Reaction Engineering, 2 Vol., 1. Ed., Wiley-VCH, 2005<br>A. Echte: Handbuch der technischen Polymerchemie, 1. Auflage, VCH-Verlagsgesellschaft, 1993<br>G. Odian: Principles of Polymerization, 4. Ed., Wiley-Interscience, 2004<br>J. Asua: Polymer Reaction Engineering, 1. Ed., Blackwell Publishing, 2007 |

| Course L2275: Practice in bioprocess engineering | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Examination Form** | Referat |
| **Examination duration and scale** | 45 min |
| **Lecturer** | Prof. An-Ping Zeng, Prof. Ralf Pörtner, Dr. Willfried Blümke |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | Content of this course is a concrete insight into the principles, processes and structures of an industrial biotechnology company. In addition to practical illustrative examples, aspects beyond the actual process engineering area are also addressed, such as e.g. Sustainability and engineering. |
| **Literature** | Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen]<br>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.<br>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract<br>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003<br>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage<br>Krahe M (2003) Biochemical Engineering. Ullmann´s Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html<br>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts |

| Course L1321: Safety of Chemical Reactions | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Klausur |
| **Examination duration and scale** | |
| **Lecturer** | Prof. Hans-Ulrich Moritz |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | |
| **Literature** | |

| Course L0379: Ceramics Technology | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Examination Form** | Klausur |
| **Examination duration and scale** | 90 Minuten |
| **Lecturer** | Dr. Rolf Janßen |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | Introduction to ceramic processing with emphasis on advanced structural ceramics. The course focus predominatly on powder-based processing, e.g. “powder-metauurgical techniques and sintering (soild state and liquid phase). Also, some aspects of glass and cement science as well as new developments in powderless forming techniques of ceramics and ceramic composites will be addressed Examples will be discussed in order to give engineering students an understanding of technology development and specific applications of ceramic components.<br>**Content:** 1. Introduction<br>Inhalt: 2. Raw materials<br>3. Powder fabrication<br>4. Powder processing<br>5. Shape-forming processes<br>6. Densification, sintering<br>7. Glass and Cement technology<br>8. Ceramic-metal joining techniques |
| **Literature** | W.D. Kingery, „Introduction to Ceramics“, John Wiley & Sons, New York, 1975<br>ASM Engineering Materials Handbook Vol.4 „Ceramics and Glasses“, 1991<br>D.W. Richerson, „Modern Ceramic Engineering“, Marcel Decker, New York, 1992<br>Skript zur Vorlesung |

| Course L0354: Environmental Analysis | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Examination Form** | Klausur |
| **Examination duration and scale** | 45 Minuten |
| **Lecturer** | Dr. Dorothea Rechtenbach, Dr. Henning Mangels |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | Introduction<br>Sampling in different environmental compartments, sample transportation, sample storage<br>Sample preparation<br>Photometry<br>Wastewater analysis<br>Introduction into chromatography<br>Gas chromatography<br>HPLC<br>Mass spectrometry<br>Optical emission spectrometry<br>Atom absorption spectrometry<br>Quality assurance in environmental analysis |
| **Literature** | Roger Reeve, Introduction to Environmental Analysis, John Wiley & Sons Ltd., 2002 (TUB: USD-728)<br>Pradyot Patnaik, Handbook of environmental analysis: chemical pollutants in air, water, soil, and solid wastes, CRC Press, Boca Raton, 2010 (TUB: USD-716)<br>Chunlong Zhang, Fundamentals of Environmental Sampling and Analysis, John Wiley & Sons Ltd., Hoboken, New Jersey, 2007 (TUB: USD-741)<br>Miroslav Radojević, Vladimir N. Bashkin, Practical Environmental Analysis<br>RSC Publ., Cambridge, 2006 (TUB: USD-720)<br>Werner Funk, Vera Dammann, Gerhild Donnevert, Sarah Iannelli (Translator), Eric Iannelli (Translator), Quality Assurance in Analytical Chemistry: Applications in Environmental, Food and Materials Analysis, Biotechnology, and Medical Engineering, 2nd Edition, WILEY-VCH Verlag GmbH & Co. KGaA,Weinheim, 2007 (TUB: CHF-350)<br>STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER, 21st Edition, Andrew D. Eaton, Leonore S. Clesceri, Eugene W. Rice, and Arnold E. Greenberg, editors, 2005 (TUB:CHF-428)<br>K. Robards, P. R. Haddad, P. E. Jackson, Principles and Practice of<br>Modern Chromatographic Methods, Academic Press<br>G. Schwedt, Chromatographische Trennmethoden, Thieme Verlag<br>H. M. McNair, J. M. Miller, Basic Gas Chromatography, Wiley<br>W. Gottwald, GC für Anwender, VCH<br>B. A. Bidlingmeyer, Practical HPLC Methodology and Applications, Wiley<br>K. K. Unger, Handbuch der HPLC, GIT Verlag<br>G. Aced, H. J. Möckel, Liquidchromatographie, VCH<br>Charles B. Boss and Kenneth J. Fredeen, Concepts, Instrumentation and Techniques in Inductively Coupled Plasma Optical Emission Spectrometry<br>Perkin-Elmer Corporation 1997, On-line available at:<br>http://files.instrument.com.cn/bbs/upfile/2006291448.pdf<br>Atomic absorption spectrometry: theory, design and applications, ed. by S. J. Haswell 1991 (TUB: 2727-5614)<br>Royal Society of Chemistry, Atomic absorption spectometry (http://www.kau.edu.sa/Files/130002/Files/6785_AAs.pdf) |

## Module M0905: Research Project Process Engineering

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Research Project in Process Engineering (L1051) | Project-/problem-based Learning | 6 | 6 |

| | |
|---|---|
| **Module Responsible** | Dozenten des SD V |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Advanced state of knowledge in the master program of Process Engineering |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students know current research topics oft institutes engaged in their specialization. They can name the fundamental scientific methods used for doing related reserach. |
| *Skills* | Students are capable of completing a small, independent sub-project of currently ongoing research projects in the institutes engaged in their specialization. Students can justify and explain their approach for problem solving, they can draw conclusions from their results, and then can find new ways and methods for their work. Students are capable of comparing and assessing alterantive approaches with their own with regard to given criteria. |
| **Personal Competence** | |
| *Social Competence* | Students are able to discuss their work progress with research assistants of the supervising institute. They are capable of presenting their results in front of a professional audience. |
| *Autonomy* | Based on their competences gained so far students are capable of defining meaningful tasks within ongoing research project for themselves. They are able to develop the necessary understanding and problem solving methods. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Study work |
| **Examination duration and scale** | According to General Regulations |
| **Assignment for the Following Curricula** | Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory |

### Course L1051: Research Project in Process Engineering

| | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 6 |
| **CP** | 6 |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Lecturer** | Dozenten des SD V |
| **Language** | DE/EN |
| **Cycle** | WiSe/SoSe |
| **Content** | Working on current research topics of the chosen specialisation.<br><br>Research projects can be carried out at the institutes of process engineering, in industry or abroad. It is always necessary to have a university lecturer from the school of Process Engineering as a supervisor, who must be determined before the research project begins. |
| **Literature** | Aktuelle Literatur zu Forschungsthemen aus der gewählten Vertiefungsrichtung.<br><br>Current literature on research topics of the chosen specialization. |

## Module M1396: Hybrid Processes in Process Engineering

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Hybrid Processes in Process Engineering (L1715) | Project-/problem-based Learning | 2 | 4 |
| Hybrid Processes in Process Engineering (L1978) | Lecture | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Mirko Skiborowski |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Process and Plant Engineering 1<br>Process and Plant Engineering 2<br>Basics in Process Engineering |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to evaluate hybrid processes |
| *Skills* | Students are able to evaluate processes with regard to their suitability as hybrid processes and to interpret them accordingly. |
| **Personal Competence** | |
| *Social Competence* | Students are able to apply the principles of project management for small groups. |
| *Autonomy* | Students are able to acquire and discuss specialized knowledge about hybrid processes. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |

| **Course achievement** | **Compulsory** | **Bonus** | **Form** | **Description** |
|---|---|---|---|---|
| | Yes | 15 % | Midterm | |

| | |
|---|---|
| **Examination** | Written elaboration |
| **Examination duration and scale** | Project report incl. PM-documents |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory |

### Course L1715: Hybrid Processes in Process Engineering

| | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 2 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 92, Study Time in Lecture 28 |
| **Lecturer** | Dr. Thomas Waluga |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L1978: Hybrid Processes in Process Engineering | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Thomas Waluga |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | |
| **Literature** | - H. Schmidt-Traub; Integrated Reaction and Separation Operations: Modelling and Experimental Validation; Springer 2006<br>- K. Sundmacher, A. Kienle, A. Seidel-Morgenstern; Integrated Chemical Processes: Synthesis, Operation, Analysis, and Control; Wiley-VCH 2005<br>- Mexandre C. Dimian (Ed); Integrated Design and Simulation of Chemical Processes; in Computer Aided Chemical Engineering, Volume 13, Pages 1-698 (2003) |

## Module M0537: Applied Thermodynamics: Thermodynamic Properties for Industrial Applications

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Applied Thermodynamics: Thermodynamic Properties for Industrial Applications (L0100) | Lecture | 4 | 3 |
| Applied Thermodynamics: Thermodynamic Properties for Industrial Applications (L0230) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Dr. Sven Jakobtorweihen |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Thermodynamics III |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students are capable to formulate thermodynamic problems and to specify possible solutions. Furthermore, they can describe the current state of research in thermodynamic property predictions. |
| *Skills* | The students are capable to apply modern thermodynamic calculation methods to multi-component mixtures and relevant biological systems. They can calculate phase equilibria and partition coefficients by applying equations of state, gE models, and COSMO-RS methods. They can provide a comparison and a critical assessment of these methods with regard to their industrial relevance. The students are capable to use the software COSMOtherm and relevant property tools of ASPEN and to write short programs for the specific calculation of different thermodynamic properties. They can judge and evaluate the results from thermodynamic calculations/predictions for industrial processes. |
| **Personal Competence** | |
| *Social Competence* | Students are capable to develop and discuss solutions in small groups; further they can translate these solutions into calculation algorithms. |
| *Autonomy* | Students can rank the field of “Applied Thermodynamics” within the scientific and social context. They are capable to define research projects within the field of thermodynamic data calculation. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | **Compulsory** **Bonus** **Form** **Description**<br>Yes None Written elaboration |
| **Examination** | Oral exam |
| **Examination duration and scale** | 1 Stunde Gruppenprüfung |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Core qualification: Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0100: Applied Thermodynamics: Thermodynamic Properties for Industrial Applications | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 4 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 34, Study Time in Lecture 56 |
| **Lecturer** | Dr. Sven Jakobtorweihen, Prof. Ralf Dohrn |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Phase equilibria in multicomponent systems<br>• Partioning in biorelevant systems<br>• Calculation of phase equilibria in colloidal systems: UNIFAC, COSMO-RS (exercises in computer pool)<br>• Calculation of partitioning coefficients in biological membranes: COSMO-RS (exercises in computer pool)<br>• Application of equations of state (vapour pressure, phase equilibria, etc.) (exercises in computer pool)<br>• Intermolecular forces, interaction Potenitials<br>• Introduction in statistical thermodynamics |
| **Literature** | |

| Course L0230: Applied Thermodynamics: Thermodynamic Properties for Industrial Applications | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Sven Jakobtorweihen, Prof. Ralf Dohrn |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | exercises in computer pool, see lecture description for more details |
| **Literature** | - |

## Module M0975: Industrial Bioprocesses in Practice

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Industrial biotechnology in Chemical Industriy (L2276) | Seminar | 2 | 3 |
| Practice in bioprocess engineering (L2275) | Seminar | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Andreas Liese |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Knowledge of bioprocess engineering and process engineering at bachelor level |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After successful completion of the module<br>• the students can outline the current status of research on the specific topics discussed<br>• the students can explain the basic underlying principles of the respective industrial biotransformations |
| *Skills* | After successful completion of the module students are able to<br>• analyze and evaluate current research approaches<br>• plan industrial biotransformations basically |
| **Personal Competence** | |
| *Social Competence* | Students are able to work together as a team with several students to solve given tasks and discuss their results in the plenary and to defend them. |
| *Autonomy* | The students are able independently to present the results of their subtasks in a presentation |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Presentation |
| **Examination duration and scale** | each seminar 15 min lecture and 15 min discussion |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory<br>Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory<br>Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Management and Controlling: Elective Compulsory<br>Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Management and Controlling: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory |

| Course L2276: Industrial biotechnology in Chemical Industriy | |
|---|---|
| **Typ** | Seminar |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Stephan Freyer |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | This course gives an insight into the applications, processes, structures and boundary conditions in industrial practice. Various concrete applications of the technology, markets and other questions that will significantly influence the plant and process design will be shown. |
| **Literature** | Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen]<br><br>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.<br><br>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract<br><br>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003<br><br>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage<br><br>Krahe M (2003) Biochemical Engineering. Ullmann´s Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html<br><br>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts |

| Course L2275: Practice in bioprocess engineering | |
|---|---|
| **Typ** | Seminar |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Willfried Blümke |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | Content of this course is a concrete insight into the principles, processes and structures of an industrial biotechnology company. In addition to practical illustrative examples, aspects beyond the actual process engineering area are also addressed, such as e.g. Sustainability and engineering. |
| **Literature** | Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen]<br><br>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.<br><br>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract<br><br>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003<br><br>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage<br><br>Krahe M (2003) Biochemical Engineering. Ullmann´s Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html<br><br>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts |

# Specialization Environmental Process Engineering

## Module M0513: System Aspects of Renewable Energies

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Fuel Cells, Batteries, and Gas Storage: New Materials for Energy Production and Storage (L0021) | Lecture | 2 | 2 |
| Energy Trading (L0019) | Lecture | 1 | 1 |
| Energy Trading (L0020) | Recitation Section (small) | 1 | 1 |
| Deep Geothermal Energy (L0025) | Lecture | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Martin Kaltschmitt |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Module: Technical Thermodynamics I<br>Module: Technical Thermodynamics II |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to describe the processes in energy trading and the design of energy markets and can critically evaluate them in relation to current subject specific problems. Furthermore, they are able to explain the basics of thermodynamics of electrochemical energy conversion in fuel cells and can establish and explain the relationship to different types of fuel cells and their respective structure. Students can compare this technology with other energy storage options. In addition, students can give an overview of the procedure and the energetic involvement of deep geothermal energy. |
| *Skills* | Students can apply the learned knowledge of storage systems for excessive energy to explain for various energy systems different approaches to ensure a secure energy supply. In particular, they can plan and calculate domestic, commercial and industrial heating equipment using energy storage systems in an energy-efficient way and can assess them in relation to complex power systems. In this context, students can assess the potential and limits of geothermal power plants and explain their operating mode.<br><br>Furthermore, the students are able to explain the procedures and strategies for marketing of energy and apply it in the context of other modules on renewable energy projects. In this context they can unassistedly carry out analysis and evaluations of energie markets and energy trades. |
| **Personal Competence** | |
| *Social Competence* | Students are able to discuss issues in the thematic fields in the renewable energy sector addressed within the module. |
| *Autonomy* | Students can independently exploit sources , acquire the particular knowledge about the subject area and transform it to new questions. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 3 hours written exam |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory<br>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory<br>Renewable Energies: Core qualification: Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Water: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Elective Compulsory |

| Course L0021: Fuel Cells, Batteries, and Gas Storage: New Materials for Energy Production and Storage | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Michael Fröba |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | 1. Introduction to electrochemical energy conversion<br>2. Function and structure of electrolyte<br>3. Low-temperature fuel cell<br>  ◦ Types<br>  ◦ Thermodynamics of the PEM fuel cell<br>  ◦ Cooling and humidification strategy<br>4. High-temperature fuel cell<br>  ◦ The MCFC<br>  ◦ The SOFC<br>  ◦ Integration Strategies and partial reforming<br>5. Fuels<br>  ◦ Supply of fuel<br>  ◦ Reforming of natural gas and biogas<br>  ◦ Reforming of liquid hydrocarbons<br>6. Energetic Integration and control of fuel cell systems |
| **Literature** | • Hamann, C.; Vielstich, W.: Elektrochemie 3. Aufl.; Weinheim: Wiley - VCH, 2003 |

| Course L0019: Energy Trading | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Michael Sagorje, Dr. Sven Orlowski |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | • Basic concepts and tradable products in energy markets<br>• Primary energy markets<br>• Electricity Markets<br>• European Emissions Trading Scheme<br>• Influence of renewable energy<br>• Real options<br>• Risk management<br><br>Within the exercise the various tasks are actively discussed and applied to various cases of application. |
| **Literature** | |

| Course L0020: Energy Trading | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Michael Sagorje, Dr. Sven Orlowski |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L0025: Deep Geothermal Energy | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Ben Norden |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | 1. Introduction to the deep geothermal use<br>2. Geological Basics I<br>3. Geological Basics II<br>4. Geology and thermal aspects<br>5. Rock Physical Aspects<br>6. Geochemical aspects<br>7. Exploration of deep geothermal reservoirs<br>8. Drilling technologies, piping and expansion<br>9. Borehole Geophysics<br>10. Underground system characterization and reservoir engineering<br>11. Microbiology and Upper-day system components<br>12. Adapted investment concepts, cost and environmental aspect |
| **Literature** | • Dipippo, R.: Geothermal Power Plants: Principles, Applications, Case Studies and Environmental Impact. Butterworth Heinemann; 3rd revised edition. (29. Mai 2012)<br>• www.geo-energy.org<br>• Edenhofer et al. (eds): Renewable Energy Sources and Climate Change Mitigation; Special Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 2012.<br>• Kaltschmitt et al. (eds): Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte. Springer, 5. Aufl. 2013.<br>• Kaltschmitt et al. (eds): Energie aus Erdwärme. Spektrum Akademischer Verlag; Auflage: 1999 (3. September 2001)<br>• Huenges, E. (ed.): Geothermal Energy Systems: Exploration, Development, and Utilization. Wiley-VCH Verlag GmbH & Co. KGaA; Auflage: 1. Auflage (19. April 2010) |

