

# **Module Manual**

Master of Science (M.Sc.)

## **Chemical and Bioprocess Engineering**

Cohort: Winter Term 2021

Updated: 31st May 2021

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## Program description

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### Content

Chemical process engineering and bioprocess engineering are concerned with the development and execution of processes, in which materials are changed in nature, properties and composition. The variety of such processes is enormous. They range from the production of fuels, fertilisers, inorganic and organic chemicals to materials, pharmaceuticals and food. In addition to scientific, technical and economic aspects, legal issues, environmental protection and sustainability also play an important role in the development and execution of processes.

Chemical process engineering and bioprocess engineering are engineering disciplines that build on physical, chemical and mathematical foundations. Additionally, bioprocess engineering concerns the use of biological systems such as enzymes, cells and entire organisms in technical applications.

The International Master's Program "Chemical and Bioprocess Engineering" at TUHH prepares graduates for challenging engineering jobs in process engineering and biotechnology, as well as for independent work in research. The main course topics of the Master's program are a logical continuation of the core subjects of corresponding Bachelor's programs (e.g. process engineering, bioprocess engineering, energy and environmental engineering). In this regard, it makes no difference whether the student completed his/her Bachelor's at TUHH or at another internationally recognized university in Germany or abroad. The Master's program is characterized by its scientific orientation, clear focus in terms of content and its communication of effective, structured, interdisciplinary working methods. The course content is closely related to the research conducted at the Chemical Engineering School, uniting teaching with research. This guarantees up-to-date lecture content and the possibility of working in research at TUHH (e.g. in relation to a dissertation, seminar contributions and project work).

### Career prospects

The aim of the Chemical and Bioprocess Engineering Master's program is to provide graduates of Bachelor's engineering programs with a focus on process engineering or industrial biotechnology with the knowledge and skills that prepare them for further study (PhD) or a career in different areas of the chemical industry and/or biotechnology and plant engineering. The future careers of graduates from the programme can range from research and development to planning, process design and operation in process or bioprocess plants.

Graduates of the Master's program Chemical and Bioprocess Engineering can confidently apply for senior engineering roles. A diverse range of careers are open to graduates of the programme.

In industry:

- Development and improvement of chemical, biotechnical or environmental processes
- Project management, plant engineering and plant operation

Development of principles for and development of new equipment and processes

- Management in production facilities
- Health and safety and safety engineering
- Documentation and patent processing
- Marketing and sales

In the public sector:

- Research and teaching at universities or scientific institutes
- Technical administration and monitoring
- Working for federal and regional authorities, e.g. patent offices, trade supervisory offices, material testing authorities, German Environment Agency

Further prospects:

- Engineering firms
- Intellectual property law firms
- Expert, industry consultant
- Business start-ups

### Learning target

The International Master's Program Chemical and Bioprocess Engineering provides graduates with the theoretical knowledge and practical skills to be successful as a process engineer in industry and research. With course content covering traditional process engineering, bioprocess engineering and in-depth theoretical foundations (e.g. numerical methods, applied statistics, applied thermodynamics), graduates receive a rounded education in both chemical and bioprocess engineering, leaving them with excellent career prospects. They are able to work independently and to apply the necessary methods and processes for resolving technical issues; apply new knowledge; scrutinize methods and processes critically and further develop them.

#### Knowledge:

- Students can demonstrate complex mathematical and scientific knowledge and support this with a broad theoretical and methodical foundation.
- Students can explain principles, methods and areas of application of specialisations in process and bioprocess engineering, as well as chemical engineering in detail.
- Students can state the fundamentals of operations and management, as well as related domains such as the patent system, and relate them to their discipline.
- Students can outline elements of scientific work and research and can give an overview of their application in process and bioprocess engineering, as well as chemical engineering.

#### Skills:

- Students master the theory-led application of highly demanding theoretical and experimental methods and processes in their specialisation. They can divide more complex problems even if these are unclearly defined, apply solution processes for the partial problems and establish an overall solution.
- Students can propose, evaluate and discuss practical solutions to process engineering issues, and evaluate them responsibly taking into account non-technical conditions (e.g. social, environmental and economic).
- Students can process data and information pragmatically, evaluate it critically and draw conclusions. They can also recognize the interdisciplinary connections of a technical process problem, analyse them and assess their importance or bring their specialist area into an interdisciplinary

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context.

- Students can investigate and evaluate future technologies and scientific developments and are capable of independent research following the rules of good scientific practice (capacity to complete a PhD).

### **Social skills:**

- Students are able to outline processes and the results of their work in comprehensible written and spoken German and English.
- Students can talk about advanced content and process engineering and bioprocess engineering problems with specialists and lay people in German and English. They can respond appropriately to queries, amendments and comments.
- Students are able to work in groups. They can determine and distribute subsidiary tasks and integrate them. They can meet deadlines and interact socially. They are able and prepared to take leadership roles.

### **Autonomy:**

- Students are able to procure necessary information and set this information in the context of their own knowledge.
- Students can evaluate their existing level of competence realistically, compensate for deficits independently and undertake reasonable extensions.
- Students can develop research areas independently and find or define new problems (life-long learning and research).

## **Program structure**

The Master's program Chemical and Bioprocess Engineering is divided as follows:

- Core qualification: 12 compulsory courses, 72 LPs, 1st - 3rd semester. This encompasses:
- Specialization: 3 modules amounting to 18 CPs, 2nd and 3rd semester.
- Dissertation: 30 CPs, 4th semester.

This results in a total of 120 CPs.

It is obligatory to choose a specialization. The following specializations are offered:

- General process engineering
- Bioprocess engineering
- Chemical process engineering

Students choose three modules within their specialization amounting to a total of 18 CPs. Students can use the third semester to spend time abroad or on an industry placement as this semester is allocated for the completion of elective courses only.

**Core qualification**

**Module M0523: Business & Management**

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

**Courses**

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

Module M0524: Non-technical Courses for Master	
<b>Module Responsible</b>	Dagmar Richter
<b>Admission Requirements</b>	None
<b>Recommended Previous Knowledge</b>	None
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results
<b>Professional Competence</b> <i>Knowledge</i>	<p><b>The Nontechnical Academic Programms (NTA)</b></p> <p>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 <b>teaching architecture</b>, in its <b>teaching and learning arrangements</b>, in <b>teaching areas</b> and by means of teaching offerings in which students can qualify by opting for <b>specific competences</b> and a <b>competence level</b> at the Bachelor's or Master's level. The teaching offerings are pooled in two different catalogues for nontechnical complementary courses.</p> <p><b>The Learning Architecture</b></p> <p>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.</p> <p>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".</p> <p>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.</p> <p><b>Teaching and Learning Arrangements</b></p> <p>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.</p> <p><b>Fields of Teaching</b></p> <p>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.</p> <p>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.</p> <p><b>The Competence Level</b></p> <p>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.</p> <p>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.</p> <p><b>Specialized Competence (Knowledge)</b></p> <p>Students can</p> <ul style="list-style-type: none"> <li>• explain specialized areas in context of the relevant non-technical disciplines,</li> <li>• outline basic theories, categories, terminology, models, concepts or artistic techniques in the disciplines represented in the learning area,</li> <li>• different specialist disciplines relate to their own discipline and differentiate it as well as make connections,</li> <li>• 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,</li> <li>• Can communicate in a foreign language in a manner appropriate to the subject.</li> </ul>
<b>Professional Competence</b> <i>Skills</i>	<p><b>Professional Competence (Skills)</b></p> <p>In selected sub-areas students can</p> <ul style="list-style-type: none"> <li>• apply basic and specific methods of the said scientific disciplines,</li> <li>• question a specific technical phenomena, models, theories from the viewpoint of another, aforementioned specialist discipline,</li> <li>• to handle simple and advanced questions in aforementioned scientific disciplines in a successful manner,</li> <li>• justify their decisions on forms of organization and application in practical questions in contexts that go beyond the technical relationship to the subject.</li> </ul>

<p><b>Personal Competence</b> <i>Social Competence</i></p>	<p><b>Personal Competences (Social Skills)</b></p> <p>Students will be able</p> <ul style="list-style-type: none"> <li>• to learn to collaborate in different manner,</li> <li>• to present and analyze problems in the abovementioned fields in a partner or group situation in a manner appropriate to the addressees,</li> <li>• 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),</li> <li>• to explain nontechnical items to auditorium with technical background knowledge.</li> </ul>
<p><i>Autonomy</i></p>	<p><b>Personal Competences (Self-reliance)</b></p> <p>Students are able in selected areas</p> <ul style="list-style-type: none"> <li>• to reflect on their own profession and professionalism in the context of real-life fields of application</li> <li>• to organize themselves and their own learning processes</li> <li>• to reflect and decide questions in front of a broad education background</li> <li>• to communicate a nontechnical item in a competent way in written form or verbally</li> <li>• to organize themselves as an entrepreneurial subject country (as far as this study-focus would be chosen)</li> </ul>
<p><b>Workload in Hours</b></p>	<p>Depends on choice of courses</p>
<p><b>Credit points</b></p>	<p>6</p>

**Courses**

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

Module M0537: Applied Thermodynamics: Thermodynamic Properties for Industrial Applications				
<b>Courses</b>				
<b>Title</b>		<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
Applied Thermodynamics: Thermodynamic Properties for Industrial Applications (L0100)		Lecture	4	3
Applied Thermodynamics: Thermodynamic Properties for Industrial Applications (L0230)		Recitation Section (small)	2	3
<b>Module Responsible</b>	Dr. Sven Jakobtorweihen			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	Thermodynamics III			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>				
<i>Knowledge</i>	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.			
<i>Skills</i>	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.			
<b>Personal Competence</b>				
<i>Social Competence</i>	Students are capable to develop and discuss solutions in small groups; further they can translate these solutions into calculation algorithms.			
<i>Autonomy</i>	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.			
<b>Workload in Hours</b>	Independent Study Time 96, Study Time in Lecture 84			
<b>Credit points</b>	6			
<b>Course achievement</b>	<b>Compulsory</b>	<b>Bonus</b>	<b>Form</b>	<b>Description</b>
	Yes	None	Written elaboration	
<b>Examination</b>	Oral exam			
<b>Examination duration and scale</b>	1 Stunde Gruppenprüfung			
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core qualification: Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory			

Course L0100: Applied Thermodynamics: Thermodynamic Properties for Industrial Applications	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	4
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 34, Study Time in Lecture 56
<b>Lecturer</b>	Dr. Sven Jakobtorweihen, Prof. Ralf Dohrn
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Phase equilibria in multicomponent systems</li> <li>• Partitioning in biorelevant systems</li> <li>• Calculation of phase equilibria in colloidal systems: UNIFAC, COSMO-RS (exercises in computer pool)</li> <li>• Calculation of partitioning coefficients in biological membranes: COSMO-RS (exercises in computer pool)</li> <li>• Application of equations of state (vapour pressure, phase equilibria, etc.) (exercises in computer pool)</li> <li>• Intermolecular forces, interaction Potentials</li> <li>• Introduction in statistical thermodynamics</li> </ul>
<b>Literature</b>	



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

Module M0545: Separation Technologies for Life Sciences				
<b>Courses</b>				
<b>Title</b>		<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
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
<b>Module Responsible</b>	Dr. Pavel Gurikov			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	<p>Fundamentals of Chemistry, Fluid Process Engineering, Thermal Separation Processes, Chemical Engineering, Chemical Engineering, Bioprocess Engineering</p> <p>Basic knowledge in thermodynamics and in unit operations related to thermal separation processes</p>			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>				
<i>Knowledge</i>	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.			
<i>Skills</i>	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.			
<b>Personal Competence</b>				
<i>Social Competence</i>	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.			
<i>Autonomy</i>	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).			
<b>Workload in Hours</b>	Independent Study Time 96, Study Time in Lecture 84			
<b>Credit points</b>	6			
<b>Course achievement</b>	<b>Compulsory</b>	<b>Bonus</b>	<b>Form</b>	<b>Description</b>
	Yes	None	Presentation	
<b>Examination</b>	Written exam			
<b>Examination duration and scale</b>	120 minutes; theoretical questions and calculations			
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Core qualification: Compulsory Chemical and Bioprocess Engineering: Core qualification: Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory			

Course L0093: Chromatographic Separation Processes	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Monika Johannsen
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Introduction: overview, history of chromatography, LC (HPLC), GC, SFC</li> <li>• Fundamentals of linear (analytical) chromatography, retention time/factor, separation factor, peak resolution, band broadening, Van-Deemter equation</li> <li>• Fundamentals of nonlinear chromatography, discontinuous and continuous preparative chromatography (annular, true moving bed - TMB, simulated moving bed - SMB)</li> <li>• Adsorption equilibrium: experimental determination of adsorption isotherms and modeling</li> <li>• Equipment for chromatography, production and characterization of chromatographic adsorbents</li> <li>• Method development, scale up methods, process design, modeling of chromatographic processes, economic aspects</li> <li>• Applications: e.g. normal phase chromatography, reversed phase chromatography, hydrophobic interaction chromatography, chiral chromatography, bioaffinity chromatography, ion exchange chromatography</li> </ul>
<b>Literature</b>	<ul style="list-style-type: none"> <li>• Schmidt-Traub, H.: Preparative Chromatography of Fine Chemicals and Pharmaceutical Agents. Weinheim: Wiley-VCH (2005) - eBook</li> <li>• Carta, G.: Protein chromatography: process development and scale-up. Weinheim: Wiley-VCH (2010)</li> <li>• Guiochon, G.; Lin, B.: Modeling for Preparative Chromatography. Amsterdam: Elsevier (2003)</li> <li>• Hagel, L.: Handbook of process chromatography: development, manufacturing, validation and economics. London ;Burlington, MA Academic (2008) - eBook</li> </ul>