## Module M0874: Wastewater Systems

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Wastewater Systems - Collection, Treatment and Reuse (L0934) | Lecture | 2 | 2 |
| Wastewater Systems - Collection, Treatment and Reuse (L0943) | Recitation Section (large) | 1 | 1 |
| Advanced Wastewater Treatment (L0357) | Lecture | 2 | 2 |
| Advanced Wastewater Treatment (L0358) | Recitation Section (large) | 1 | 1 |

| | |
|---|---|
| **Module Responsible** | Prof. Ralf Otterpohl |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Knowledge of wastewater management and the key processes involved in wastewater treatment. |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to outline key areas of the full range of treatment systems in waste water management, as well as their mutual dependence for sustainable water protection. They can describe relevant economic, environmental and social factors. |
| *Skills* | Students are able to pre-design and explain the available wastewater treatment processes and the scope of their application in municipal and for some industrial treatment plants. |
| **Personal Competence** | |
| *Social Competence* | Social skills are not targeted in this module. |
| *Autonomy* | Students are in a position to work on a subject and to organize their work flow independently. They can also present on this subject. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 120 min |
| **Assignment for the Following Curricula** | Civil Engineering: Specialisation Structural Engineering: Elective Compulsory<br>Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory<br>Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory<br>Civil Engineering: Specialisation Water and Traffic: Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Environmental Engineering: Elective Compulsory<br>Environmental Engineering: Specialisation Water: Elective Compulsory<br>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Water: Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Compulsory |

| Course L0934: Wastewater Systems - Collection, Treatment and Reuse | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Ralf Otterpohl |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | •Understanding the global situation with water and wastewater<br>•Regional planning and decentralised systems<br>•Overview on innovative approaches<br>•In depth knowledge on advanced wastewater treatment options for different situations, for end-of-pipe and reuse<br>•Mathematical Modelling of Nitrogen Removal<br>•Exercises with calculations and design |
| **Literature** | Henze, Mogens:<br>Wastewater Treatment: Biological and Chemical Processes, Springer 2002, 430 pages<br><br>George Tchobanoglous, Franklin L. Burton, H. David Stensel:<br>Wastewater Engineering: Treatment and Reuse, Metcalf & Eddy<br>McGraw-Hill, 2004 - 1819 pages |

| Course L0943: Wastewater Systems - Collection, Treatment and Reuse | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Ralf Otterpohl |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L0357: Advanced Wastewater Treatment | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Joachim Behrendt |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | Survey on advanced wastewater treatment<br>reuse of reclaimed municipal wastewater<br>Precipitation<br>Flocculation<br>Depth filtration<br>Membrane Processes<br>Activated carbon adsorption<br>Ozonation<br>"Advanced Oxidation Processes"<br>Disinfection |
| **Literature** | Metcalf & Eddy, Wastewater Engineering: Treatment and Reuse, McGraw-Hill, Boston 2003<br><br>Wassertechnologie, H.H. Hahn, Springer-Verlag, Berlin 1987<br><br>Membranverfahren: Grundlagen der Modul- und Anlagenauslegung, T. Melin und R. Rautenbach, Springer-Verlag, Berlin 2007<br><br>Trinkwasserdesinfektion: Grundlagen, Verfahren, Anlagen, Geräte, Mikrobiologie, Chlorung, Ozonung, UV-Bestrahlung, Membranfiltration, Qualitätssicherung, W. Roeske, Oldenbourg-Verlag, München 2006<br><br>Organische Problemstoffe in Abwässern, H. Gulyas, GFEU, Hamburg 2003 |

| Course L0358: Advanced Wastewater Treatment | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Dr. Joachim Behrendt |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | Aggregate organic compounds (sum parameters)<br>Industrial wastewater<br>Processes for industrial wastewater treatment<br>Precipitation<br>Flocculation<br>Activated carbon adsorption<br>Recalcitrant organic compounds |
| **Literature** | Metcalf & Eddy, Wastewater Engineering: Treatment and Reuse, McGraw-Hill, Boston 2003<br>Wassertechnologie, H.H. Hahn, Springer-Verlag, Berlin 1987<br>Membranverfahren: Grundlagen der Modul- und Anlagenauslegung, T. Melin und R. Rautenbach, Springer-Verlag, Berlin 2007<br>Trinkwasserdesinfektion: Grundlagen, Verfahren, Anlagen, Geräte, Mikrobiologie, Chlorung, Ozonung, UV-Bestrahlung, Membranfiltration, Qualitätssicherung, W. Roeske, Oldenbourg-Verlag, München 2006<br>Organische Problemstoffe in Abwässern, H. Gulyas, GFEU, Hamburg 2003 |

## Module M0875: Nexus Engineering - Water, Soil, Food and Energy

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Ecological Town Design - Water, Energy, Soil and Food Nexus (L1229) | Seminar | 2 | 2 |
| Water & Wastewater Systems in a Global Context (L0939) | Lecture | 2 | 4 |

| | |
|---|---|
| **Module Responsible** | Prof. Ralf Otterpohl |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basic knowledge of the global situation with rising poverty, soil degradation, migration to cities, lack of water resources and sanitation |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can describe the facets of the global water situation. Students can judge the enormous potential of the implementation of synergistic systems in Water, Soil, Food and Energy supply. |
| *Skills* | Students are able to design ecological settlements for different geographic and socio-economic conditions for the main climates around the world. |
| **Personal Competence** | |
| *Social Competence* | The students are able to develop a specific topic in a team and to work out milestones according to a given plan. |
| *Autonomy* | Students are in a position to work on a subject and to organize their work flow independently. They can also present on this subject. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Subject theoretical and practical work |
| **Examination duration and scale** | During the course of the semester, the students work towards mile stones. The work includes presentations and papers. Detailed information can be found at the beginning of the smester in the StudIP course module handbook. |
| **Assignment for the Following Curricula** | Civil Engineering: Specialisation Water and Traffic: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Environmental Engineering: Core qualification: Elective Compulsory<br>Joint European Master in Environmental Studies - Cities and Sustainability: Core qualification: Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Water: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Elective Compulsory |

| Course L1229: Ecological Town Design - Water, Energy, Soil and Food Nexus | |
|---|---|
| **Typ** | Seminar |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Ralf Otterpohl |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Participants Workshop: Design of the most attractive productive Town<br>• Keynote lecture and video<br>• The limits of Urbanization / Green Cities<br>• The tragedy of the Rural: Soil degradation, agro chemical toxification, migration to cities<br>• Global Ecovillage Network: Upsides and Downsides around the World<br>• Visit of an Ecovillage<br>• Participants Workshop: Resources for thriving rural areas, Short presentations by participants, video competion<br>• TUHH Rural Development Toolbox<br>• Integrated New Town Development<br>• Participants workshop: Design of New Towns: Northern, Arid and Tropical cases<br>• Outreach: Participants campaign<br>• City with the Rural: Resilience, quality of live and productive biodiversity |
| **Literature** | • Ralf Otterpohl 2013: Gründer-Gruppen als Lebensentwurf: "Synergistische Wertschöpfung in erweiterten Kleinstadt- und Dorfstrukturen", in „Regionales Zukunftsmanagement Band 7: Existenzgründung unter regionalökonomischer Perspektive, Pabst Publisher, Lengerich<br>• http://youtu.be/9hmkgn0nBgk (Miracle Water Village, India, Integrated Rainwater Harvesting, Water Efficiency, Reforestation and Sanitation)<br>• TEDx New Town Ralf Otterpohl: http://youtu.be/_M0J2u9BrbU |

| Course L0939: Water & Wastewater Systems in a Global Context | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 92, Study Time in Lecture 28 |
| **Lecturer** | Prof. Ralf Otterpohl |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Keynote lecture and video<br>• Water & Soil: Water availability as a consequence of healthy soils<br>• Water and it's utilization, Integrated Urban Water Management<br>• Water & Energy, lecture and panel discussion pro and con for a specific big dam project<br>• Rainwater Harvesting on Catchment level, Holistic Planned Grazing, Multi-Use-Reforestation<br>• Sanitation and Reuse of water, nutrients and soil conditioners, Conventional and Innovative Approaches<br>• Why are there excreta in water? Public Health, Awareness Campaigns<br>• Rehearsal session, Q&A |
| **Literature** | • Montgomery, David R. 2007: Dirt: The Erosion of Civilizations, University of California Press<br>• Liu, John D.: http://eempc.org/hope-in-a-changing_climate/ (Integrated regeneration of the Loess Plateau, China, and sites in Ethiopia and Rwanda)<br>• http://youtu.be/9hmkgn0nBgk (Miracle Water Village, India, Integrated Rainwater Harvesting, Water Efficiency, Reforestation and Sanitation) |

## Module M0897: Computer Aided Process Engineering (CAPE)

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| CAPE with Computer Exercises (L1039) | Lecture | 2 | 3 |
| Methods of Process Safety and Dangerous Substances (L1040) | Lecture | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Georg Fieg |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | thermal separation processes<br>heat and mass transport processes |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | students can:<br>- outline types of simulation tools<br>- describe principles of flowsheet and equation oriented simulation tools<br>- describe the setting of flowsheet simulation tools<br>- explain the main differences between steady state and dynamic simulations<br>- present the fundamentals of toxicology and hazardous materials<br>- explain the main methods of safety engineering<br>- present the importance of safety analysis with respect to plant design<br>- describe the definitions within the legal accident insurance<br>accident insurance |
| *Skills* | students can:<br>- conduct steady state and dynamic simulations<br>- evaluate simulation results and transform them in the practice<br>- choose and combine suitable simulation models into a production plant<br>- evaluate the achieved simulation results regarding practical importance<br>- evaluate the results of many experimental methods regarding safety aspects<br>- review, compare and use results of safety considerations for a plant design |
| **Personal Competence** | |
| *Social Competence* | students are able to:<br>- work together in teams in order to simulate process elements and develop an integral process<br>- develop in teams a safety concept for a process and present it to the audience |
| *Autonomy* | students are able to<br>- act responsible with respect to environment and needs of the society |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |

| Course achievement | Compulsory | Bonus | Form | Description |
|---|---|---|---|---|
| | Yes | None | Group discussion | Gruppendiskussionen finden im Rahmen der PC-Übungen statt |

| | |
|---|---|
| **Examination** | Written exam |
| **Examination duration and scale** | 180 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L1039: CAPE with Computer Exercises | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Georg Fieg |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | I. Introduction<br><br>1. Fundamentals of steady state process simulation<br><br>1.1. Classes of simulation tools<br>1.2. Sequential-modularer approach<br>1.3. Operating mode of ASPEN PLUS<br>2. Introduction in ASPEN PLUS<br>2.1. GUI<br>2.2. Estimation methods of physical properties<br>2.3. Aspen tools (z.B. Designspecification)<br>2.4. Convergence methods<br><br>II. Exercices using ASPEN PLUS and ACM<br><br>Performance and constraints of ASPEN PLUS<br>ASPEN datenbank using<br>Estimation methods of physical properties<br>Application of model databank, process synthesis<br><br>Design specifications<br><br>Sensitivity analysis<br>Optimization tasks<br>Industrial cases |
| **Literature** | - G. Fieg: Lecture notes<br>- Seider, W.D.; Seader, J.D.; Lewin, D.R.: Product and Process Design Principles: Synthesis, Analysis, and Evaluation; Hoboken, J. Wiley & Sons, 2010 |

| Course L1040: Methods of Process Safety and Dangerous Substances | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Georg Fieg, Dr. Thomas Waluga |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | |
| **Literature** | Bender, H.: Sicherer Umgang mit Gefahrstoffen; Weinheim (2005)<br>Bender, H.: Das Gefahrstoffbuch. Sicherer Umgang mit Gefahrstoffen in der Praxis; Weinheim (2002)<br>Birett, K.: Umgang mit Gefahrstoffen; Heidelberg (2011)<br>Birgersson, B.; Sterner, O.; Zimerson, E.: Chemie und Gesundheit; Weinheim (1988)<br><br>O. Antelmann, Diss. an der TU Berlin, 2001<br>R. Dittmeyer, W. Keim, G. Kreysa, A. Oberholz, Chemische Technik, Prozesse und Produkte, Band 1<br><br>Methodische Grundlagen, VCH, 2004-2006, S. 719<br><br>H. Pohle, Chemische Industrie, Umweltschutz, Arbeitsschutz, Anlagensicherheit, VCH, Weinheim, 1991<br><br>J. Steinbach, Chemische Sicherheitstechnik, VCH, Weinheim, 1995<br><br>G. Suter, Identifikation sicherheitskritischer Prozesse, P&A Kompendium, 2004 |