Course L0112: Unit Operations for Bio-Related Systems	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Pavel Gurikov
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<p>Contents:</p> <ul style="list-style-type: none"> <li>• Introduction: overview about the separation process in biotechnology and pharmacy</li> <li>• Handling of multicomponent systems</li> <li>• Adsorption of biologic molecules</li> <li>• Crystallization of biologic molecules</li> <li>• Reactive extraction</li> <li>• Aqueous two-phase systems</li> <li>• Micellar systems: micellar extraction and micellar chromatographie</li> <li>• Electrophoresis</li> <li>• Choice of the separation process for the specific systems</li> </ul> <p>Learning Outcomes:</p> <ul style="list-style-type: none"> <li>• Basic knowledge of separation processes for biotechnological and pharmaceutical processes</li> <li>• Identification of specific features and limitations in bio-related systems</li> <li>• Proof of economical value of the process</li> </ul>
<b>Literature</b>	<p>"Handbook of Bioseparations", Ed. S. Ahuja  <a href="http://www.elsevier.com/books/handbook-of-bioseparations-2/ahuja/978-0-12-045540-9">http://www.elsevier.com/books/handbook-of-bioseparations-2/ahuja/978-0-12-045540-9</a></p> <p>"Bioseparations Engineering" M. R. Ladish  <a href="http://eu.wiley.com/WileyCDA/WileyTitle/productCd-0471244767.html">http://eu.wiley.com/WileyCDA/WileyTitle/productCd-0471244767.html</a></p>

<b>Course L0113: Unit Operations for Bio-Related Systems</b>	
<b>Typ</b>	Project-/problem-based Learning
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Pavel Gurikov
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	See interlocking course
<b>Literature</b>	See interlocking course

Module M0973: Biocatalysis			
<b>Courses</b>			
<b>Title</b>		<b>Typ</b>	<b>Hrs/wk</b> <b>CP</b>
Biocatalysis and Enzyme Technology (L1158)		Lecture	2                  3
Technical Biocatalysis (L1157)		Lecture	2                  3
<b>Module Responsible</b>	Prof. Andreas Liese		
<b>Admission Requirements</b>	None		
<b>Recommended Previous Knowledge</b>	Knowledge of bioprocess engineering and process engineering at bachelor level		
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results		
<b>Professional Competence</b>			
<i>Knowledge</i>	After successful completion of this course, students will be able to <ul style="list-style-type: none"> <li>• reflect a broad knowledge about enzymes and their applications in academia and industry</li> <li>• have an overview of relevant biotransformations und name the general definitions</li> </ul>		
<i>Skills</i>	After successful completion of this course, students will be able to <ul style="list-style-type: none"> <li>• understand the fundamentals of biocatalysis and enzyme processes and transfer this to new tasks</li> <li>• know the several enzyme reactors and the important parameters of enzyme processes</li> <li>• use their gained knowledge about the realisation of processes. Transfer this to new tasks</li> <li>• analyse and discuss special tasks of processes in plenum and give solutions</li> <li>• communicate and discuss in English</li> </ul>		
<b>Personal Competence</b>			
<i>Social Competence</i>	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.		
<i>Autonomy</i>	After completion of this module, participants will be able to solve a technical problem independently including a presentation of the results.		
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56		
<b>Credit points</b>	6		
<b>Course achievement</b>	None		
<b>Examination</b>	Written exam		
<b>Examination duration and scale</b>	90 min		
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Core qualification: Compulsory Chemical and Bioprocess Engineering: Core qualification: Compulsory Environmental Engineering: Specialisation Biotechnology: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory		

Course L1158: Biocatalysis and Enzyme Technology	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Andreas Liese
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	1. Introduction: Impact and potential of enzyme-catalysed processes in biotechnology. 2. History of microbial and enzymatic biotransformations. 3. Chirality - definition & measurement 4. Basic biochemical reactions, structure and function of enzymes. 5. Biocatalytic retrosynthesis of asymmetric molecules 6. Enzyme kinetics: mechanisms, calculations, multisubstrate reactions. 7. Reactors for biotransformations.
<b>Literature</b>	<ul style="list-style-type: none"> <li>• K. Faber: Biotransformations in Organic Chemistry, Springer, 5th Ed., 2004</li> <li>• A. Liese, K. Seelbach, C. Wandrey: Industrial Biotransformations, Wiley-VCH, 2006</li> <li>• R. B. Silverman: The Organic Chemistry of Enzyme-Catalysed Reactions, Academic Press, 2000</li> <li>• K. Buchholz, V. Kasche, U. Bornscheuer: Biocatalysts and Enzyme Technology. VCH, 2005.</li> <li>• R. D. Schmidt: Pocket Guide to Biotechnology and Genetic Engineering, Wiley-VCH, 2003</li> </ul>

<b>Course L1157: Technical Biocatalysis</b>	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Andreas Liese
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ol style="list-style-type: none"> <li>1. Introduction</li> <li>2. Production and Down Stream Processing of Biocatalysts</li> <li>3. Analytics (offline/online)</li> <li>4. Reaction Engineering &amp; Process Control <ul style="list-style-type: none"> <li>• Definitions</li> <li>• Reactors</li> <li>• Membrane Processes</li> <li>• Immobilization</li> </ul> </li> <li>5. Process Optimization <ul style="list-style-type: none"> <li>• Simplex / DOE / GA</li> </ul> </li> <li>6. Examples of Industrial Processes <ul style="list-style-type: none"> <li>• food / feed</li> <li>• fine chemicals</li> </ul> </li> <li>7. Non-Aqueous Solvents as Reaction Media <ul style="list-style-type: none"> <li>• ionic liquids</li> <li>• scCO<sub>2</sub></li> <li>• solvent free</li> </ul> </li> </ol>
<b>Literature</b>	<ul style="list-style-type: none"> <li>• A. Liese, K. Seelbach, C. Wandrey: Industrial Biotransformations, Wiley-VCH, 2006</li> <li>• H. Chmiel: Bioprozeßtechnik, Elsevier, 2005</li> <li>• K. Buchholz, V. Kasche, U. Bornscheuer: Biocatalysts and Enzyme Technology, VCH, 2005</li> <li>• R. D. Schmidt: Pocket Guide to Biotechnology and Genetic Engineering, Woley-VCH, 2003</li> </ul>