## Module M0512: Use of Solar Energy

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Energy Meteorology (L0016) | Lecture | 1 | 1 |
| Energy Meteorology (L0017) | Recitation Section (small) | 1 | 1 |
| Collector Technology (L0018) | Lecture | 2 | 2 |
| Solar Power Generation (L0015) | Lecture | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Martin Kaltschmitt |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | none |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | With the completion of this module, students will be able to deal with technical foundations and current issues and problems in the field of solar energy and explain and evaulate these critically in consideration of the prior curriculum and current subject specific issues. In particular they can professionally describe the processes within a solar cell and explain the specific features of application of solar modules. Furthermore, they can provide an overview of the collector technology in solar thermal systems. |
| *Skills* | Students can apply the acquired theoretical foundations of exemplary energy systems using solar radiation. In this context, for example they can assess and evaluate potential and constraints of solar energy systems with respect to different geographical assumptions. They are able to dimension solar energy systems in consideration of technical aspects and given assumptions. Using module-comprehensive knowledge students can evalute the economic and ecologic conditions of these systems. They can select calculation methods within the radiation theory for these topics. |
| **Personal Competence** | |
| *Social Competence* | Students are able to discuss issues in the thematic fields in the renewable energy sector addressed within the module. |
| *Autonomy* | Students can independently exploit sources and acquire the particular knowledge about the subject area with respect to emphasis fo the lectures. Furthermore, with the assistance of lecturers, they can discrete use calculation methods for analysing and dimensioning solar energy systems. Based on this procedure they can concrete assess their specific learning level and can consequently define the further workflow. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 3 hours written exam |
| **Assignment for the Following Curricula** | Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory<br>Energy Systems: Specialisation Energy Systems: Elective Compulsory<br>International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory<br>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory<br>Renewable Energies: Core qualification: Compulsory<br>Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory |

| Course L0016: Energy Meteorology | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Dr. Volker Matthias, Dr. Beate Geyer |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | • Introduction: radiation source Sun, Astronomical Foundations, Fundamentals of radiation<br>• Structure of the atmosphere<br>• Properties and laws of radiation<br>  ◦ Polarization<br>  ◦ Radiation quantities<br>  ◦ Planck's radiation law<br>  ◦ Wien's displacement law<br>  ◦ Stefan-Boltzmann law<br>  ◦ Kirchhoff's law<br>  ◦ Brightness temperature<br>  ◦ Absorption, reflection, transmission<br>• Radiation balance, global radiation, energy balance<br>• Atmospheric extinction<br>• Mie and Rayleigh scattering<br>• Radiative transfer<br>• Optical effects in the atmosphere<br>• Calculation of the sun and calculate radiation on inclined surfaces |
| **Literature** | • Helmut Kraus: Die Atmosphäre der Erde<br>• Hans Häckel: Meteorologie<br>• Grant W. Petty: A First Course in Atmosheric Radiation<br>• Martin Kaltschmitt, Wolfgang Streicher, Andreas Wiese: Renewable Energy<br>• Alexander Löw, Volker Matthias: Skript Optik Strahlung Fernerkundung |

| Course L0017: Energy Meteorology | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Dr. Beate Geyer |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L0018: Collector Technology | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Agis Papadopoulos |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | • Introduction: Energy demand and application of solar energy.<br>• Heat transfer in the solar thermal energy: conduction, convection, radiation.<br>• Collectors: Types, structure, efficiency, dimensioning, concentrated systems.<br>• Energy storage: Requirements, types.<br>• Passive solar energy: components and systems.<br>• Solar thermal low temperature systems: collector variants, construction, calculation.<br>• Solar thermal high temperature systems: Classification of solar power plants construction.<br>• Solar air conditioning. |
| **Literature** | • Vorlesungsskript.<br>• Kaltschmitt, Streicher und Wiese (Hrsg.). Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte, 5. Auflage, Springer, 2013.<br>• Stieglitz und Heinzel .Thermische Solarenergie: Grundlagen, Technologie, Anwendungen. Springer, 2012.<br>• Von Böckh und Wetzel. Wärmeübertragung: Grundlagen und Praxis, Springer, 2011.<br>• Baehr und Stephan. Wärme- und Stoffübertragung. Springer, 2009.<br>• de Vos. Thermodynamics of solar energy conversion. Wiley-VCH, 2008.<br>• Mohr, Svoboda und Unger. Praxis solarthermischer Kraftwerke. Springer, 1999. |

| Course L0015: Solar Power Generation | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Alf Mews, Martin Schlecht, Roman Fritsches |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | 1. Introduction<br>2. Primary energy and consumption, available solar energy<br>3. Physics of the ideal solar cell<br>4. Light absorption PN junction characteristic values of the solar cell efficiency<br>5. Physics of the real solar cell<br>6. Charge carrier recombination characteristics, junction layer recombination, equivalent circuit<br>7. Increasing the efficiency<br>8. Methods for increasing the quantum yield, and reduction of recombination<br>9. Straight and tandem structures<br>10. Hetero-junction, Schottky, electrochemical, MIS and SIS-cell tandem cell<br>11. Concentrator<br>12. Concentrator optics and tracking systems<br>13. Technology and properties: types of solar cells, manufacture, single crystal silicon and gallium arsenide, polycrystalline silicon, and silicon thin film cells, thin-film cells on carriers (amorphous silicon, CIS, electrochemical cells)<br>14. Modules<br>15. Circuits |
| **Literature** | • A. Götzberger, B. Voß, J. Knobloch: Sonnenenergie: Photovoltaik, Teubner Studienskripten, Stuttgart, 1995<br>• A. Götzberger: Sonnenenergie: Photovoltaik : Physik und Technologie der Solarzelle, Teubner Stuttgart, 1994<br>• H.-J. Lewerenz, H. Jungblut: Photovoltaik, Springer, Berlin, Heidelberg, New York, 1995<br>• A. Götzberger: Photovoltaic solar energy generation, Springer, Berlin, 2005<br>• C. Hu, R. M. White: Solar Cells, Mc Graw Hill, New York, 1983<br>• H.-G. Wagemann: Grundlagen der photovoltaischen Energiewandlung: Solarstrahlung, Halbleitereigenschaften und Solarzellenkonzepte, Teubner, Stuttgart, 1994<br>• R. J. van Overstraeten, R.P. Mertens: Physics, technology and use of photovoltaics, Adam Hilger Ltd, Bristol and Boston, 1986<br>• B. O. Seraphin: Solar energy conversion Topics of applied physics V 01 31, Springer, Berlin, Heidelberg, New York, 1995<br>• P. Würfel: Physics of Solar cells, Principles and new concepts, Wiley-VCH, Weinheim 2005<br>• U. Rindelhardt: Photovoltaische Stromversorgung, Teubner-Reihe Umwelt, Stuttgart 2001<br>• V. Quaschning: Regenerative Energiesysteme, Hanser, München, 2003<br>• G. Schmitz: Regenerative Energien, Ringvorlesung TU Hamburg-Harburg 1994/95, Institut für Energietechnik |

## Module M0511: Electricity Generation from Wind and Hydro Power

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Renewable Energy Projects in Emerged Markets (L0014) | Project Seminar | 1 | 1 |
| Hydro Power Use (L0013) | Lecture | 1 | 1 |
| Wind Turbine Plants (L0011) | Lecture | 2 | 3 |
| Wind Energy Use - Focus Offshore (L0012) | Lecture | 1 | 1 |

| | |
|---|---|
| **Module Responsible** | Dr. Joachim Gerth |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Module: Technical Thermodynamics I,<br>Module: Technical Thermodynamics II,<br>Module: Fundamentals of Fluid Mechanics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | By ending this module students can explain in detail knowledge of wind turbines with a particular focus of wind energy use in offshore conditions and can critical comment these aspects in consideration of current developments. Furthermore, they are able to describe fundamentally the use of water power to generate electricity. The students reproduce and explain the basic procedure in the implementation of renewable energy projects in countries outside Europe.<br><br>Through active discussions of various topics within the seminar of the module, students improve their understanding and the application of the theoretical background and are thus able to transfer what they have learned in practice. |
| *Skills* | Students are able to apply the acquired theoretical foundations on exemplary water or wind power systems and evaluate and assess technically the resulting relationships in the context of dimensioning and operation of these energy systems. They can in compare critically the special procedure for the implementation of renewable energy projects in countries outside Europe with the in principle applied approach in Europe and can apply this procedure on exemplary theoretical projects. |
| **Personal Competence** | |
| *Social Competence* | Students can discuss scientific tasks subjet-specificly and multidisciplinary within a seminar. |
| *Autonomy* | Students can independently exploit sources in the context of the emphasis of the lecture material to clear the contents of the lecture and to acquire the particular knowledge about the subject area. |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 3 hours written exam |
| **Assignment for the Following Curricula** | Civil Engineering: Specialisation Structural Engineering: Elective Compulsory<br>Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory<br>Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Energy Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory<br>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Production: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Materials: Elective Compulsory<br>Renewable Energies: Core qualification: Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Elective Compulsory |

| Course L0014: Renewable Energy Projects in Emerged Markets | |
|---|---|
| **Typ** | Project Seminar |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Andreas Wiese |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | 1. Introduction<br>  ◦ Development of renewable energies worldwide<br>  ▪ History<br>  ▪ Future markets<br>  ◦ Special challenges in new markets - Overview<br>2. Sample project wind farm Korea<br>  ◦ Survey<br>  ◦ Technical Description<br>  ◦ Project phases and characteristics<br>3. Funding and financing instruments for EE projects in new markets<br>  ◦ Overview funding opportunitie<br>  ◦ Overview countries with feed-in laws<br>  ◦ Major funding programs<br>4. CDM projects - why, how , examples<br>  ◦ Overview CDM process<br>  ◦ Examples<br>  ◦ Exercise CDM<br>5. Rural electrification and hybrid systems - an important future market for EE<br>  ◦ Rural Electrification - Introduction<br>  ◦ Types of Elektrizifierungsprojekten<br>  ◦ The role of the EEInterpretation of hybrid systems<br>  ◦ Project example: hybrid system Galapagos Islands<br>6. Tendering process for EE projects - examples<br>  ◦ South Africa<br>  ◦ Brazil<br>7. Selected projects from the perspective of a development bank - Wesley Urena Vargas, KfW Development Bank<br>  ◦ Geothermal<br>  ◦ Wind or CSP<br><br>Within the seminar, the various topics are actively discussed and applied to various cases of application. |
| **Literature** | Folien der Vorlesung |

| Course L0013: Hydro Power Use | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Stefan Achleitner |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | • Introduction, importance of water power in the national and global context<br>• Physical basics: Bernoulli's equation, usable height of fall, hydrological measures, loss mechanisms, efficiencies<br>• Classification of Hydropower: Flow and Storage hydropower, low and high pressure systems<br>• Construction of hydroelectric power plants: description of the individual components and their technical system interaction<br>• Structural engineering components; representation of dams, weirs, dams, power houses, computer systems, etc.<br>• Energy Technical Components: Illustration of the different types of hydraulic machinery, generators and grid connection<br>• Hydropower and the Environment<br>• Examples from practice |
| **Literature** | • Schröder, W.; Euler, G.; Schneider, K.: Grundlagen des Wasserbaus; Werner, Düsseldorf, 1999, 4. Auflage<br>• Quaschning, V.: Regenerative Energiesysteme: Technologie - Berechnung - Simulation; Carl Hanser, München, 2011, 7. Auflage<br>• Giesecke, J.; Heimerl, S.; Mosony, E.: Wasserkraftanlagen - Planung, Bau und Betrieb; Springer, Berlin, Heidelberg, 2009, 5. Auflage<br>• von König, F.; Jehle, C.: Bau von Wasserkraftanlagen - Praxisbezogene Planungsunterlagen; C. F. Müller, Heidelberg, 2005, 4. Auflage<br>• Strobl, T.; Zunic, F.: Wasserbau: Aktuelle Grundlagen - Neue Entwicklungen; Springer, Berlin, Heidelberg, 2006 |

| Course L0011: Wind Turbine Plants | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Rudolf Zellermann, Dr. Jochen Oexmann |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | • Historical development<br>• Wind: origins, geographic and temporal distribution, locations<br>• Power coefficient, rotor thrust<br>• Aerodynamics of the rotor<br>• Operating performance<br>• Power limitation, partial load, pitch and stall control<br>• Plant selection, yield prediction, economy<br>• Excursion |
| **Literature** | Gasch, R., Windkraftanlagen, 4. Auflage, Teubner-Verlag, 2005 |

| Course L0012: Wind Energy Use - Focus Offshore | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Martin Skiba |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | • Introduction, importance of offshore wind power generation, Specific requirements for offshore engineering<br>• Physical fundamentals for utilization of wind energy<br>• Design and operation of offshore wind turbines, presentation of different concepts of offshore wind turbines, representation of the individual system components and their system-technical relationships<br>• Foundation engineering, offshore site investigation, presentation of different concepts of offshore foundation structures, planning and fabrication of foundation structures<br>• Electrical infrastructure of an offshore wind farm, Inner Park cabling, offshore substation, grid connection<br>• Installation of offshore wind farms, installation techniques and auxiliary devices, construction logistics<br>• Development and planning of offshore wind farms<br>• Operation and optimization of offshore wind farms<br>• Day excursion |
| **Literature** | • Gasch, R.; Twele, J.: Windkraftanlagen - Grundlagen, Entwurf, Planung und Betrieb; Vieweg + Teubner, Stuttgart, 2007, 7. Auflage<br>• Molly, J. P.: Windenergie - Theorie, Anwendung, Messung; C. F. Müller, Heidel-berg, 1997, 3. Auflage<br>• Hau, E.: Windkraftanalagen; Springer, Berlin, Heidelberg, 2008, 4.Auflage<br>• Heier, S.: Windkraftanlagen - Systemauslegung, Integration und Regelung; Vieweg + Teubner, Stuttgart, 2009, 5. Auflage<br>• Jarass, L.; Obermair, G.M.; Voigt, W.: Windenergie: Zuverlässige Integration in die Energieversorgung; Springer, Berlin, Heidelberg, 2009, 2. Auflage |

## Module M0518: Waste and Energy

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Waste Recycling Technologies (L0047) | Lecture | 2 | 2 |
| Waste Recycling Technologies (L0048) | Recitation Section (small) | 1 | 2 |
| Waste to Energy (L0049) | Project-/problem-based Learning | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Kerstin Kuchta |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basics of process engineering |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to describe and explain in detail techniques, processes and concepts for treatment and energy recovery from wastes. |
| *Skills* | The students are able to select suitable processes for the treatment and energy recovery of wastes. They can evaluate the efforts and costs for processes and select economically feasible treatment Concepts. Students are able to evaluate alternatives even with incomplete information. Students are able to prepare systematic documentation of work results in form of reports, presentations and are able to defend their findings in a group. |
| **Personal Competence** | |
| *Social Competence* | Students can participate in subject-specific and interdisciplinary discussions, develop cooperated solutions and defend their own work results in front of others and promote the scientific development of collegues. Furthermore, they can give and accept professional constructive criticism. |
| *Autonomy* | Students can independently tap knowledge of the subject area and transform it to new questions. They are capable, in consultation with supervisors, to assess their learning level and define further steps on this basis. Furthermore, they can define targets for new application-or research-oriented duties in accordance with the potential social, economic and cultural impact. |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Credit points** | 6 |
| **Course achievement** | **Compulsory** **Bonus** **Form** **Description**<br>Yes 20 % Written elaboration |
| **Examination** | Presentation |
| **Examination duration and scale** | PowerPoint presentation (10-15 minutes) |
| **Assignment for the Following Curricula** | Environmental Engineering: Specialisation Waste and Energy: Elective Compulsory<br>International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory<br>Joint European Master in Environmental Studies - Cities and Sustainability: Core qualification: Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory |

| Course L0047: Waste Recycling Technologies | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Kerstin Kuchta |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Fundamentals on primary and secondary production of raw materials (steel, aluminum, phosphorous, copper, precious metals, rare metals)<br>• Use and demand of metals and minerals in industry and society<br>• collection systems and concepts<br>• quota and efficiency<br>• Advanced sorting technologies<br>• mechanical pretreatment<br>• advanced treatment<br>• Chemical analysis of Critical Materials in post-consumer products<br>• Analytical tools in Resource Management (Material Flow Analysis, Recycling Performance Indicators, Criticality Assessment, statistical analysis of uncertainties) |
| **Literature** | |

| Course L0048: Waste Recycling Technologies | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Kerstin Kuchta |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Fundamentals on primary and secondary production of raw materials (steel, aluminum, phosphorous, copper, precious metals, rare metals)<br>• Use and demand of metals and minerals in industry and society<br>• collection systems and concepts<br>• quota and efficiency<br>• Advanced sorting technologies<br>• mechanical pretreatment<br>• advanced treatment<br>• Chemical analysis of Critical Materials in post-consumer products<br>• Analytical tools in Resource Management (Material Flow Analysis, Recycling Performance Indicators, Criticality Assessment, statistical analysis of uncertainties) |
| **Literature** | |

| **Course L0049: Waste to Energy** | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Rüdiger Siechau |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Project-based lecture<br>• Introduction into the " Waste to Energy " consisting of:<br>  ◦ Thermal Process ( incinerator , RDF combustion )<br>  ◦ Biological processes ( Wet-/Dryfermentation )<br>  ◦ technology , energy , emissions, approval , etc.<br>• Group work<br>  ◦ design of systems/plants for energy recovery from waste<br>  ◦ The following points are to be processed :<br>  ▪ Input: waste ( fraction collection and transportation, current quantity , material flows , possible amount of development )<br>  ▪ Plant (design, process diagram , technology, energy production )<br>  ▪ Output ( energy quantity / type , by-products )<br>  ▪ Costs and revenues<br>  ▪ Climate and resource protection ( CO2 balance , substitution of primary raw materials / fossil fuels )<br>  ▪ Location and approval (infrastructure , expiration authorization procedure)<br>  ▪ Focus at the whole concept ( advantages, disadvantages , risks and opportunities , discussion )<br>• Grading: No Exam , but presentation of the results of the working group |
| **Literature** | **Literatur:**<br><br>Einführung in die Abfallwirtschaft; Martin Kranert, Klaus Cord-Landwehr (Hrsg.); Vieweg + Teubner Verlag; 2010<br><br>Powerpoint-Folien in Stud IP<br><br>**Literature:**<br>Introduction to Waste Management; Kranert Martin , Klaus Cord - Landwehr (Ed. ), Vieweg + Teubner Verlag , 2010<br><br>PowerPoint slides in Stud IP |

## Module M0749: Waste Treatment and Solid Matter Process Technology

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Solid Matter Process Technology for Biomass (L0052) | Lecture | 2 | 2 |
| Thermal Waste Treatment (L0320) | Lecture | 2 | 2 |
| Thermal Waste Treatment (L1177) | Recitation Section (large) | 1 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Kerstin Kuchta |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basics of<br>• thermo dynamics<br>• fluid dynamics<br>• chemistry |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students can name, describe current issue and problems in the field of thermal waste treatment and particle process engineering and contemplate them in the context of their field.<br><br>The industrial application of unit operations as part of process engineering is explained by actual examples of waste incineration technologies and solid biomass processes. Compostion, particle sizes, transportation and dosing, drying and agglomeration of renewable resources and wastes are described as important unit operations when producing solid fuels and bioethanol, producing and refining edible oils, electricity , heat and mineral recyclables. |
| *Skills* | The students are able to select suitable processes for the treatment of wastes or raw material with respect to their characteristics and the process aims. They can evaluate the efforts and costs for processes and select economically feasible treatment concepts. |
| **Personal Competence** | |
| *Social Competence* | Students can<br>• respectfully work together as a team and discuss technical tasks<br>• participate in subject-specific and interdisciplinary discussions,<br>• develop cooperated solutions<br>• promote the scientific development and accept professional constructive criticism. |
| *Autonomy* | Students can independently tap knowledge of the subject area and transform it to new questions. They are capable, in consultation with supervisors, to assess their learning level and define further steps on this basis. Furthermore, they can define targets for new application-or research-oriented duties in accordance with the potential social, economic and cultural impact. |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 120 min |
| **Assignment for the Following Curricula** | Civil Engineering: Specialisation Water and Traffic: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory<br>International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Elective Compulsory |

| Course L0052: Solid Matter Process Technology for Biomass | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Werner Sitzmann |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | The industrial application of unit operations as part of process engineering is explained by actual examples of solid biomass processes. Size reduction, transportation and dosing, drying and agglomeration of renewable resources are described as important unit operations when producing solid fuels and bioethanol, producing and refining edible oils, when making Btl - and WPC - products. Aspects of explosion protection and plant design complete the lecture. |
| **Literature** | Kaltschmitt M., Hartmann H. (Hrsg.): Energie aus Bioamsse, Springer Verlag, 2001, ISBN 3-540-64853-4<br><br>Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz, Schriftenreihe Nachwachsende Rohstoffe,<br><br>Fachagentur Nachwachsende Rohstoffe e.V. www.nachwachsende-rohstoffe.de<br><br>Bockisch M.: Nahrungsfette und -öle, Ulmer Verlag, 1993, ISBN 380000158175 |

| Course L0320: Thermal Waste Treatment | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Kerstin Kuchta |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Introduction, actual state-of-the-art of waste incineration, aims. legal background, reaction principals<br>• basics of incineration processes: waste composition, calorific value, calculation of air demand and flue gas composition<br>• Incineration techniques: grate firing, ash transfer, boiler<br>• Flue gas cleaning: Volume, composition, legal frame work and emission limits, dry treatment, scrubber, de-nox techniques, dioxin elimination, Mercury elimination<br>• Ash treatment: Mass, quality, treatment concepts, recycling, disposal |
| **Literature** | Thomé-Kozmiensky, K. J. (Hrsg.): Thermische Abfallbehandlung Bande 1-7. EF-Verlag für Energie- und Umwelttechnik, Berlin, 196 - 2013. |

| Course L1177: Thermal Waste Treatment | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Kerstin Kuchta |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M1308: Modelling and technical design of bio refinery processes

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Biorefineries - Technical Design and Optimization (L1832) | Project-/problem-based Learning | 3 | 3 |
| CAPE in Energy Engineering (L0022) | Projection Course | 3 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Martin Kaltschmitt |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Bachelor degree in Process Engineering, Bioprocess Engineering or Energy- and Environmental Engineering |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The tudents can completely design a technical process including mass and energy balances, calculation and layout of different process devices, layout of measurement- and control systems as well as modeling of the overall process.<br>Furthermore, they can describe the basics of the general procedure for the processing of modeling tasks, especially with ASPEN PLUS ® and ASPEN CUSTOM MODELER ®. |
| *Skills* | Students are able to simulate and solve scientific task in the context of renewable energy technologies by:<br>• development of modul-comprehensive approaches for the dimensioning and design of production processes<br>• evaluating alternatives input parameter to solve the particular task even with incomplete information,<br>• a systematic documentation of the work results in form of a written version, the presentation itself and the defense of contents.<br><br>They can use the ASPEN PLUS ® and ASPEN CUSTOM MODELER ® for modeling energy systems and to evaluate the simulation solutions.<br><br>Through active discussions of various topics within the seminars and exercises of the module, students improve their understanding and the application of the theoretical background and are thus able to transfer what they have learned in practice. |
| **Personal Competence** | |
| *Social Competence* | Students can<br>• respectfully work together as a team with around 2-3 members,<br>• participate in subject-specific and interdisciplinary discussions in the area of dimensioning and design of production processes, and can develop cooperated solutions,<br>• defend their own work results in front of fellow students and<br><br>assess the performance of fellow students in comparison to their own performance. Furthermore, they can accept professional constructive criticism. |
| *Autonomy* | Students can independently tap knowledge regarding to the given task. They are capable, in consultation with supervisors, to assess their learning level and define further steps on this basis. Furthermore, they can define targets for new application-or research-oriented duties in accordance with the potential social, economic and cultural impact. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written elaboration |
| **Examination duration and scale** | Written report incl. presentation |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Renewable Energies: Core qualification: Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory |

| Course L1832: Biorefineries - Technical Design and Optimization | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 3 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 48, Study Time in Lecture 42 |
| **Lecturer** | Prof. Oliver Lüdtke |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | **I. Repetition of engineering basics**<br>1. Shell and tube heat exchangers<br>2. Steam generators and refrigerating machines<br>3. Pumps and turbines<br>4. Flow in piping networks<br>5. Pumping and mixing of non-newtonian fluids<br>6. Requirements to a detailed layout plan<br>**II. Calculation:**<br>1. Planning and design of a specific bio-refinery plant section, such as Ethanol distillation and fermentation. This is based on empirical valuse of a real, industrial plant.<br>◦ Mass and energy balances (Aspen)<br>◦ Equipment design (heat exchangers, pumps, pipes, tanks, etc.) (<br>◦ Isolation, wall thickness and material selection<br>◦ Energy demand (electrical, heat or cooling), design of steam boilers and appliances<br>◦ Selection of fittings, measuring instruments and safety equipment<br>◦ Definition of main control loops<br>2. Hereby, the dependencies of transport phenomena between certain plant sections become evident and methods of calculation are introduced.<br>3. In Detail Engineering , it is focused on aspects of plant engineering planning that are relevant for the subsequent construction of the plant.<br>4. Depending of time requirement and group size a cost estimation and preparation of a complete R&I flow chart can be implemented as well. |
| **Literature** | Perry, R.;Green, R.: Perry's Chemical Engineers' Handbook, 8 th Edition, McGraw Hill Professional, 2007<br>Sinnot, R. K.: Chemical Engineering Design, Elsevier, 2014 |

| Course L0022: CAPE in Energy Engineering | |
|---|---|
| **Typ** | Projection Course |
| **Hrs/wk** | 3 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 48, Study Time in Lecture 42 |
| **Lecturer** | Prof. Martin Kaltschmitt |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | • CAPE = *Computer*-Aided-Project-Engineering<br>• INTRODUCTION TO THE THEORY<br>◦ Classes of simulation programs<br>◦ Sequential modular approach<br>◦ Equation-oriented approach<br>◦ Simultaneous modular approach<br>◦ General procedure for the processing of modeling tasks<br>◦ Special procedure for solving models with repatriations<br>• COMPUTER EXERCISES renewable energy projects WITH ASPEN PLUS ® AND ASPEN CUSTOM MODELER ®<br>◦ Scope, potential and limitations of Aspen Plus ® and Aspen Custom Modeler ®<br>◦ Use of integrated databases for material data<br>◦ Methods for estimating non-existent physical property data<br>◦ Use of model libraries and Process Synthesis<br>◦ Application of design specifications and sensitivity analyzes<br>◦ Solving optimization problems<br>Within the seminar, the various tasks are actively discussed and applied to various cases of application. |
| **Literature** | • Aspen Plus® - Aspen Plus User Guide<br>• William L. Luyben; Distillation Design and Control Using Aspen Simulation; ISBN-10: 0-471-77888-5 |

## Module M1287: Risk Management, Hydrogen and Fuel Cell Technology

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Applied Fuel Cell Technology (L1831) | Lecture | 2 | 2 |
| Risk Management in the Energy Industry (L1748) | Lecture | 2 | 2 |
| Hydrogen Technology (L0060) | Lecture | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Martin Kaltschmitt |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | None |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | With completion of this module students can explain basics of risk management involving thematical adjacent contexts and can describe an optimal management of energy systems.<br><br>Furthermore, students can reproduce solid theoretical knowledge about the potentials and applications of new information technologies in logistics and explain technical aspects of the use, production and processing of hydrogen. |
| *Skills* | With completion of this module students are able to evaluate risks of energy systems with respect to energy economic conditions in an efficient way. This includes that the students can assess the risks in operational planning of power plants from a technical, economic and ecological perspective.<br><br>In this context, students can evaluate the potentials of logistics and information technology in particular on energy issues.<br><br>I n addition, students are able to describe the energy transfer medium hydrogen according to its applications, the given security and its existing service capacities and limits as well as to evaluate these aspects from a technical, environmental and economic perspective. |
| **Personal Competence** | |
| *Social Competence* | Students are able to discuss issues in the thematic fields in the renewable energy sector addressed within the module. |
| *Autonomy* | Students can independently exploit sources on the emphasis of the lectures and acquire the contained knowledge. In this way, they can recognize their lacks of knowledge and can consequently define the further workflow. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 3 hours written exam |
| **Assignment for the Following Curricula** | Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory<br>Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory<br>Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory |

### Course L1831: Applied Fuel Cell Technology

| | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Klaus Bonhoff |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | The lecture provide an insight into the various possibilities of fuel cells in the energy system (electricity, heat and transport). These are presented and discussed for individual fuel types and application-oriented requirements; also compared with alternative technologies in the system. These different possibilities will be presented regardind the state-of-the-art development of the technologies and exemplary applications from Germany and worldwide. Also the emerging trends and lines of development will be discussed. Besides to the technical aspects, which are the focus of the event, also energy, environmental and industrial policy aspects are discussed - also in the context of changing circumstances in the German and international energy system. |
| **Literature** | Vorlesungsunterlagen |

| Course L1748: Risk Management in the Energy Industry | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Christian Wulf |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | • Basics of risk management<br>  ◦ Definition of terms<br>  ◦ Risk types<br>  ◦ Risk management process<br>  ◦ Enterprise risk management<br>• Markets and instruments in energy trading<br>  ◦ Basics of futures and spot trading<br>  ◦ Notation in energy markets<br>  ◦ Options<br>• Kennzahlendefinition<br>  ◦ Assessing of market risks<br>  ◦ Assessing of credit risks<br>  ◦ Assessing of operational risks<br>  ◦ Assessing of liquidy risks<br>• Risk monitoring and reporting<br>• Risk treatment |
| **Literature** | • Roggi, O. (2012): Risk Taking: A Corporate Governance Perspective, International Finance Corporation, New York<br>• Hull, J. C. (2012): Options, Futures, and other Derivatives, 8. Auflage, Pearson Verlag, New York<br>• Albrecht, P.; Maurer, R. (2008): Investment- und Risikomanagement, 3. Auflage, Schäffer-Poeschel Verlag, Stuttgart<br>• Rittenberg, L.; Martens, F. (2012): Understanding and Communicating Risk Appetite, Treadway Commission, Durham |

| Course L0060: Hydrogen Technology | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Martin Dornheim |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | 1. Energy economy<br>2. Hydrogen economy<br>3. Occurrence and properties of hydrogen<br>4. Production of hydrogen (from hydrocarbons and by electrolysis)<br>5. Separation and purification Storage and transport of hydrogen<br>6. Security<br>7. Fuel cells<br>8. Projects |
| **Literature** | • Skriptum zur Vorlesung<br>• Winter, Nitsch: Wasserstoff als Energieträger<br>• Ullmann’s Encyclopedia of Industrial Chemistry<br>• Kirk, Othmer: Encyclopedia of Chemical Technology<br>• Larminie, Dicks: Fuel cell systems explained |

## Module M0705: Groundwater

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Geohydraulic and Solute Transport (L0539) | Lecture | 2 | 2 |
| Geohydraulic and Solute Transport (L0540) | Recitation Section (small) | 1 | 1 |
| Simulation in Groundwater Hydrology (L0541) | Lecture | 1 | 1 |
| Simulation in Groundwater Hydrology (L0542) | Recitation Section (small) | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | NN |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Ground water hydrology<br>• Hydromechanics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students are able to describe the fate of solutes in the subsurface along the path between soil and water body quantitatively and qualitatively. They are able to do this with simulation models. |
| *Skills* | The students are able to describe conceptually movement and storage of water in the unsaturated zone. They are able to analyse pF- functions and Ku functions. They can model transport of solutes in the unsaturated and saturated zoned. They are able to determine dispersiities, sorption coefficients, decay rates and dissolution rates for organic and inorganic substances. |
| **Personal Competence** | |
| *Social Competence* | The students can help to each other. |
| *Autonomy* | none |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 60 min written exam and written papers |
| **Assignment for the Following Curricula** | Civil Engineering: Specialisation Structural Engineering: Elective Compulsory<br>Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory<br>Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory<br>Civil Engineering: Specialisation Water and Traffic: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Water: Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Elective Compulsory |

### Course L0539: Geohydraulic and Solute Transport

| | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Wilfried Schneider |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | Pump test analysis, water content-water suction functions, unsaturated hydraulic conductivity function, Brooks-Corey relation, van Genuchten relation, solute transport in unsaturated zone, solute transport and reactions in groundwater |
| **Literature** | Todd; K. (2005): Groundwater Hydrology<br>Fetter, C.W. (2001): Applied Hydrogeology<br>Hölting & Coldewey (2005): Hydrogeologie<br>Charbeneau, R.J. (2000): Groundwater Hydraulics and pollutant Transport |

| Course L0540: Geohydraulic and Solute Transport | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Wilfried Schneider |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L0541: Simulation in Groundwater Hydrology | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Sonja Götz (geb. Schröter) |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | Basics and theoretical background of simulation models frequently used in science and practise for pumping test analysis, water movement in vadose zone, solute transport in vadose zone, groundwater recharge, solute transport in groundwater |
| **Literature** | Handbücher der verwendeten Slumationsmodelle werden bereitgestellt. |

| Course L0542: Simulation in Groundwater Hydrology | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Sonja Götz (geb. Schröter) |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0876: Aquatic Chemistry