Module M1038: Particle Technology for International Master Programs				
<b>Courses</b>				
<b>Title</b>		<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
Exercise Particle Technology for International Master Program (L1928)		Recitation Section (large)	1	1
Particle Technology for IMP (L1289)		Lecture	2	3
Practicle Course Particle Technology for IMP (L1290)		Practical Course	3	2
<b>Module Responsible</b>	Prof. Stefan Heinrich			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	none			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>				
<i>Knowledge</i>	Students are able - to list and to describe processes and unit-operations of solids process engineering, - to describe the characterization of particles and explain particle distributions and their bulk properties.			
<i>Skills</i>	students are able to  <ul style="list-style-type: none"> <li>• choose and design apparatuses and processes for solids processing according to the desired solids properties of the product</li> <li>• assess solids with respect to their behavior in solids processing steps</li> </ul>			
<b>Personal Competence</b>				
<i>Social Competence</i>	students are able to analyze and orally discuss problems in a scientific way.			
<i>Autonomy</i>	students are able to analyze and solve problems regarding solid particles independently			
<b>Workload in Hours</b>	Independent Study Time 96, Study Time in Lecture 84			
<b>Credit points</b>	6			
<b>Course achievement</b>	<b>Compulsory</b>	<b>Bonus</b>	<b>Form</b>	<b>Description</b>
	Yes	None	Written elaboration	sechs Berichte (pro Versuch ein Bericht) à 5-10 Seiten
<b>Examination</b>	Written exam			
<b>Examination duration and scale</b>	90 minutes			
<b>Assignment for the Following Curricula</b>	Chemical and Bioprocess Engineering: Core qualification: Compulsory			
Course L1928: Exercise Particle Technology for International Master Program				
<b>Typ</b>	Recitation Section (large)			
<b>Hrs/wk</b>	1			
<b>CP</b>	1			
<b>Workload in Hours</b>	Independent Study Time 16, Study Time in Lecture 14			
<b>Lecturer</b>	Prof. Stefan Heinrich			
<b>Language</b>	EN			
<b>Cycle</b>	WiSe			
<b>Content</b>				
<b>Literature</b>				

Course L1289: Particle Technology for IMP	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Stefan Heinrich
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Description of particles and particle distributions</li> <li>• Description of a separation process</li> <li>• Description of a particle mixture</li> <li>• Particle size reduction</li> <li>• Agglomeration, particle size enlargement</li> <li>• Storage and flow of bulk solids</li> <li>• Basics of fluid/particle flows</li> <li>• classifying processes</li> <li>• Separation of particles from fluids</li> <li>• Basic fluid mechanics of fluidized beds</li> <li>• Pneumatic and hydraulic transport</li> </ul>
<b>Literature</b>	<ul style="list-style-type: none"> <li>• M. Rhodes: Introduction to Particle Technology, John Wiley &amp; Sons, 1998</li> <li>• M.E. Fayed &amp; L. Otten: Handbook of Powder Science &amp; Technology, 2nd Ed., Chapman &amp; Hall, 1997</li> <li>• M. Stieß: Mechanische Verfahrenstechnik 1, 2.Auflage, Springer-Verlag, 1995 (German)</li> <li>• M. Stieß: Mechanische Verfahrenstechnik 2, Springer-Verlag, 1994 (German)</li> </ul>

Course L1290: Practicle Course Particle Technology for IMP	
<b>Typ</b>	Practical Course
<b>Hrs/wk</b>	3
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 18, Study Time in Lecture 42
<b>Lecturer</b>	Prof. Stefan Heinrich
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<p>Following experiments have to be carried out:</p> <ul style="list-style-type: none"> <li>• Sieving</li> <li>• Bulk properties</li> <li>• Size reduction</li> <li>• Mixing</li> <li>• Gas cyclone</li> <li>• Blaine-test, filtration</li> <li>• Sedimentation</li> </ul>
<b>Literature</b>	<ul style="list-style-type: none"> <li>• M. Rhodes: Introduction to Particle Technology, John Wiley &amp; Sons, 1998</li> <li>• M.E. Fayed &amp; L. Otten: Handbook of Powder Science &amp; Technology, 2nd Ed., Chapman &amp; Hall, 1997</li> <li>• M. Stieß: Mechanische Verfahrenstechnik 1, 2.Auflage, Springer-Verlag, 1995 (German)</li> <li>• M. Stieß: Mechanische Verfahrenstechnik 2, Springer-Verlag, 1994 (German)</li> </ul>



Module M1018: Process Systems Engineering and Transport Processes				
Courses				
Title		Typ	Hrs/wk	CP
Multiphase Flows (L0104)		Lecture	2	2
Process Systems Engineering (L1243)		Integrated Lecture	2	2
Heat & Mass Transfer in Process Engineering (L0103)		Lecture	2	2
<b>Module Responsible</b>	Prof. Michael Schlüter			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	<ul style="list-style-type: none"> <li>• Fundamentals in Fluid Dynamics</li> <li>• Fundamentals of Heat &amp; Mass Transport</li> <li>• Particle Technology</li> <li>• Separation Technology</li> <li>• Reactor Design and Operation</li> <li>• Fundamentals of Process Control</li> </ul>			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>	<p><i>Knowledge</i> The students are able to describe the transport processes in single- and multiphase flows. They are able to explain the analogy between heat- and mass transfer as well as the limits of this analogy. The students are able to write down the main transport laws and their application as well as the limits of application.</p> <p>Students are able to:</p> <ul style="list-style-type: none"> <li>• describe how transport coefficients for heat- and mass transfer can be derived experimentally,</li> <li>• define fundamentals of process synthesis and process control,</li> <li>• present and explain the hierarchical method of Douglas regarding process synthesis,</li> <li>• interpret heat recovery systems,</li> <li>• explain the pinch point method,</li> <li>• illustrate the interactions in process control systems.</li> </ul> <p><i>Skills</i> Students are able to:</p> <ul style="list-style-type: none"> <li>• use transport processes for the design of technical processes.</li> <li>• utilize methods of process synthesis to develop a whole production process</li> <li>• conduct a thermal analysis of a process regarding the heat and cooling demands</li> <li>• utilize the pinch point method</li> <li>• develop and evaluate a process control system</li> </ul>			
<b>Personal Competence</b>	<p><i>Social Competence</i> The students are able to discuss in international teams in English and develop an approach under pressure of time.</p> <p><i>Autonomy</i> 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.</p>			
<b>Workload in Hours</b>	Independent Study Time 96, Study Time in Lecture 84			
<b>Credit points</b>	6			
<b>Course achievement</b>	None			
<b>Examination</b>	Written exam			
<b>Examination duration and scale</b>	90 min			
<b>Assignment for the Following Curricula</b>	Chemical and Bioprocess Engineering: Core qualification: Compulsory			