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Chemistry of Drinking Water Treatment (L0311) | Lecture | 2 | 1 |
| Chemistry of Drinking Water Treatment (L0312) | Recitation Section (large) | 1 | 2 |
| Practical Course Aquatic Chemistry (L0965) | Practical Course | 4 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Kerstin Kuchta |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | none |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students are able to describe the solubility of gases, carbonic acid system and calcium carbonate, blending, softening and redox processes as well as materials and legal requirements on drinking water treatment. |
| *Skills* | The participants must take responsibility for partial aspects of the practical course within the group.<br><br>In addition, the participants are able to compile and evaluate designs and layouts of plants and test transcripts as well as the analysis and techniques, measurements and professional relevant methods. Out of the need to prepare laboratory transcripts on the experiments the students can communicate in a technical way and debate their own results in detail in a group. |
| **Personal Competence** | |
| *Social Competence* | Students can work together as a team of 2-5 persons, participate in subject-specific and interdisciplinary discussions, develop cooperated solutions and defend their own work results in front of others and promote the scientific development of colleagues. Furthermore, they can give and accept professional constructive criticisms. |
| *Autonomy* | Students can accumulate knowledge of the subject area and practice it in the lab. |
| **Workload in Hours** | Independent Study Time 82, Study Time in Lecture 98 |
| **Credit points** | 6 |
| **Course achievement** | **Compulsory** **Bonus** **Form** **Description**<br>Yes None Written elaboration |
| **Examination** | Written exam |
| **Examination duration and scale** | 1 hour |
| **Assignment for the Following Curricula** | Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0311: Chemistry of Drinking Water Treatment | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 2, Study Time in Lecture 28 |
| **Lecturer** | Dr. Klaus Johannsen |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | The topic of this course is water chemistry with respect to drinking water treatment and water distribution<br><br>Major topics are solubility of gases, carbonic acid system and calcium carbonate, blending, softening, redox processes, materials and legal requirements on drinking water treatment. Focus is put on generally accepted rules of technology (DVGW- and DIN-standards).<br><br>Special emphasis is put on calculations using realistic analysis data (e.g. calculation of pH or calcium carbonate dissolution potential) in exercises. Students can get a feedback and gain extra points for exam by solving problems for homework.<br><br>Knowledge of drinking water treatment processes is vital for this lecture. Therefore the most important processes are explained coordinated with the course " Water resources management" in the beginning of the semester. |
| **Literature** | **MHW (rev. by Crittenden, J. et al.):** Water treatment principles and design. John Wiley & Sons, Hoboken, 2005.<br><br>**Stumm, W., Morgan, J.J.**: Aquatic chemistry. John Wiley & Sons, New York, 1996.<br><br>**DVGW (Hrsg.):** Wasseraufbereitung - Grundlagen und Verfahren. Oldenbourg Industrie Verlag, München, 2004.<br><br>**Jensen, J. N.**: A Problem Solving Approach to Aquatic Chemistry. John Wiley & Sons, Inc., New York, 2003. |

| Course L0312: Chemistry of Drinking Water Treatment | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Dr. Klaus Johannsen |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L0965: Practical Course Aquatic Chemistry | |
|---|---|
| **Typ** | Practical Course |
| **Hrs/wk** | 4 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 34, Study Time in Lecture 56 |
| **Lecturer** | Prof. Kerstin Kuchta |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | The practical course is conducted as a block course and lasts for 1 week. There are simple but typical methods for chemical analysis for water, sewage, soil and waste taught, which serve the students as the basis for their later work in this area.<br><br>In this practical course for example the Institutes of Wastewater Management and Water Protection (IAG), Environmental Technology and Energy Economics(IUE), Water Resources and Water Supply (IWW) are involved.<br>In the following examples of experiments and methods taught in the course are summarized:<br><br>• Surface waters: sampling of water and sediment<br>• Determination of the pH-value<br>• Determination of the redox potential<br>• Determination of a heavy metal (Zn)<br>• Acid neutralizing capacity (sediment)<br>• Flocculation or co-precipitation of water-suspended titanium dioxide particles<br>• Precipitation of phosphate with Fe3 +<br>• determine the toxicity of wastewater componentsagainst bacteria<br>• denitrification<br>• Electrical conductivity<br>• Acid and base capacity (m-and p-value)<br>• Determination of permanent gases (H2, O2, N2, CO2, CH4) in Landfill Gas<br>• Determining a grading curve by screens<br>• Determination of volatile organic acids and the total content of inorganic carbonate (FOS / TAC) by means of pH titration in samples from biogas plants |
| **Literature** | |

## Module M0902: Wastewater Treatment and Air Pollution Abatement

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Biological Wastewater Treatment (L0517) | Lecture | 2 | 3 |
| Air Pollution Abatement (L0203) | Lecture | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Dr. Swantje Pietsch |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basic knowledge of biology and chemistry<br>basic knowledge of solids process engineering and separation technology |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After successful completion of the module students are able to<br>• name and explain biological processes for waste water treatment,<br>• characterize waste water and sewage sludge<br>• discuss legal regulations in the area of emissions and air quality<br>• classify off gas tretament processes and to define their area of application |
| *Skills* | Students are able to<br>• choose and design processs steps for the biological waste water treatment<br>• combine processes for cleaning of off-gases depending on the pollutants contained in the gases |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 min |
| **Assignment for the Following Curricula** | Civil Engineering: Specialisation Water and Traffic: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Environmental Engineering: Elective Compulsory<br>Environmental Engineering: Specialisation Waste and Energy: Elective Compulsory<br>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory<br>Joint European Master in Environmental Studies - Cities and Sustainability: Specialisation Water: Elective Compulsory<br>Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Water: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Compulsory |

| Course L0517: Biological Wastewater Treatment | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Joachim Behrendt |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | Charaterisation of Wastewater<br>Metobolism of Microorganisms<br>Kinetic of mirobiotic processes<br>Calculation of bioreactor for wastewater treatment<br>Concepts of Wastewater treatment<br>Design of WWTP<br>Excursion to a WWTP<br>Biofilms<br>Biofim Reactors<br>Anaerobic Wastewater and sldge treatment<br>resources oriented sanitation technology<br>Future challenges of wastewater treatment |
| **Literature** | **Gujer, Willi**<br>Siedlungswasserwirtschaft : mit 84 Tabellen<br>ISBN: 3540343296 (Gb.) URL: http://www.gbv.de/dms/bs/toc/516261924.pdf URL: http://deposit.d-nb.de/cgi-bin/dokserv?id=2842122&prov=M&dok_var=1&dok_ext=htm<br>Berlin [u.a.] : Springer, 2007<br>TUB_HH_Katalog<br>**Henze, Mogens**<br>Wastewater treatment : biological and chemical processes<br>ISBN: 3540422285 (Pp.)<br>Berlin [u.a.] : Springer, 2002<br>TUB_HH_Katalog<br>**Imhoff, Karl** (Imhoff, Klaus R.;)<br>Taschenbuch der Stadtentwässerung : mit 10 Tafeln<br>ISBN: 3486263331 ((Gb.))<br>München [u.a.] : Oldenbourg, 1999<br>TUB_HH_Katalog<br>**Lange, Jörg** (Otterpohl, Ralf; Steger-Hartmann, Thomas;)<br>Abwasser : Handbuch zu einer zukunftsfähigen Wasserwirtschaft<br>ISBN: 3980350215 (kart.) URL: http://www.gbv.de/du/services/agi/52567E5D44DA0809C12570220050BF25/000000700334<br>Donaueschingen-Pfohren : Mall-Beton-Verl., 2000<br>TUB_HH_Katalog<br>**Mudrack, Klaus** (Kunst, Sabine;)<br>Biologie der Abwasserreinigung : 18 Tabellen<br>ISBN: 382741427X URL: http://www.gbv.de/du/services/agi/94B581161B6EC747C1256E3F005A8143/420000114903<br>Heidelberg [u.a.] : Spektrum, Akad. Verl., 2003<br>TUB_HH_Katalog<br>**Tchobanoglous, George** (Metcalf & Eddy, Inc., ;)<br>Wastewater engineering : treatment and reuse<br>ISBN: 0070418780 (alk. paper) ISBN: 0071122508 (ISE (*pbk))<br>Boston [u.a.] : McGraw-Hill, 2003<br>TUB_HH_Katalog<br>**Henze, Mogens**<br>Activated sludge models ASM1, ASM2, ASM2d and ASM3<br>ISBN: 1900222248<br>London : IWA Publ., 2002<br>TUB_HH_Katalog<br>**Kunz, Peter**<br>Umwelt-Bioverfahrenstechnik<br>Vieweg, 1992<br>**Bauhaus-Universität., Arbeitsgruppe Weiterbildendes Studium Wasser und Umwelt** (Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall, ;)<br>Abwasserbehandlung : Gewässerbelastung, Bemessungsgrundlagen, Mechanische Verfahren, Biologische Verfahren, Reststoffe aus der Abwasserbehandlung, Kleinkläranlagen<br>ISBN: 3860682725 URL: http://www.gbv.de/dms/weimar/toc/513989765_toc.pdf URL: http://www.gbv.de/dms/weimar/abs/513989765_abs.pdf<br>Weimar : Universitätsverl, 2006<br>TUB_HH_Katalog<br>**Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall**<br>DWA-Regelwerk<br>Hennef : DWA, 2004<br>TUB_HH_Katalog<br>**Wiesmann, Udo** (Choi, In Su; Dombrowski, Eva-Maria;)<br>Fundamentals of biological wastewater treatment<br>ISBN: 3527312196 (Gb.) URL: http://deposit.ddb.de/cgi-bin/dokserv?id=2774611&prov=M&dok_var=1&dok_ext=htm<br>Weinheim : WILEY-VCH, 2007<br>TUB_HH_Katalog |

| Course L0203: Air Pollution Abatement | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Swantje Pietsch |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | In the lecture methods for the reduction of emissions from industrial plants are treated. At the beginning a short survey of the different forms of air pollutants is given. In the second part physical principals for the removal of particulate and gaseous pollutants form flue gases are treated. Industrial applications of these principles are demonstrated with examples showing the removal of specific compounds, e.g. sulfur or mercury from flue gases of incinerators. |
| **Literature** | Handbook of air pollution prevention and control, Nicholas P. Cheremisinoff. - Amsterdam [u.a.] : Butterworth-Heinemann, 2002<br>Atmospheric pollution : history, science, and regulation, Mark Zachary Jacobson. - Cambridge [u.a.] : Cambridge Univ. Press, 2002<br>Air pollution control technology handbook, Karl B. Schnelle. - Boca Raton [u.a.] : CRC Press, c 2002<br>Air pollution, Jeremy Colls. - 2. ed. - London [u.a.] : Spon, 2002 |

## Module M0949: Rural Development and Resources Oriented Sanitation for different Climate Zones

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Rural Development and Resources Oriented Sanitation for different Climate Zones (L0942) | Seminar | 2 | 3 |
| Rural Development and Resources Oriented Sanitation for different Climate Zones (L0941) | Lecture | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Ralf Otterpohl |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basic knowledge of the global situation with rising poverty, soil degradation, lack of water resources and sanitation |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can describe resources oriented wastewater systems mainly based on source control in detail. They can comment on techniques designed for reuse of water, nutrients and soil conditioners.<br>Students are able to discuss a wide range of proven approaches in Rural Development from and for many regions of the world. |
| *Skills* | Students are able to design low-tech/low-cost sanitation, rural water supply, rainwater harvesting systems, measures for the rehabilitation of top soil quality combined with food and water security. Students can consult on the basics of soil building through “Holisitc Planned Grazing” as developed by Allan Savory. |
| **Personal Competence** | |
| *Social Competence* | The students are able to develop a specific topic in a team and to work out milestones according to a given plan. |
| *Autonomy* | Students are in a position to work on a subject and to organize their work flow independently. They can also present on this subject. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Subject theoretical and practical work |
| **Examination duration and scale** | During the course of the semester, the students work towards mile stones. The work includes presentations and papers. Detailed information will be provided at the beginning of the smester. |
| **Assignment for the Following Curricula** | Civil Engineering: Specialisation Water and Traffic: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory<br>Environmental Engineering: Specialisation Water: Elective Compulsory<br>International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory<br>Joint European Master in Environmental Studies - Cities and Sustainability: Specialisation Water: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Water: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Elective Compulsory |

| Course L0942: Rural Development and Resources Oriented Sanitation for different Climate Zones | |
|---|---|
| **Typ** | Seminar |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Ralf Otterpohl |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Central part of this module is a group work on a subtopic of the lectures. The focus of these projects will be based on an interview with a target audience, practitioners or scientists.<br>• The group work is divided into several Milestones and Assignments. The outcome will be presented in a final presentation at the end of the semester. |
| **Literature** | • J. Lange, R. Otterpohl 2000: Abwasser - Handbuch zu einer zukunftsfähigen Abwasserwirtschaft. Mallbeton Verlag (TUHH Bibliothek)<br>• Winblad, Uno and Simpson-Hébert, Mayling 2004: Ecological Sanitation, EcoSanRes, Sweden (free download)<br>• Schober, Sabine: WTO/TUHH Award winning Terra Preta Toilet Design: http://youtu.be/w_R09cYq6ys |

| Course L0941: Rural Development and Resources Oriented Sanitation for different Climate Zones | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Ralf Otterpohl |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Living Soil - THE key element of Rural Development<br>• Participatory Approaches<br>• Rainwater Harvesting<br>• Ecological Sanitation Principles and practical examples<br>• Permaculture Principles of Rural Development<br>• Performance and Resilience of Organic Small Farms<br>• Going Further: The TUHH Toolbox for Rural Development<br>• EMAS Technologies, Low cost drinking water supply |
| **Literature** | • Miracle Water Village, India, Integrated Rainwater Harvesting, Water Efficiency, Reforestation and Sanitation: http://youtu.be/9hmkgn0nBgk<br>• Montgomery, David R. 2007: Dirt: The Erosion of Civilizations, University of California Press |

## Module M1033: Special Areas of Process Engineering and Bioprocess Engineering

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Chemical Kinetics (L0508) | Lecture | 2 | 2 |
| Solid Matter Process in chemical Industry (L2021) | Lecture | 2 | 2 |
| Interfaces and Colloids (L0194) | Lecture | 2 | 2 |
| Industrial Inorganic and Organic Processes (L0531) | Lecture | 2 | 2 |
| Industrial biotechnology in Chemical Industriy (L2276) | Lecture | 2 | 3 |
| Optics for Engineers (L2437) | Lecture | 2 | 2 |
| Optics for Engineers (L2438) | Project-/problem-based Learning | 2 | 2 |
| Polymer Reaction Engineering (L1244) | Lecture | 2 | 2 |
| Practice in bioprocess engineering (L2275) | Lecture | 2 | 3 |
| Safety of Chemical Reactions (L1321) | Lecture | 2 | 2 |
| Ceramics Technology (L0379) | Lecture | 2 | 3 |
| Environmental Analysis (L0354) | Lecture | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Michael Schlüter |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | The students should have passed the Bachelor modules "Process Engineering" successfully. |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to find their way around selected special areas of Process Engineering within the scope of Process Engineering.<br>Students are able to explain technical dependencies and models in selected special areas of Process Engineering. |
| *Skills* | Students are able to apply basic methods in selected areas of process engineering. |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | Students can chose independently, in which field the want to deepen their knowledge and skills through the election of courses. |
| **Workload in Hours** | Depends on choice of courses |
| **Credit points** | 6 |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| Course L0508: Chemical Kinetics | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Klausur |
| **Examination duration and scale** | 120 Minuten |
| **Lecturer** | Prof. Raimund Horn |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | - Micro kinetics, formal kinetics, molecularity, reaction order, integrated rate laws<br><br>- Complex reactions, reversible reactions, consecutive reactions, parallel reactions, approximation methods: steady-state, pseudo-first order, numerical solution of rate equations , example : Belousov-Zhabotinskii reaction<br><br>- Experimental methods of kinetics, integral approach, differential approach, initial rate method, method of half-life, relaxation methods<br><br>- Collision theory, Maxwell velocity distribution, collision numbers, line of centers model<br><br>- Transition state theory, partition functions of atoms and molecules, examples, calculating reaction equilibria on the basis of molecular data only, heats of reaction, calculating rates of reaction by means of statistical thermodynamics<br><br>- Kinetics of heterogeneous reactions, peculiarities of heterogeneous reactions, mean-field approximation, Langmuir adsorption isotherm, reaction mechanisms, Langmuir-Hinshelwood Mechanism, Eley-Rideal Mechanism, steady-state approximation, quasi-equilibrium approximation, most abundant reaction intermediate (MARI), reaction order, apparent activation energy, example: CO oxidation, transition state theory of surface reactions, Sabatier´s principle, sticking coefficient, parameter fitting<br><br>- Explosions, cold flames |
| **Literature** | J. I. Steinfeld, J. S. Francisco, W. L . Hase: Chemical Kinetics & Dynamics, Prentice Hall<br><br>K. J. Laidler: Chemical Kinetics, Harper & Row Publishers<br><br>R. K. Masel. Chemical Kinetics & Catalysis , Wiley<br><br>I. Chorkendorff,, J. W. Niemantsverdriet: Concepts of modern Catalysis and Kinetics, Wiley |