Course L0104: Multiphase Flows	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Michael Schlüter
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Interfaces in MPF (boundary layers, surfactants)</li> <li>• Hydrodynamics &amp; pressure drop in Film Flows</li> <li>• Hydrodynamics &amp; pressure drop in Gas-Liquid Pipe Flows</li> <li>• Hydrodynamics &amp; pressure drop in Bubbly Flows</li> <li>• Mass Transfer in Film Flows</li> <li>• Mass Transfer in Gas-Liquid Pipe Flows</li> <li>• Mass Transfer in Bubbly Flows</li> <li>• Reactive mass Transfer in Multiphase Flows</li> <li>• Film Flow: Application Trickle Bed Reactors</li> <li>• Pipe Flow: Application Tubular Reactors</li> <li>• Bubbly Flow: Application Bubble Column Reactors</li> </ul>
<b>Literature</b>	<p>Brauer, H.: Grundlagen der Einphasen- und Mehrphasenströmungen. Verlag Sauerländer, Aarau, Frankfurt (M), 1971.</p> <p>Clift, R.; Grace, J.R.; Weber, M.E.: Bubbles, Drops and Particles, Academic Press, New York, 1978.</p> <p>Fan, L.-S.; Tsuchiya, K.: Bubble Wake Dynamics in Liquids and Liquid-Solid Suspensions, Butterworth-Heinemann Series in Chemical Engineering, Boston, USA, 1990.</p> <p>Hewitt, G.F.; Delhay, J.M.; Zuber, N. (Ed.): Multiphase Science and Technology. Hemisphere Publishing Corp, Vol. 1/1982 bis Vol. 6/1992.</p> <p>Kolev, N.I.: Multiphase flow dynamics. Springer, Vol. 1 and 2, 2002.</p> <p>Levy, S.: Two-Phase Flow in Complex Systems. Verlag John Wiley &amp; Sons, Inc, 1999.</p> <p>Crowe, C.T.: Multiphase Flows with Droplets and Particles. CRC Press, Boca Raton, Fla, 1998.</p>

Course L1243: Process Systems Engineering	
<b>Typ</b>	Integrated Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Mirko Skiborowski
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<p>Introduction</p> <p>Process Synthesis</p> <p>Synthesis of Heat Recovery Systems</p> <p>Process Control</p>
<b>Literature</b>	<p>J. M. Douglas, Conceptual Design of Chemical Processes, McGraw-Hill, 1988</p> <p>J.L.A. Koolen, Design of Simple and Robust Process Plants, Wiley-VCH, Weinheim, 2001</p> <p>T. McAvoy, Interaction Analysis, Instrument Society of Amerika, 1983</p> <p>B.A. Ogunnaike, W.H. Ray, Process Dynamics, Modeling and Control, Oxford University Press, 1994</p>

<b>Course L0103: Heat &amp; Mass Transfer in Process Engineering</b>	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Michael Schlüter
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Introduction - Transport Processes in Chemical Engineering</li> <li>• Molecular Heat- and Mass Transfer: Applications of Fourier's and Fick's Law</li> <li>• Convective Heat and Mass Transfer: Applications in Process Engineering</li> <li>• Unsteady State Transport Processes: Cooling &amp; Drying</li> <li>• Transport at fluidic Interfaces: Two Film, Penetration, Surface Renewal</li> <li>• Transport Laws &amp; Balance Equations with turbulence, sinks and sources</li> <li>• Experimental Determination of Transport Coefficients</li> <li>• Design and Scale Up of Reactors for Heat- and Mass Transfer</li> <li>• Reactive Mass Transfer</li> <li>• Processes with Phase Changes - Evaporization and Condensation</li> <li>• Radiative Heat Transfer - Fundamentals</li> <li>• Radiative Heat Transfer - Solar Energy</li> </ul>
<b>Literature</b>	<ol style="list-style-type: none"> <li>1. Baehr, Stephan: Heat and Mass Transfer, Wiley 2002.</li> <li>2. Bird, Stewart, Lightfoot: Transport Phenomena, Springer, 2000.</li> <li>3. John H. Lienhard: A Heat Transfer Textbook, Phlogiston Press, Cambridge Massachusetts, 2008.</li> <li>4. Myers: Analytical Methods in Conduction Heat Transfer, McGraw-Hill, 1971.</li> <li>5. Incropera, De Witt: Fundamentals of Heat and Mass Transfer, Wiley, 2002.</li> <li>6. Beek, Muttzall: Transport Phenomena, Wiley, 1983.</li> <li>7. Crank: The Mathematics of Diffusion, Oxford, 1995.</li> <li>8. Madhusudana: Thermal Contact Conductance, Springer, 1996.</li> <li>9. Treybal: Mass-Transfer-Operation, McGraw-Hill, 1987.</li> </ol>

Module M0896: Bioprocess and Biosystems Engineering				
<b>Courses</b>				
<b>Title</b>		<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
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
<b>Module Responsible</b>	Prof. An-Ping Zeng			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	Knowledge of bioprocess engineering and process engineering at bachelor level			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>	<p><i>Knowledge</i> After completion of this module, participants will be able to:</p> <ul style="list-style-type: none"> <li>• differentiate between different kinds of bioreactors and describe their key features</li> <li>• identify and characterize the peripheral and control systems of bioreactors</li> <li>• depict integrated biosystems (bioprocesses including up- and downstream processing)</li> <li>• name different sterilization methods and evaluate those in terms of different applications</li> <li>• recall and define the advanced methods of modern systems-biological approaches</li> <li>• connect the multiple "omics"-methods and evaluate their application for biological questions</li> <li>• recall the fundamentals of modeling and simulation of biological networks and biotechnological processes and to discuss their methods</li> <li>• 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.</li> </ul> <p><i>Skills</i> After completion of this module, participants will be able to:</p> <ul style="list-style-type: none"> <li>• describe different process control strategies for bioreactors and chose them after analysis of characteristics of a given bioprocess</li> <li>• plan and construct a bioreactor system including peripherals from lab to pilot plant scale</li> <li>• adapt a present bioreactor system to a new process and optimize it</li> <li>• develop concepts for integration of bioreactors into bioproduction processes</li> <li>• combine the different modeling methods into an overall modeling approach, to apply these methods to specific problems and to evaluate the achieved results critically</li> <li>• connect all process components of biotechnological processes for a holistic system view.</li> </ul> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> 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.</p> <p>The students can reflect their specific knowledge orally and discuss it with other students and teachers.</p> <p><i>Autonomy</i> 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.</p> <ul style="list-style-type: none"> <li>•</li> </ul>			
<b>Workload in Hours</b>	Independent Study Time 110, Study Time in Lecture 70			
<b>Credit points</b>	6			
<b>Course achievement</b>	<b>Compulsory</b>	<b>Bonus</b>	<b>Form</b>	<b>Description</b>
	Yes	20 %	Presentation	
<b>Examination</b>	Written exam			
<b>Examination duration and scale</b>	120 min			
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Core qualification: Compulsory Chemical and Bioprocess Engineering: Core qualification: Compulsory Environmental Engineering: Specialisation Biotechnology: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Core qualification: Compulsory			

Course L1034: Bioreactor Design and Operation	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. An-Ping Zeng
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	<p><b>Design of bioreactors and peripheries:</b></p> <ul style="list-style-type: none"> <li>• reactor types and geometry</li> <li>• materials and surface treatment</li> <li>• agitation system design</li> <li>• insertion of stirrer</li> <li>• sealings</li> <li>• fittings and valves</li> <li>• peripherals</li> <li>• materials</li> <li>• standardization</li> <li>• demonstration in laboratory and pilot plant</li> </ul> <p><b>Sterile operation:</b></p> <ul style="list-style-type: none"> <li>• theory of sterilisation processes</li> <li>• different sterilisation methods</li> <li>• sterilisation of reactor and probes</li> <li>• industrial sterile test, automated sterilisation</li> <li>• introduction of biological material</li> <li>• autoclaves</li> <li>• continuous sterilisation of fluids</li> <li>• deep bed filters, tangential flow filters</li> <li>• demonstration and practice in pilot plant</li> </ul> <p><b>Instrumentation and control:</b></p> <ul style="list-style-type: none"> <li>• temperature control and heat exchange</li> <li>• dissolved oxygen control and mass transfer</li> <li>• aeration and mixing</li> <li>• used gassing units and gassing strategies</li> <li>• control of agitation and power input</li> <li>• pH and reactor volume, foaming, membrane gassing</li> </ul> <p><b>Bioreactor selection and scale-up:</b></p> <ul style="list-style-type: none"> <li>• selection criteria</li> <li>• scale-up and scale-down</li> <li>• reactors for mammalian cell culture</li> </ul> <p><b>Integrated biosystem:</b></p> <ul style="list-style-type: none"> <li>• interactions and integration of microorganisms, bioreactor and downstream processing</li> <li>• Miniplant technologies</li> </ul> <p><b>Team work with presentation:</b></p> <ul style="list-style-type: none"> <li>• Operation mode of selected bioprocesses (e.g. fundamentals of batch, fed-batch and continuous cultivation)</li> </ul>
<b>Literature</b>	<ul style="list-style-type: none"> <li>• Storhas, Winfried, Bioreaktoren und periphere Einrichtungen, Braunschweig: Vieweg, 1994</li> <li>• Chmiel, Horst, Bioprozeßtechnik; Springer 2011</li> <li>• Krahe, Martin, Biochemical Engineering, Ullmann's Encyclopedia of Industrial Chemistry</li> <li>• Pauline M. Doran, Bioprocess Engineering Principles, Second Edition, Academic Press, 2013</li> <li>• Other lecture materials to be distributed</li> </ul>

<b>Course L1037: Bioreactors and Biosystems Engineering</b>	
<b>Typ</b>	Project-/problem-based Learning
<b>Hrs/wk</b>	1
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 46, Study Time in Lecture 14
<b>Lecturer</b>	Prof. An-Ping Zeng
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	<p><b>Introduction to Biosystems Engineering (Exercise)</b></p> <p><b>Experimental basis and methods for biosystems analysis</b></p> <ul style="list-style-type: none"> <li>• Introduction to genomics, transcriptomics and proteomics</li> <li>• More detailed treatment of metabolomics</li> <li>• Determination of in-vivo kinetics</li> <li>• Techniques for rapid sampling</li> <li>• Quenching and extraction</li> <li>• Analytical methods for determination of metabolite concentrations</li> </ul> <p><b>Analysis, modelling and simulation of biological networks</b></p> <ul style="list-style-type: none"> <li>• Metabolic flux analysis</li> <li>• Introduction</li> <li>• Isotope labelling</li> <li>• Elementary flux modes</li> <li>• Mechanistic and structural network models</li> <li>• Regulatory networks</li> <li>• Systems analysis</li> <li>• Structural network analysis</li> <li>• Linear and non-linear dynamic systems</li> <li>• Sensitivity analysis (metabolic control analysis)</li> </ul> <p><b>Modelling and simulation for bioprocess engineering</b></p> <ul style="list-style-type: none"> <li>• Modelling of bioreactors</li> <li>• Dynamic behaviour of bioprocesses</li> </ul> <p><b>Selected projects for biosystems engineering</b></p> <ul style="list-style-type: none"> <li>• Miniaturisation of bioreaction systems</li> <li>• Miniplant technology for the integration of biosynthesis and downstream processing</li> <li>• Technical and economic overall assessment of bioproduction processes</li> </ul>
<b>Literature</b>	<p>E. Klipp et al. Systems Biology in Practice, Wiley-VCH, 2006</p> <p>R. Dohrn: Miniplant-Technik, Wiley-VCH, 2006</p> <p>G.N. Stephanopoulos et. al.: Metabolic Engineering, Academic Press, 1998</p> <p>I.J. Dunn et. al.: Biological Reaction Engineering, Wiley-VCH, 2003</p> <p>Lecture materials to be distributed</p>

<b>Course L1036: Biosystems Engineering</b>	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. An-Ping Zeng
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	<p><b>Introduction to Biosystems Engineering</b></p> <p><b>Experimental basis and methods for biosystems analysis</b></p> <ul style="list-style-type: none"> <li>• Introduction to genomics, transcriptomics and proteomics</li> <li>• More detailed treatment of metabolomics</li> <li>• Determination of in-vivo kinetics</li> <li>• Techniques for rapid sampling</li> <li>• Quenching and extraction</li> <li>• Analytical methods for determination of metabolite concentrations</li> </ul> <p><b>Analysis, modelling and simulation of biological networks</b></p> <ul style="list-style-type: none"> <li>• Metabolic flux analysis</li> <li>• Introduction</li> <li>• Isotope labelling</li> <li>• Elementary flux modes</li> <li>• Mechanistic and structural network models</li> <li>• Regulatory networks</li> <li>• Systems analysis</li> <li>• Structural network analysis</li> <li>• Linear and non-linear dynamic systems</li> <li>• Sensitivity analysis (metabolic control analysis)</li> </ul> <p><b>Modelling and simulation for bioprocess engineering</b></p> <ul style="list-style-type: none"> <li>• Modelling of bioreactors</li> <li>• Dynamic behaviour of bioprocesses</li> </ul> <p><b>Selected projects for biosystems engineering</b></p> <ul style="list-style-type: none"> <li>• Miniaturisation of bioreaction systems</li> <li>• Miniplant technology for the integration of biosynthesis and downstream processing</li> <li>• Technical and economic overall assessment of bioproduction processes</li> </ul>
<b>Literature</b>	<p>E. Klipp et al. Systems Biology in Practice, Wiley-VCH, 2006</p> <p>R. Dohrn: Miniplant-Technik, Wiley-VCH, 2006</p> <p>G.N. Stephanopoulos et. al.: Metabolic Engineering, Academic Press, 1998</p> <p>I.J. Dunn et. al.: Biological Reaction Engineering, Wiley-VCH, 2003</p> <p>Lecture materials to be distributed</p>