| Course L2021: Solid Matter Process in chemical Industry | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Schriftliche Ausarbeitung |
| **Examination duration and scale** | 12 Seiten |
| **Lecturer** | Prof. Frank Kleine Jäger |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | |
| **Literature** | |

| Course L0194: Interfaces and Colloids | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Schriftliche Ausarbeitung |
| **Examination duration and scale** | 1 Stunde |
| **Lecturer** | Dr. Philip Jaeger |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | 1.Fundamentals, definitions 1.1 Thermodynamics of interfaces 1.2 Surfactants 1.3 Interfacial tension (Principles, Methods, Examples) 1.4 Wetting, adhesion 2.Dispersions 2.1 Droplet formation 2.2 Stabilization 2.3 Physical Properties 2.4 Rheology 2.5 Microemulsions 3. Transport Phenomena 3.1 Mass transport across phase boundaries 3.2 Interfacial convection - Marangoni flow 3.3 Influence of surfactants on interfacial area and transport resistance (bubbles, droplets, falling films) 4. Applications 4.1 Food Emulsification 4.2 Crude oil recovery (EOR) 4.3 Coating 4.4 Separation technology (Spray towers, packed columns) 4.5 Nucleation (Polymer foams, evaporation) 4.6 Recent developments (Surfactant aided extraction) |
| **Literature** | A.W. Adamson: Physical Chemistry of Surfaces, 5th ed., J. Wiley & Sons New York, 1990. P. Becher : Emulsions - Theory and Practice, 1965. P. Becher : Encyclopedia of Emulsion Technology, Vol. 1, Dekker New York, 1983. S.S. Dukhin, G. Kretzschmar, R. Miller: Dynamics of Adsorption at Liquid Interfaces, Elsevier Amsterdam, 1995. D.J. McClements: Food Emulsions - Principle, Practices and Techniques, 2nd ed., CRC Press Boca Raton, 2005. D. Myers: Surfaces, Interfaces and Colloids, VCH-Verlagsgesellschaft Weinheim, 1991. P. Sherman: Emulsion Science, 1968. J. Lyklema: Fundamentals of Interface and Colloid Science, Vol. III, Academic Press London, 2000. A.I. Rusanov: Phasengleichgewichte und Grenzflächenerscheinungen, Akademie Verlag, Berlin 1978. P. C. Hiemenz, R. Rajagopalan: Principles of Colloid and Surface Chemistry, 3rd ed. Marcel Dekker, New York 1997. P. Grassmann: Physikalische Grundlagen der Verfahrenstechnik, Verlag Salle und Sauerländer, 1983. M.J. Schwuger: Lehrbuch der Grenzflächenchemie, Thieme Verlag, 1996. |

| Course L0531: Industrial Inorganic and Organic Processes | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Klausur |
| **Examination duration and scale** | 45 Minuten |
| **Lecturer** | Dr. Achim Bartsch |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | The occupational area of chemical engineers is principally the chemical industry.<br><br>This survey course will focus on history, economic significance, technical applications, and main production processes in detail of major primary bulk inorganic and organic chemicals. Disposition of raw materials as well as ecological problems are discussed.<br><br>Inorganic Products<br><br>* inorganic raw materials (hydrogen and compounds, nitrogen and compounds...)<br><br>* inorganic fertilizers<br><br>* metals and their compounds<br><br>* semiconductors<br><br>* inorganic solids (building materials, ceramics, fibers, pigments ...)<br><br>...<br><br>Organic Products<br><br>* bulk products for organic synthesis (synthesis gas, C1-compounds)<br><br>* Production and processing of olefines, alcohols, hydrocarbons, aromatics<br><br>* Petroleum and Petrochemicals<br><br>* Surfactants and Detergents<br><br>* Production and processing of oleochemicals<br><br>* Synthetic Polymers<br><br>... |
| **Literature** | Ullmann's Encyclopedia of Industrial Chemistry, Wiley online library 2014<br><br>M. Bertau, A. Müller, P. Fröhlich und M. Katzberg: Industrielle Anorganische Chemie, Wiley-VCH 2013<br><br>Hans-Jürgen Arpe: Industrielle Organische Chemie, Wiley-VCH 2007 |

| Course L2276: Industrial biotechnology in Chemical Industriy | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Examination Form** | Referat |
| **Examination duration and scale** | 45 min |
| **Lecturer** | Prof. Andreas Liese, Dr. Stephan Freyer |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | This course gives an insight into the applications, processes, structures and boundary conditions in industrial practice. Various concrete applications of the technology, markets and other questions that will significantly influence the plant and process design will be shown. |
| **Literature** | Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen]<br><br>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.<br><br>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract<br><br>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003<br><br>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage<br><br>Krahe M (2003) Biochemical Engineering. Ullmann´s Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html<br><br>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts |

| Course L2437: Optics for Engineers | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Fachtheoretisch-fachpraktische Arbeit |
| **Examination duration and scale** | Vorstellung eines eigenen Optikentwurfs mit anschließender Diskussion, 10 Minuten Vorstellung + maximal 20 Minuten Diskussion |
| **Lecturer** | Prof. Thorsten Kern |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Basic values for optical systems and lighting technology<br>• Spectrum, black-bodies, color-perception<br>• Light-Sources und their characterization<br>• Photometrics<br>• Ray-Optics<br>• Matrix-Optics<br>• Stops, Pupils and Windows<br>• Light-field Technology<br>• Introduction to Wave-Optics<br>• Introduction to Holography |
| **Literature** | |

| Course L2438: Optics for Engineers | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Fachtheoretisch-fachpraktische Arbeit |
| **Examination duration and scale** | Vorstellung eines eigenen Optikentwurfs mit anschließender Diskussion, 10 Minuten Vorstellung + maximal 20 Minuten Diskussion |
| **Lecturer** | Prof. Thorsten Kern |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L1244: Polymer Reaction Engineering | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Schriftliche Ausarbeitung |
| **Examination duration and scale** | 1 Stunde |
| **Lecturer** | Prof. Hans-Ulrich Moritz |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | Introduction into polymer reaction engineering, free and controlled radical polymerization, coordination polymerization of olefins, ionic “living” polymerization, step polymerization (polyaddition, polycondensation), copolymerization, emulsion polymerization, specific challenges of the industrial implementation of polymerization reactions (viscosity increase, heat removal, scale-up, reactor safety, modelling of polymerization reactions and reactors), key competitive factors in polymer industry in Germany, EU and worldwide. |
| **Literature** | W. Keim: Kunststoffe - Synthese, Herstellungsverfahren, Apparaturen, 1. Auflage, Wiley-VCH, 2006<br>T. Meyer, J. Keurentjes: Handbook of Polymer Reaction Engineering, 2 Vol., 1. Ed., Wiley-VCH, 2005<br>A. Echte: Handbuch der technischen Polymerchemie, 1. Auflage, VCH-Verlagsgesellschaft, 1993<br>G. Odian: Principles of Polymerization, 4. Ed., Wiley-Interscience, 2004<br>J. Asua: Polymer Reaction Engineering, 1. Ed., Blackwell Publishing, 2007 |

| Course L2275: Practice in bioprocess engineering | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Examination Form** | Referat |
| **Examination duration and scale** | 45 min |
| **Lecturer** | Prof. An-Ping Zeng, Prof. Ralf Pörtner, Dr. Willfried Blümke |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | Content of this course is a concrete insight into the principles, processes and structures of an industrial biotechnology company. In addition to practical illustrative examples, aspects beyond the actual process engineering area are also addressed, such as e.g. Sustainability and engineering. |
| **Literature** | Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen]<br>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.<br>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract<br>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003<br>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage<br>Krahe M (2003) Biochemical Engineering. Ullmann´s Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html<br>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts |

| Course L1321: Safety of Chemical Reactions | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Examination Form** | Klausur |
| **Examination duration and scale** | |
| **Lecturer** | Prof. Hans-Ulrich Moritz |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | |
| **Literature** | |

| Course L0379: Ceramics Technology | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Examination Form** | Klausur |
| **Examination duration and scale** | 90 Minuten |
| **Lecturer** | Dr. Rolf Janßen |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | Introduction to ceramic processing with emphasis on advanced structural ceramics. The course focus predominatly on powder-based processing, e.g. “powder-metauurgical techniques and sintering (soild state and liquid phase). Also, some aspects of glass and cement science as well as new developments in powderless forming techniques of ceramics and ceramic composites will be addressed Examples will be discussed in order to give engineering students an understanding of technology development and specific applications of ceramic components.<br>**Content:** 1. Introduction<br>Inhalt: 2. Raw materials<br>3. Powder fabrication<br>4. Powder processing<br>5. Shape-forming processes<br>6. Densification, sintering<br>7. Glass and Cement technology<br>8. Ceramic-metal joining techniques |
| **Literature** | W.D. Kingery, „Introduction to Ceramics“, John Wiley & Sons, New York, 1975<br>ASM Engineering Materials Handbook Vol.4 „Ceramics and Glasses“, 1991<br>D.W. Richerson, „Modern Ceramic Engineering“, Marcel Decker, New York, 1992<br>Skript zur Vorlesung |

| Course L0354: Environmental Analysis | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Examination Form** | Klausur |
| **Examination duration and scale** | 45 Minuten |
| **Lecturer** | Dr. Dorothea Rechtenbach, Dr. Henning Mangels |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | Introduction<br>Sampling in different environmental compartments, sample transportation, sample storage<br>Sample preparation<br>Photometry<br>Wastewater analysis<br>Introduction into chromatography<br>Gas chromatography<br>HPLC<br>Mass spectrometry<br>Optical emission spectrometry<br>Atom absorption spectrometry<br>Quality assurance in environmental analysis |
| **Literature** | Roger Reeve, Introduction to Environmental Analysis, John Wiley & Sons Ltd., 2002 (TUB: USD-728)<br>Pradyot Patnaik, Handbook of environmental analysis: chemical pollutants in air, water, soil, and solid wastes, CRC Press, Boca Raton, 2010 (TUB: USD-716)<br>Chunlong Zhang, Fundamentals of Environmental Sampling and Analysis, John Wiley & Sons Ltd., Hoboken, New Jersey, 2007 (TUB: USD-741)<br>Miroslav Radojević, Vladimir N. Bashkin, Practical Environmental Analysis<br>RSC Publ., Cambridge, 2006 (TUB: USD-720)<br>Werner Funk, Vera Dammann, Gerhild Donnevert, Sarah Iannelli (Translator), Eric Iannelli (Translator), Quality Assurance in Analytical Chemistry: Applications in Environmental, Food and Materials Analysis, Biotechnology, and Medical Engineering, 2nd Edition, WILEY-VCH Verlag GmbH & Co. KGaA,Weinheim, 2007 (TUB: CHF-350)<br>STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER, 21st Edition, Andrew D. Eaton, Leonore S. Clesceri, Eugene W. Rice, and Arnold E. Greenberg, editors, 2005 (TUB:CHF-428)<br>K. Robards, P. R. Haddad, P. E. Jackson, Principles and Practice of<br>Modern Chromatographic Methods, Academic Press<br>G. Schwedt, Chromatographische Trennmethoden, Thieme Verlag<br>H. M. McNair, J. M. Miller, Basic Gas Chromatography, Wiley<br>W. Gottwald, GC für Anwender, VCH<br>B. A. Bidlingmeyer, Practical HPLC Methodology and Applications, Wiley<br>K. K. Unger, Handbuch der HPLC, GIT Verlag<br>G. Aced, H. J. Möckel, Liquidchromatographie, VCH<br>Charles B. Boss and Kenneth J. Fredeen, Concepts, Instrumentation and Techniques in Inductively Coupled Plasma Optical Emission Spectrometry<br>Perkin-Elmer Corporation 1997, On-line available at:<br>http://files.instrument.com.cn/bbs/upfile/2006291448.pdf<br>Atomic absorption spectrometry: theory, design and applications, ed. by S. J. Haswell 1991 (TUB: 2727-5614)<br>Royal Society of Chemistry, Atomic absorption spectometry (http://www.kau.edu.sa/Files/130002/Files/6785_AAs.pdf) |

## Module M0905: Research Project Process Engineering

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Research Project in Process Engineering (L1051) | Project-/problem-based Learning | 6 | 6 |

| | |
|---|---|
| **Module Responsible** | Dozenten des SD V |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Advanced state of knowledge in the master program of Process Engineering |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students know current research topics oft institutes engaged in their specialization. They can name the fundamental scientific methods used for doing related reserach. |
| *Skills* | Students are capable of completing a small, independent sub-project of currently ongoing research projects in the institutes engaged in their specialization. Students can justify and explain their approach for problem solving, they can draw conclusions from their results, and then can find new ways and methods for their work. Students are capable of comparing and assessing alterantive approaches with their own with regard to given criteria. |
| **Personal Competence** | |
| *Social Competence* | Students are able to discuss their work progress with research assistants of the supervising institute. They are capable of presenting their results in front of a professional audience. |
| *Autonomy* | Based on their competences gained so far students are capable of defining meaningful tasks within ongoing research project for themselves. They are able to develop the necessary understanding and problem solving methods. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Study work |
| **Examination duration and scale** | According to General Regulations |
| **Assignment for the Following Curricula** | Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory |

### Course L1051: Research Project in Process Engineering

| | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 6 |
| **CP** | 6 |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Lecturer** | Dozenten des SD V |
| **Language** | DE/EN |
| **Cycle** | WiSe/SoSe |
| **Content** | Working on current research topics of the chosen specialisation.<br><br>Research projects can be carried out at the institutes of process engineering, in industry or abroad. It is always necessary to have a university lecturer from the school of Process Engineering as a supervisor, who must be determined before the research project begins. |
| **Literature** | Aktuelle Literatur zu Forschungsthemen aus der gewählten Vertiefungsrichtung.<br><br>Current literature on research topics of the chosen specialization. |

## Module M1294: Bioenergy

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Biofuels Process Technology (L0061) | Lecture | 1 | 1 |
| Biofuels Process Technology (L0062) | Recitation Section (small) | 1 | 1 |
| World Market for Commodities from Agriculture and Forestry (L1769) | Lecture | 1 | 1 |
| Thermal Utilization of Biomass (L1767) | Lecture | 2 | 2 |
| Thermal Biomass Utilization (L2386) | Practical Course | 1 | 1 |

| | |
|---|---|
| **Module Responsible** | Prof. Martin Kaltschmitt |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | none |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to reproduce an in-depth outline of energy production from biomass, aerobic and anaerobic waste treatment processes, the gained products and the treatment of produced emissions. |
| *Skills* | Students can apply the learned theoretical knowledge of biomass-based energy systems to explain relationships for different tasks, like dimesioning and design of biomass power plants. In this context, students are also able to solve computational tasks for combustion, gasification and biogas, biodiesel and bioethanol use. |
| **Personal Competence** | |
| *Social Competence* | Students can participate in discussions to design and evaluate energy systems using biomass as an energy source. |
| *Autonomy* | Students can independently exploit sources with respect to the emphasis of the lectures. They can choose and aquire the for the particular task useful knowledge. Furthermore, they can solve computational tasks of biomass-based energy systems independently with the assistance of the lecture. Regarding to this they can assess their specific learning level and can consequently define the further workflow. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 3 hours written exam |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory<br>Energy Systems: Specialisation Energy Systems: Elective Compulsory<br>International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory<br>Renewable Energies: Core qualification: Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory |

| Course L0061: Biofuels Process Technology | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Oliver Lüdtke |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | • General introduction<br>• What are biofuels?<br>• Markets & trends<br>• Legal framework<br>• Greenhouse gas savings<br>• Generations of biofuels<br>  ◦ first-generation bioethanol<br>  ▪ raw materials<br>  ▪ fermentation distillation<br>  ◦ biobutanol / ETBE<br>  ◦ second-generation bioethanol<br>  ▪ bioethanol from straw<br>  ◦ first-generation biodiesel<br>  ▪ raw materials<br>  ▪ Production Process<br>  ▪ Biodiesel & Natural Resources<br>  ◦ HVO / HEFA<br>  ◦ second-generation biodiesel<br>  ▪ Biodiesel from Algae<br>• Biogas as fuel<br>  ◦ the first biogas generation<br>  ▪ raw materials<br>  ▪ fermentation<br>  ▪ purification to biomethane<br>  ◦ Biogas second generation and gasification processes<br>• Methanol / DME from wood and Tall oil © |
| **Literature** | • Skriptum zur Vorlesung<br>• Drapcho, Nhuan, Walker; Biofuels Engineering Process Technology<br>• Harwardt; Systematic design of separations for processing of biorenewables<br>• Kaltschmitt; Hartmann; Energie aus Biomasse: Grundlagen, Techniken und Verfahren<br>• Mousdale; Biofuels - Biotechnology, Chemistry and Sustainable Development<br>• VDI Wärmeatlas |

| Course L0062: Biofuels Process Technology | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Oliver Lüdtke |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | • Life Cycle Assessment<br>  ◦ Good example for the evaluation of CO2 savings potential by alternative fuels - Choice of system boundaries and databases<br>• Bioethanol production<br>  ◦ Application task in the basics of thermal separation processes (rectification, extraction) will be discussed. The focus is on a column design, including heat demand, number of stages, reflux ratio ...<br>• Biodiesel production<br>  ◦ Procedural options for solid / liquid separation, including basic equations for estimating power, energy demand, selectivity and throughput<br>• Biomethane production<br>  ◦ Chemical reactions that are relevant in the production of biofuels, including equilibria, activation energies, shift reactions |
| **Literature** | Skriptum zur Vorlesung |

| Course L1769: World Market for Commodities from Agriculture and Forestry | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Michael Köhl, Bernhard Chilla |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | 1) Markets for Agricultural Commodities<br>What are the major markets and how are markets functioning<br>Recent trends in world production and consumption.<br>World trade is growing fast. Logistics. Bottlenecks.<br>The major countries with surplus production<br>Growing net import requirements, primarily of China, India and many other countries.<br>Tariff and non-tariff market barriers. Government interferences.<br><br>2) Closer Analysis of Individual Markets<br>Thomas Mielke will analyze in more detail the global vegetable oil markets, primarily palm oil, soya oil, rapeseed oil, sunflower oil. Also the raw material (the oilseed) as well as the by-product (oilmeal) will be included. The major producers and consumers.<br>Vegetable oils and oilmeals are extracted from the oilseed. The importance of vegetable oils and animal fats will be highlighted, primarily in the food industry in Europe and worldwide. But in the past 15 years there have also been rapidly rising global requirements of oils & fats for non-food purposes, primarily as a feedstock for biodiesel but also in the chemical industry.<br>Importance of oilmeals as an animal feed for the production of livestock and aquaculture<br>Oilseed area, yields per hectare as well as production of oilseeds. Analysis of the major oilseeds worldwide. The focus will be on soybeans, rapeseed, sunflowerseed, groundnuts and cottonseed.<br>Regional differences in productivity. The winners and losers in global agricultural production.<br><br>3) Forecasts: Future Global Demand & Production of Vegetable Oils<br>Big challenges in the years ahead: Lack of arable land for the production of oilseeds, grains and other crops. Competition with livestock. Lack of water. What are possible solutions? Need for better education & management, more mechanization, better seed varieties and better inputs to raise yields.<br>The importance of prices and changes in relative prices to solve market imbalances (shortage situations as well as surplus situations). How does it work? Time lags.<br>Rapidly rising population, primarily the number of people considered “middle class” in the years ahead.<br>Higher disposable income will trigger changing diets in favour of vegetable oils and livestock products.<br>Urbanization. Today, food consumption per caput is partly still very low in many developing countries, primarily in Africa, some regions of Asia and in Central America. What changes are to be expected?<br>The myth and the realities of palm oil in the world of today and tomorrow.<br>Labour issues curb production growth: Some examples: 1) Shortage of labour in oil palm plantations in Malaysia. 2) Structural reforms overdue for the agriculture in India, China and other countries to become more productive and successful, thus improving the standard of living of smallholders. |
| **Literature** | Lecture material |

| Course L1767: Thermal Utilization of Biomass | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Martin Kaltschmitt |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | Goal of this course is it to discuss the physical, chemical, and biological as well as the technical, economic, and environmental basics of all options to provide energy from biomass from a German and international point of view. Additionally different system approaches to use biomass for energy, aspects to integrate bioenergy within the energy system, technical and economic development potentials, and the current and expected future use within the energy system are presented.<br><br>The course is structured as follows:<br><br>• Biomass as an energy carrier within the energy system; use of biomass in Germany and world-wide, overview on the content of the course<br>• Photosynthesis, composition of organic matter, plant production, energy crops, residues, organic waste<br>• Biomass provision chains for woody and herbaceous biomass, harvesting and provision, transport, storage, drying<br>• Thermo-chemical conversion of solid biofuels<br>  ◦ Basics of thermo-chemical conversion<br>  ◦ Direct thermo-chemical conversion through combustion: combustion technologies for small and large scale units, electricity generation technologies, flue gas treatment technologies, ashes and their use<br>  ◦ Gasification: Gasification technologies, producer gas cleaning technologies, options to use the cleaned producer gas for the provision of heat, electricity and/or fuels<br>  ◦ Fast and slow pyrolysis: Technologies for the provision of bio-oil and/or for the provision of charcoal, oil cleaning technologies, options to use the pyrolysis oil and charcoal as an energy carrier as well as a raw material<br>• Physical-chemical conversion of biomass containing oils and/or fats: Basics, oil seeds and oil fruits, vegetable oil production, production of a biofuel with standardized characteristics (trans-esterification, hydrogenation, co-processing in existing refineries), options to use this fuel, options to use the residues (i.e. meal, glycerine)<br>• Bio-chemical conversion of biomass<br>  ◦ Basics of bio-chemical conversion<br>  ◦ Biogas: Process technologies for plants using agricultural feedstock, sewage sludge (sewage gas), organic waste fraction (landfill gas), technologies for the provision of bio methane, use of the digested slurry<br>  ◦ Ethanol production: Process technologies for feedstock containing sugar, starch or celluloses, use of ethanol as a fuel, use of the stillage |
| **Literature** | **Kaltschmitt, M.; Hartmann, H. (Hrsg.): Energie aus Biomasse; Springer, Berlin, Heidelberg, 2009, 2. Auflage** |

| Course L2386: Thermal Biomass Utilization | |
|---|---|
| **Typ** | Practical Course |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Martin Kaltschmitt, Dr. Isabel Höfer |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | The experiments of the practical lab course illustrate the different aspects of heat generation from biogenic solid fuels. First, different biomasses (e.g. wood, straw or agricultural residues) will be investigated; the focus will be on the calorific value of the biomass. Furthermore, the used biomass will be pelletized, the pellet properties analysed and a combustion test carried out on a pellet combustion system. The gaseous and solid pollutant emissions, especially the particulate matter emissions, are measured and the composition of the particulate matter is investigated in a further experiment. Another focus of the practical course is the consideration of options for the reduction of particulate matter emissions from biomass combustion. In the practical course, a method for particulate matter reduction will be developed and tested. All experiments will be evaluated and the results presented.<br><br>Within the practical lab course the students discuss different technical-scientific tasks, both subject-specifically and interdisciplinary. They<br>discuss various approaches to solving the problem and advise on the theoretical or practical implementation. |
| **Literature** | - Kaltschmitt, Martin; Hartmann, Hans; Hofbauer, Hermann: Energie aus Biomasse: Grundlagen, Techniken und Verfahren. 3. Auflage. Berlin Heidelberg: Springer Science & Business Media, 2016. - ISBN 978-3-662-47437-2<br>- Versuchsskript |

## Module M1303: Energy Projects and their Assessment

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Development of Renewable Energy Projects (L0003) | Lecture | 2 | 2 |
| Renewable Energy Projects in Emerged Markets (L0014) | Project Seminar | 2 | 2 |
| Economics of an Energy Provision from Renewables (L0005) | Lecture | 1 | 1 |
| Economics of an Energy Provision from Renewables (L0006) | Project Seminar | 1 | 1 |

| | |
|---|---|
| **Module Responsible** | Prof. Martin Kaltschmitt |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Environmental Assessment |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | By ending this module, students can describe the planning and development of projects using renewable energy sources. Furthermore they are able to explain the special emphasis on the economic and legal aspects in this context.<br><br>The learning content of the different topics of the module are use-oriented; thus students can apply them i.a. in professional fields of consultation or supervision of energy projects. |
| *Skills* | By ending the module the students can apply the learned theoretical foundations of the development of renewable energy projects to exemplary energy projects and can explain technically and conceptually the resulting correlations with respect to legal and economic requirements.<br><br>As a basis for the design of renewable energy systems they can calculate the demand for thermal and/or electrical energy at operating and regional level. Regarding to this calculation they can choose and dimension possible energy systems.<br><br>To assess sustainability aspects of renewable energy projects, the students can choose and discuss the right methodology according to the particular task.<br><br>Through active discussions of various topics within the seminars and exercises of the module, students improve their understanding and the application of the theoretical background and are thus able to transfer what they have learned in practice. |
| **Personal Competence** | |
| *Social Competence* | Students will be able to edit scientific tasks in the context of the economic analysis of renewable energy projects in a group with a high number of participants and can organize the processing time within the group. They can perform subject-specific and interdisciplinary discussions. Consequently, they can asses the knowledge of their fellow students and are able to deal with feedback on their own performance. Students can present their group results in front of others. |
| *Autonomy* | Regarding to the contents of the lectures and to solve the tasks for the economical analysis of renewable energy projects the students are able to exploit sources and acquire the particular knowledge about the subject area independently and self-organized. Based on this expertise they are able to use indenpendently calculation methods for these tasks. Regarding to these calculations, guided by the lecturers, the students can recognize self-organized theri personal level of knowledge. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 2 hours written exam + Written assay from project seminar |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory<br>Renewable Energies: Core qualification: Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory |

| Course L0003: Development of Renewable Energy Projects | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Martin Kaltschmitt |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | • Development of renewable energy projects from the analysis of the local situation to the final energy project: what steps have to be completed in order to implement a successful regenerative energy project and what factors must be considered<br>• Survey of energy demand; methods to collect the demand for thermal and/or electrical energy at operational and regional level until the point of a development of an energy master plan<br>• Technology of renewable energy: how to combine the various options for using renewable energy with different supply situation in the most reasonable way? How can under certain conditions ideal combinations look like?<br>• Feasibility study, requirements and content of a feasibility study<br>• Legal framework for plant construction; representation of authorization rights, including the entire formal procedure for the different approval procedures in the context of the BImSch legislation; further legal requirements (including laws pertaining to construction, water and waterways, noise, etc.<br>• Company structures; which company structure is the most appropriate for the various applications? What are the pros and cons?<br>• Risk management: how the risks of renewable energy projects can be best determined? How the minimizing of risk can be ensured?<br>• Insurance: which kinds of insurance exit? Why do you need insurance? What requirements must be met in order to obtain certain types of insurance for certain renewable energy projects for the construction and operational phase?<br>• Acceptance: how the acceptance of an application for the use of renewable energy can be assessed and improved? How the acceptance can be measured?<br>• Organization of realization of a project: how the construction phase of a renewable energy system is organized after the end of the planning period?<br>• Acceptance: Which are the acceptance steps until the regular continuous operation (VOB acceptance, safety acceptance, approval by authority)<br>• Examples: good and less good examples of project development |
| **Literature** | • Script zur Vorlesung mit Literaturhinweisen |

| **Course L0014: Renewable Energy Projects in Emerged Markets** | |
|---|---|
| **Typ** | Project Seminar |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Andreas Wiese |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | 1. Introduction<br>  ◦ Development of renewable energies worldwide<br>  ▪ History<br>  ▪ Future markets<br>  ◦ Special challenges in new markets - Overview<br>2. Sample project wind farm Korea<br>  ◦ Survey<br>  ◦ Technical Description<br>  ◦ Project phases and characteristics<br>3. Funding and financing instruments for EE projects in new markets<br>  ◦ Overview funding opportunitie<br>  ◦ Overview countries with feed-in laws<br>  ◦ Major funding programs<br>4. CDM projects - why, how , examples<br>  ◦ Overview CDM process<br>  ◦ Examples<br>  ◦ Exercise CDM<br>5. Rural electrification and hybrid systems - an important future market for EE<br>  ◦ Rural Electrification - Introduction<br>  ◦ Types of Elektrizifierungsprojekten<br>  ◦ The role of the EEInterpretation of hybrid systems<br>  ◦ Project example: hybrid system Galapagos Islands<br>6. Tendering process for EE projects - examples<br>  ◦ South Africa<br>  ◦ Brazil<br>7. Selected projects from the perspective of a development bank - Wesley Urena Vargas, KfW Development Bank<br>  ◦ Geothermal<br>  ◦ Wind or CSP<br><br>Within the seminar, the various topics are actively discussed and applied to various cases of application. |
| **Literature** | Folien der Vorlesung |

| Course L0005: Economics of an Energy Provision from Renewables | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Andreas Wiese |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | • Introduction: definitions; importance of cost and profitability statements for projects in the "Renewable Energies"; prices and costs; efficiency of energy systems versus profitability of individual project<br>• Cost estimates and cost calculations<br>  ◦ Definitions<br>  ◦ Cost calculation<br>  ◦ Cost estimation<br>  ◦ Calculation of costs for the provision of work and power<br>  ◦ Cost summaries for renewable energy technologies<br>  ◦ Energy Storage: cost overviews; impact on the cost of renewable energy projects<br>• Efficiency calculation<br>  ◦ Definitions<br>  ◦ Methods: static methods, dynamic methods (eg. LCOE (levelised cost of electricity))<br>  ◦ Economic versus national economic approach<br>  ◦ Power and work in cost accounting<br>  ◦ Energy storage and its influence on the efficiency calculation<br>• The due diligence process as an attendant of economic analysis<br>• Consideration of uncertainty in projects for renewable energy<br>  ◦ Definitions<br>  ◦ Technical uncertainty<br>  ◦ Cost uncertainties<br>  ◦ Other uncertainties<br>• Project financing<br>  ◦ Definitions<br>  ◦ Project -versus corporate finance<br>  ◦ Funding models<br>  ◦ Equity ratio , DSCR<br>  ◦ Treatment of risks in project financing<br>  ◦ Funding opportunities for renewable energy projects<br>  ◦ Possible funding approaches<br>  ◦ Legal requirements in Germany (EEG )<br>  ◦ Emissions trading and carbon credits |
| **Literature** | Script der Vorlesung |

| Course L0006: Economics of an Energy Provision from Renewables | |
|---|---|
| **Typ** | Project Seminar |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Andreas Wiese |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | Calculation of tasks to evaluate the economics of a renewable energy project, with the aim to deepen the complex knowledge of economic analysis and market analysis. Processing is carried out individually or in smaller groups. The following topics are covered:<br>• Stat. and dyn. calculation of profitability<br>• Cost estimate plus stat. and dyn. calculation of profitability<br>• sensitivity analysis<br>• joint production<br>• Grid parity calculation<br>Within the seminar, the various tasks are actively discussed and applied to various cases of application. |
| **Literature** | Skript der Vorlesung |