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	
<b>Module Responsible</b>	Prof. Raimund Horn			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	Content of the bachelor-modules "process technology", as well as particle technology, fluidmechanics in process-technology and transport processes.			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>	<p><i>Knowledge</i> 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 analytical tools for specific catalytic applications.</p> <p><i>Skills</i> After successful completion 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 knowledge discretely to develop and conduct experiments. They are able to appraise achieved results into a more general context and draw conclusions out of them.</p> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> The students are able to plan, prepare, conduct and document experiments according to scientific guidelines in small groups.</p> <p>The students can discuss their subject related knowledge among each other and with their teachers.</p> <p><i>Autonomy</i> The students are able to obtain further information for experimental planning and assess their relevance autonomously.</p>			
<b>Workload in Hours</b>				
<b>Credit points</b>				
<b>Course achievement</b>				
	<b>Compulsory</b>	<b>Bonus</b>	<b>Form</b>	<b>Description</b>
	Yes	None	Presentation	
<b>Examination</b>	Written exam			
<b>Examination duration and scale</b>	120 min			
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core qualification: Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory			



<b>Course L0223: Analysis and Design of Heterogeneous Catalytic Reactors</b>	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Raimund Horn
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	<ol style="list-style-type: none"> <li>1. Material- and Energybalance of the two-dimensional pseudo-homogeneous reactor model</li> <li>2. Numerical solution of ordinary differential equations (Euler, Runge-Kutta, solvers for stiff problems, step controlled solvers)</li> <li>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)</li> <li>4. Partial differential equations (classification, numerical solution Lösung, finite difference method, method of lines)</li> <li>5. Examples of reactor design (isothermal tubular reactor with axial dispersion, dehydrogenation of ethyl benzene, wrong-way behaviour)</li> <li>6. Boundary value problems (numerical solution, shooting method, concentration- and temperature profiles in a catalyst pellet, multiphase reactors, trickle bed reactor)</li> </ol>
<b>Literature</b>	<ol style="list-style-type: none"> <li>1. Lecture notes R. Horn</li> <li>2. Lecture notes F. Keil</li> <li>3. G. F. Froment, K. B. Bischoff, J. De Wilde, Chemical Reactor Analysis and Design, John Wiley &amp; Sons, 2010</li> <li>4. R. Aris, Elementary Chemical Reactor Analysis, Dover Publ. Inc., 2000</li> </ol>

Course L0533: Modern Methods in Heterogeneous Catalysis	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Raimund Horn
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	<p>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.</p> <p>Heterogeneous catalysis plays also a key role in any future energy scenario (fuel cells, electrocatalytic splitting of water) and in environmental engineering (automotive catalysis, photocatalytic abatement of water pollutants).</p> <p>Heterogeneous catalysis is an interdisciplinary science requiring knowledge of different scientific disciplines such as</p> <ul style="list-style-type: none"> <li>• Materials Science (synthesis and characterization of solid catalysts)</li> <li>• Physics (structure and electronic properties of solids, defects)</li> <li>• Physical Chemistry (thermodynamics, reaction mechanisms, chemical kinetics, adsorption, desorption, spectroscopy, surface chemistry, theory)</li> <li>• Reaction Engineering (catalytic reactors, mass- and heat transport in catalytic reactors, multi-scale modeling, application of heterogeneous catalysis)</li> </ul> <p>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 acquired 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.</p>
<b>Literature</b>	<ul style="list-style-type: none"> <li>• J.M. Thomas, W.J. Thomas: Principles and Practice of Heterogeneous Catalysis, VCH</li> <li>• I. Chorkendorff, J. W. Niemantsverdriet, Concepts of Modern Catalysis and Kinetics, WILEY-VCH</li> <li>• B.C. Gates: Catalytic Chemistry, John Wiley</li> <li>• R.A. van Santen, P.W.N.M. van Leeuwen, J.A. Moulijn, B.A. Averill (Eds.): Catalysis: an integrated approach, Elsevier</li> <li>• D.P. Woodruff, T.A. Delchar: Modern Techniques of Surface Science, Cambridge Univ. Press</li> <li>• J.W. Niemantsverdriet: Spectroscopy in Catalysis, VCH</li> <li>• F. Delannay (Ed.): Characterization of heterogeneous catalysts, Marcel Dekker</li> <li>• C.H. Bartholomew, R.J. Farrauto: Fundamentals of Industrial Catalytic Processes (2nd Ed.), Wiley</li> </ul>

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

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
<b>Module Responsible</b>	Prof. Johannes Gescher		
<b>Admission Requirements</b>	None		
<b>Recommended Previous Knowledge</b>	Bachelor with basic knowledge in microbiology and genetics		
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results		
<b>Professional Competence</b>			
<i>Knowledge</i>	After successfully finishing this module, students are able <ul style="list-style-type: none"> <li>• to give an overview of genetic processes in the cell</li> <li>• to explain the application of industrial relevant biocatalysts</li> <li>• to explain and prove genetic differences between pro- and eukaryotes</li> </ul>		
<i>Skills</i>	After successfully finishing this module, students are able <ul style="list-style-type: none"> <li>• to explain and use advanced molecularbiological methods</li> <li>• to recognize problems in interdisciplinary fields</li> </ul>		
<b>Personal Competence</b>			
<i>Social Competence</i>	Students are able to <ul style="list-style-type: none"> <li>• write protocols and PBL-summaries in teams</li> <li>• to lead and advise members within a PBL-unit in a group</li> <li>• develop and distribute work assignments for given problems</li> </ul>		
<i>Autonomy</i>	Students are able to <ul style="list-style-type: none"> <li>• search information for a given problem by themselves</li> <li>• prepare summaries of their search results for the team</li> <li>• make themselves familiar with new topics</li> </ul>		
<b>Workload in Hours</b>	Independent Study Time 110, Study Time in Lecture 70		
<b>Credit points</b>	6		
<b>Course achievement</b>	None		
<b>Examination</b>	Written exam		
<b>Examination duration and scale</b>	60 min exam		
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Core qualification: Compulsory Chemical and Bioprocess Engineering: Core qualification: Compulsory Environmental Engineering: Core qualification: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory		

Course L0877: Applied Molecular Biology	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Johannes Gescher
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	<p>Lecture and PBL</p> <ul style="list-style-type: none"> <li>- Methods in genetics / molecular cloning</li> <li>- Industrial relevance of microbes and their biocatalysts</li> <li>- Biotransformation at extreme conditions</li> <li>- Genomics</li> <li>- Protein engineering techniques</li> <li>- Synthetic biology</li> </ul>
<b>Literature</b>	<p>Relevante Literatur wird im Kurs zur Verfügung gestellt.</p> <p>Grundwissen in Molekularbiologie, Genetik, Mikrobiologie und Biotechnologie erforderlich.</p> <p>Lehrbuch: Brock - Mikrobiologie / Microbiology (Madigan et al.)</p>