## Module M1309: Dimensioning and Assessment of Renewable Energy Systems

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Environmental Technology and Energy Economics (L0137) | Project-/problem-based Learning | 2 | 2 |
| Electricity Generation from Renewable Sources of Energy (L0046) | Seminar | 2 | 2 |
| Heat Provision from Renewable Sources of Energy (L0045) | Seminar | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Martin Kaltschmitt |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | none |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students can describe current issue and problems in the field of renewable energies. Furthermore, they can explain aspects in relation to the provision of heat or electricity through different renewable technologies, and explain and assess them in a technical, economical and environmental way. |
| *Skills* | Students are able to solve scientific problems in the context of heat and electricity supply using renewable energy systems by:<br>• using module-comprehensive knowledge for different applications,<br>• evaluating alternative input parameter regarding the solution of the task in the case of incomplete information (technical, economical and ecological parameter),<br>• a systematic documentation of the work results in form of a written version, the presentation itself and the defense of contents. |
| **Personal Competence** | |
| *Social Competence* | Students can<br>• respectfully work together as a team with around 2-3 members,<br>• participate in subject-specific and interdisciplinary discussions in the area of dimensioning and analysis of potentials of heat and electricty supply using renewable energie, and can develop cooperated solutions,<br>• defend their own work results in front of fellow students and<br>• assess the performance of fellow students in comparison to their own performance. Furthermore, they can accept professional constructive criticism. |
| *Autonomy* | Students can independently tap knowledge regarding to the given task. They are capable, in consultation with supervisors, to assess their learning level and define further steps on this basis. Furthermore, they can define targets for new application-or research-oriented duties in accordance with the potential social, economic and cultural impact. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written elaboration |
| **Examination duration and scale** | per course: 20 minutes presentation + written report |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Renewable Energies: Core qualification: Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory |

| Course L0137: Environmental Technology and Energy Economics | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Martin Kaltschmitt |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | • Preliminary discussion with the rules of the lecture<br>• Issue of topics from the field of renewable energy technology in the form of a tender of engineering services to a group of students (depending on the number of participating students)<br>• "Procurement" deal with aspects of the design, costing and environmental, economic and technical evaluation of various energy generation concepts (eg onshore wind power generation, commercial-scale photovoltaic power generation, biogas production, geothermal power and heat generation) under very special circumstances<br>• Submission of a written solution of the task and distribution to the participants by the student / group of students<br>• Presentation of the edited theme (20 min) with PPT presentation and subsequent discussion (20 minutes)<br>• Attendance is mandatory for all seminars |
| **Literature** | Eigenständiges Literaturstudium in der Bibliothek und aus anderen Quellen. |

| Course L0046: Electricity Generation from Renewable Sources of Energy | |
|---|---|
| **Typ** | Seminar |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Martin Kaltschmitt |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | • Preliminary discussion with the seminar rules<br>• Distribution of the topics related to the subject of the seminar to individual students / groups of students (depending on the number of participating students)<br>• Delivery of a five-page summary of the seminar topic and distribution to the participants by the student / group of students<br>• Presentation of the processed topic (30 min) with PPT presentation and subsequent discussion (20 minutes)<br>• Attendance is mandatory for all seminars |
| **Literature** | • Eigenständiges Literaturstudium in der Bibliothek und aus anderen Quellen. |

| Course L0045: Heat Provision from Renewable Sources of Energy | |
|---|---|
| **Typ** | Seminar |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Martin Kaltschmitt |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | • Preliminary discussion with the seminar rules<br>• Distribution of the topics related to the subject of the seminar to individual students / groups of students (depending on the number of participating students)<br>• Delivery of a five-page summary of the seminar topic and distribution to the participants by the student / group of students<br>• Presentation of the processed topic (30 min) with PPT presentation and subsequent discussion (20 minutes)<br>• Attendance is mandatory for all seminars |
| **Literature** | Eigenständiges Literaturstudium in der Bibliothek und aus anderen Quellen. |

## Module M0822: Process Modeling in Water Technology

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Process Modelling of Wastewater Treatment (L0522) | Project-/problem-based Learning | 2 | 3 |
| Process Modeling in Drinking Water Treatment (L0314) | Project-/problem-based Learning | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Dr. Klaus Johannsen |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Knowledge of the most important processes in drinking water and waste water treatment. |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to explain selected processes of drinking water and waste water treatment in detail. They are able to explain basics as well as possibilities and limitations of dynamic modeling. |
| *Skills* | Students are able to use the most important features Modelica offers. They are able to transpose selected processes in drinking water and waste water treatment into a mathematical model in Modelica with respect to equilibrium, kinetics and mass balances. They are able to set up and apply models and assess their possibilities and limitations. |
| **Personal Competence** | |
| *Social Competence* | Students are able to solve problems and document solutions in a group with members of different technical background. They are able to give appropriate feedback and can work constructively with feedback concerning their work. |
| *Autonomy* | Students are able to define a problem, gain the required knowledge and set up a model. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 1,5 hours |
| **Assignment for the Following Curricula** | Civil Engineering: Specialisation Water and Traffic: Elective Compulsory<br>Environmental Engineering: Specialisation Water: Elective Compulsory<br>Joint European Master in Environmental Studies - Cities and Sustainability: Specialisation Water: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Water: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Elective Compulsory |

| Course L0522: Process Modelling of Wastewater Treatment | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Joachim Behrendt |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | Mass and energy balances<br><br>Tracer modelling<br><br>Activated Sludge Model<br><br>Wastewater Treatment Plant Modelling (continously and SBR)<br><br>Sludge Treatment (ADM, aerobic autothermal)<br><br>Biofilm Modelling |
| **Literature** | **Henze, Mogens** (Seminar on Activated Sludge Modelling, ; Kollekolle Seminar on Activated Sludge Modelling, ;)<br>Activated sludge modelling : processes in theory and practice ; selected proceedings of the 5th Kollekolle Seminar on Activated Sludge Modelling, held in Kollekolle, Denmark, 10 - 12 September 2001<br>ISBN: 1843394146<br>[London] : IWA Publ., 2002<br>TUB_HH_Katalog<br>**Henze, Mogens**<br>Activated sludge models ASM1, ASM2, ASM2d and ASM3<br>ISBN: 1900222248<br>London : IWA Publ., 2002<br>TUB_HH_Katalog<br>**Henze, Mogens**<br>Wastewater treatment : biological and chemical processes<br>ISBN: 3540422285 (Pp.)<br>Berlin [u.a.] : Springer, 2002<br>TUB_HH_Katalog<br>**Wiesmann, Udo** (Choi, In Su; Dombrowski, Eva-Maria;)<br>Fundamentals of biological wastewater treatment<br>ISBN: 3527312196 (Gb.) URL: http://deposit.ddb.de/cgi-bin/dokserv?id=2774611&prov=M&dok_var=1&dok_ext=htm<br>Weinheim : WILEY-VCH, 2007<br>TUB_HH_Katalog |

| Course L0314: Process Modeling in Drinking Water Treatment | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Klaus Johannsen |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | In this course selected drinking water treatment processes (e.g. aeration or activated carbon adsorption) are modeled dynamically using the programming language Modelica, that is increasingly used in industry. In this course OpenModelica is used, an free access frontend of the programming language Modelica.<br><br>In the beginning of the course the use of OpenModelica is explainded by means of simple examples. Together required elements and structure of the model are developed. The implementation in OpenModelica and the application of the model is done individually or in groups respectively. Students get feedback and can gain extra points for the exam. |
| **Literature** | **OpenModelica:** https://openmodelica.org/index.php/download/download-windows<br><br>**OpenModelica - Modelica Tutorial:** https://openmodelica.org/index.php/useresresources/userdocumentation<br><br>**OpenModelica - Users Guide:** https://openmodelica.org/index.php/useresresources/userdocumentation<br><br>**Peter Fritzson:** Principles of Object-Oriented Modeling and Simulation with Modelica 2.1,Wiley-IEEE Press, ISBN 0-471-471631.<br><br>**MHW (rev. by Crittenden, J. et al.):** Water treatment principles and design. John Wiley & Sons, Hoboken, 2005.<br><br>**Stumm, W., Morgan, J.J.**: Aquatic chemistry. John Wiley & Sons, New York, 1996.<br><br>**DVGW (Hrsg.):** Wasseraufbereitung - Grundlagen und Verfahren. Oldenbourg Industrie Verlag, München, 2004. |

## Module M0802: Membrane Technology

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Membrane Technology (L0399) | Lecture | 2 | 3 |
| Membrane Technology (L0400) | Recitation Section (small) | 1 | 2 |
| Membrane Technology (L0401) | Practical Course | 1 | 1 |

| | |
|---|---|
| **Module Responsible** | Prof. Mathias Ernst |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basic knowledge of water chemistry. Knowledge of the core processes involved in water, gas and steam treatment |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students will be able to rank the technical applications of industrially important membrane processes. They will be able to explain the different driving forces behind existing membrane separation processes. Students will be able to name materials used in membrane filtration and their advantages and disadvantages. Students will be able to explain the key differences in the use of membranes in water, other liquid media, gases and in liquid/gas mixtures. |
| *Skills* | Students will be able to prepare mathematical equations for material transport in porous and solution-diffusion membranes and calculate key parameters in the membrane separation process. They will be able to handle technical membrane processes using available boundary data and provide recommendations for the sequence of different treatment processes. Through their own experiments, students will be able to classify the separation efficiency, filtration characteristics and application of different membrane materials. Students will be able to characterise the formation of the fouling layer in different waters and apply technical measures to control this. |
| **Personal Competence** | |
| *Social Competence* | Students will be able to work in diverse teams on tasks in the field of membrane technology. They will be able to make decisions within their group on laboratory experiments to be undertaken jointly and present these to others. |
| *Autonomy* | Students will be in a position to solve homework on the topic of membrane technology independently. They will be capable of finding creative solutions to technical questions. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 min |
| **Assignment for the Following Curricula** | Civil Engineering: Specialisation Water and Traffic: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory<br>Environmental Engineering: Specialisation Water: Elective Compulsory<br>Joint European Master in Environmental Studies - Cities and Sustainability: Specialisation Water: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Water: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Environment: Elective Compulsory<br>Water and Environmental Engineering: Specialisation Cities: Elective Compulsory |

| Course L0399: Membrane Technology | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Mathias Ernst |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | The lecture on membrane technology supply provides students with a broad understanding of existing membrane treatment processes, encompassing pressure driven membrane processes, membrane application in electrodialyis, pervaporation as well as membrane distillation. The lectures main focus is the industrial production of drinking water like particle separation or desalination; however gas separation processes as well as specific wastewater oriented applications such as membrane bioreactor systems will be discussed as well.<br><br>Initially, basics in low pressure and high pressure membrane applications are presented (microfiltration, ultrafiltration, nanofiltration, reverse osmosis). Students learn about essential water quality parameter, transport equations and key parameter for pore membrane as well as solution diffusion membrane systems. The lecture sets a specific focus on fouling and scaling issues and provides knowledge on methods how to tackle with these phenomena in real water treatment application. A further part of the lecture deals with the character and manufacturing of different membrane materials and the characterization of membrane material by simple methods and advanced analysis.<br><br>The functions, advantages and drawbacks of different membrane housings and modules are explained. Students learn how an industrial membrane application is designed in the succession of treatment steps like pre-treatment, water conditioning, membrane integration and post-treatment of water. Besides theory, the students will be provided with knowledge on membrane demo-site examples and insights in industrial practice. |
| **Literature** | • T. Melin, R. Rautenbach: Membranverfahren: Grundlagen der Modul- und Anlagenauslegung (2., erweiterte Auflage), Springer-Verlag, Berlin 2004.<br>• Marcel Mulder, Basic Principles of Membrane Technology, Kluwer Academic Publishers, Dordrecht, The Netherlands<br>• Richard W. Baker, Membrane Technology and Applications, Second Edition, John Wiley & Sons, Ltd., 2004 |

| Course L0400: Membrane Technology | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Mathias Ernst |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L0401: Membrane Technology | |
|---|---|
| **Typ** | Practical Course |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Mathias Ernst |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0975: Industrial Bioprocesses in Practice

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Industrial biotechnology in Chemical Industriy (L2276) | Seminar | 2 | 3 |
| Practice in bioprocess engineering (L2275) | Seminar | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Andreas Liese |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Knowledge of bioprocess engineering and process engineering at bachelor level |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | After successful completion of the module<br>• the students can outline the current status of research on the specific topics discussed<br>• the students can explain the basic underlying principles of the respective industrial biotransformations |
| *Skills* | After successful completion of the module students are able to<br>• analyze and evaluate current research approaches<br>• plan industrial biotransformations basically |
| **Personal Competence** | |
| *Social Competence* | Students are able to work together as a team with several students to solve given tasks and discuss their results in the plenary and to defend them. |
| *Autonomy* | The students are able independently to present the results of their subtasks in a presentation |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Presentation |
| **Examination duration and scale** | each seminar 15 min lecture and 15 min discussion |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory<br>Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory<br>Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Management and Controlling: Elective Compulsory<br>Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Management and Controlling: Elective Compulsory<br>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory |

| Course L2276: Industrial biotechnology in Chemical Industriy | |
|---|---|
| **Typ** | Seminar |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Stephan Freyer |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | This course gives an insight into the applications, processes, structures and boundary conditions in industrial practice. Various concrete applications of the technology, markets and other questions that will significantly influence the plant and process design will be shown. |
| **Literature** | Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen]<br><br>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.<br><br>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract<br><br>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003<br><br>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage<br><br>Krahe M (2003) Biochemical Engineering. Ullmann´s Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html<br><br>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts |

| Course L2275: Practice in bioprocess engineering | |
|---|---|
| **Typ** | Seminar |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dr. Willfried Blümke |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | Content of this course is a concrete insight into the principles, processes and structures of an industrial biotechnology company. In addition to practical illustrative examples, aspects beyond the actual process engineering area are also addressed, such as e.g. Sustainability and engineering. |
| **Literature** | Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen]<br><br>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.<br><br>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract<br><br>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003<br><br>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage<br><br>Krahe M (2003) Biochemical Engineering. Ullmann´s Encyclopedia of Industrial Chemistry. http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html<br><br>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts |

# Thesis

## Module M-002: Master Thesis

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|

| | |
|---|---|
| **Module Responsible** | Professoren der TUHH |
| **Admission Requirements** | • According to General Regulations §21 (1):<br><br>At least 60 credit points have to be achieved in study programme. The examinations board decides on exceptions. |
| **Recommended Previous Knowledge** | |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | • The students can use specialized knowledge (facts, theories, and methods) of their subject competently on specialized issues.<br>• The students can explain in depth the relevant approaches and terminologies in one or more areas of their subject, describing current developments and taking up a critical position on them.<br>• The students can place a research task in their subject area in its context and describe and critically assess the state of research. |
| *Skills* | The students are able:<br><br>• To select, apply and, if necessary, develop further methods that are suitable for solving the specialized problem in question.<br>• To apply knowledge they have acquired and methods they have learnt in the course of their studies to complex and/or incompletely defined problems in a solution-oriented way.<br>• To develop new scientific findings in their subject area and subject them to a critical assessment. |
| **Personal Competence** | |
| *Social Competence* | Students can<br><br>• Both in writing and orally outline a scientific issue for an expert audience accurately, understandably and in a structured way.<br>• Deal with issues competently in an expert discussion and answer them in a manner that is appropriate to the addressees while upholding their own assessments and viewpoints convincingly. |
| *Autonomy* | Students are able:<br><br>• To structure a project of their own in work packages and to work them off accordingly.<br>• To work their way in depth into a largely unknown subject and to access the information required for them to do so.<br>• To apply the techniques of scientific work comprehensively in research of their own. |
| **Workload in Hours** | Independent Study Time 900, Study Time in Lecture 0 |
| **Credit points** | 30 |
| **Course achievement** | None |
| **Examination** | Thesis |
| **Examination duration and scale** | According to General Regulations |
| **Assignment for the Following Curricula** | Civil Engineering: Thesis: Compulsory<br>Bioprocess Engineering: Thesis: Compulsory<br>Chemical and Bioprocess Engineering: Thesis: Compulsory<br>Computer Science: Thesis: Compulsory<br>Electrical Engineering: Thesis: Compulsory<br>Energy and Environmental Engineering: Thesis: Compulsory<br>Energy Systems: Thesis: Compulsory<br>Environmental Engineering: Thesis: Compulsory<br>Aircraft Systems Engineering: Thesis: Compulsory<br>Global Innovation Management: Thesis: Compulsory<br>Computational Science and Engineering: Thesis: Compulsory<br>Information and Communication Systems: Thesis: Compulsory<br>International Management and Engineering: Thesis: Compulsory<br>Joint European Master in Environmental Studies - Cities and Sustainability: Thesis: Compulsory<br>Logistics, Infrastructure and Mobility: Thesis: Compulsory<br>Materials Science: Thesis: Compulsory<br>Mathematical Modelling in Engineering: Theory, Numerics, Applications: Thesis: Compulsory<br>Mechanical Engineering and Management: Thesis: Compulsory<br>Mechatronics: Thesis: Compulsory |

| | |
|---|---|
| | Biomedical Engineering: Thesis: Compulsory<br>Microelectronics and Microsystems: Thesis: Compulsory<br>Product Development, Materials and Production: Thesis: Compulsory<br>Renewable Energies: Thesis: Compulsory<br>Naval Architecture and Ocean Engineering: Thesis: Compulsory<br>Ship and Offshore Technology: Thesis: Compulsory<br>Teilstudiengang Lehramt Metalltechnik: Thesis: Compulsory<br>Theoretical Mechanical Engineering: Thesis: Compulsory<br>Process Engineering: Thesis: Compulsory<br>Water and Environmental Engineering: Thesis: Compulsory<br>Certification in Engineering & Advisory in Aviation: Thesis: Compulsory |