Course L0999: Technical Microbiology	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Johannes Gescher
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• History of microbiology and biotechnology</li> <li>• Enzymes</li> <li>• Molecular biology</li> <li>• Fermentation</li> <li>• Downstream Processing</li> <li>• Industrial microbiological processes</li> <li>• Technical enzyme application</li> <li>• Biological Waste Water treatment</li> </ul>
<b>Literature</b>	<p><b>Microbiology</b>, 2013, Madigan, M., Martinko, J. M., Stahl, D. A., Clark, D. P. (eds.), formerly „Brock“, Pearson</p> <p><b>Industrielle Mikrobiologie</b>, 2012, Sahn, H., Antranikian, G., Stahmann, K.-P., Takors, R. (eds.) Springer Berlin, Heidelberg, New York, Tokyo.</p> <p><b>Angewandte Mikrobiologie</b>, 2005, Antranikian, G. (ed.), Springer, Berlin, Heidelberg, New York, Tokyo.</p>

Course L1000: Technical Microbiology	
<b>Typ</b>	Recitation Section (large)
<b>Hrs/wk</b>	1
<b>CP</b>	1
<b>Workload in Hours</b>	Independent Study Time 16, Study Time in Lecture 14
<b>Lecturer</b>	Prof. Johannes Gescher
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	See interlocking course
<b>Literature</b>	See interlocking course

Module M0904: Process Design Project				
<b>Courses</b>				
<b>Title</b>		<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
Process Design Project (L1050)		Projection Course	6	6
<b>Module Responsible</b>	Dozenten des SD V			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	<ul style="list-style-type: none"> <li>• Particle Technology and Solid Process Engineering</li> <li>• Transport Processes</li> <li>• Process- and Plant Design II</li> <li>• Fluid Mechanics for Process Engineering</li> <li>• Chemical Reaction Engineering</li> <li>• Bioprocess- and Biosystems-Engineering</li> </ul>			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>	<p><i>Knowledge</i> After the students passed the project course successfully they know:</p> <ul style="list-style-type: none"> <li>• how a team is working together so solve a complex task in process engineering</li> <li>• what kind of tools are necessary to design a process</li> <li>• what kind of drawbacks and difficulties are coming up by designing a process</li> </ul> <p><i>Skills</i> After passing the Module successfully the students are able to:</p> <ul style="list-style-type: none"> <li>• utilize tools for process design for a specific given process engineering task,</li> <li>• choose and connect apparatuses for a complete process,</li> <li>• collecting all relevant data for an economical and ecological evaluation,</li> <li>• optimization of calculation sequence with respect to flowsheet simulation.</li> </ul> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> The students are able to discuss in international teams in english and develop an approach under pressure of time.</p> <p><i>Autonomy</i> 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.</p>			
<b>Workload in Hours</b>	Independent Study Time 96, Study Time in Lecture 84			
<b>Credit points</b>	6			
<b>Course achievement</b>	None			
<b>Examination</b>	Subject theoretical and practical work			
<b>Examination duration and scale</b>	.			
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Core qualification: Compulsory Chemical and Bioprocess Engineering: Core qualification: Compulsory Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory Process Engineering: Core qualification: Compulsory			

Course L1050: Process Design Project	
<b>Typ</b>	Projection Course
<b>Hrs/wk</b>	6
<b>CP</b>	6
<b>Workload in Hours</b>	Independent Study Time 96, Study Time in Lecture 84
<b>Lecturer</b>	NN
<b>Language</b>	DE/EN
<b>Cycle</b>	WiSe
<b>Content</b>	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.
<b>Literature</b>	

Module M1047: Research project IMP Chemical and Bioprocess Engineering			
<b>Courses</b>			
<b>Title</b>	Research Project IMP Chemical and Bioprocess Engineering (L1388)	<b>Typ</b>	Project-/problem-based Learning
		<b>Hrs/wk</b>	6
		<b>CP</b>	6
<b>Module Responsible</b>	Dozenten des SD V		
<b>Admission Requirements</b>	None		
<b>Recommended Previous Knowledge</b>	Advanced state of knowledge in the international master program of Chemical and Bioprocess Engineering.		
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results		
<b>Professional Competence</b>	Students know current research topics oft institutes engaged in their specialization. They can name the fundamental scientific methods for doing related reserach.		
<i>Knowledge</i>			
<i>Skills</i>	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 alternative approaches with their own with regard to given criteria.		
<b>Personal Competence</b>	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.		
<i>Social Competence</i>			
<i>Autonomy</i>	Based on their competences gained so far students are capable of defining meaningful tasks within ongoing research projects for themselves. They are able to develop the necessary understanding and problem solving methods.		
<b>Workload in Hours</b>	Independent Study Time 96, Study Time in Lecture 84		
<b>Credit points</b>	6		
<b>Course achievement</b>	None		
<b>Examination</b>	Study work		
<b>Examination duration and scale</b>	Accordinging General Regulations		
<b>Assignment for the Following Curricula</b>	Chemical and Bioprocess Engineering: Core qualification: Compulsory		

Course L1388: Research Project IMP Chemical and Bioprocess Engineering	
<b>Typ</b>	Project-/problem-based Learning
<b>Hrs/wk</b>	6
<b>CP</b>	6
<b>Workload in Hours</b>	Independent Study Time 96, Study Time in Lecture 84
<b>Lecturer</b>	Dozenten des SD V
<b>Language</b>	DE/EN
<b>Cycle</b>	WiSe/SoSe
<b>Content</b>	Students work on a sub-project of a currently ongoing research project in one of the institutes working in their field of specialization. The nature of this sub-project can be theory or experiment but it can also combine theoretical and experimental work. The sub-project can also be used to prepare a subsequent master project, for example by conducting a literature survey and doing preparative experiments.
<b>Literature</b>	Bücher, Zeitschriften und Patentliteratur des jeweiligen Forschungsgebiets.  Books, journals and patent literature of the respective field of research.

## Specialization General Process Engineering

In the direction General Process Engineering, the students can construct their program emphasis freely.

For students with correspondingly good German language levels the modules in German language from the Masters Biotechnology and Process Engineering are available as well.

### 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

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

<b>Course L1229: Ecological Town Design - Water, Energy, Soil and Food Nexus</b>	
<b>Typ</b>	Seminar
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Ralf Otterpohl
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Participants Workshop: Design of the most attractive productive Town</li> <li>• Keynote lecture and video</li> <li>• The limits of Urbanization / Green Cities</li> <li>• The tragedy of the Rural: Soil degradation, agro chemical toxification, migration to cities</li> <li>• Global Ecovillage Network: Upsides and Downsides around the World</li> <li>• Visit of an Ecovillage</li> <li>• Participants Workshop: Resources for thriving rural areas, Short presentations by participants, video competition</li> <li>• TUHH Rural Development Toolbox</li> <li>• Integrated New Town Development</li> <li>• Participants workshop: Design of New Towns: Northern, Arid and Tropical cases</li> <li>• Outreach: Participants campaign</li> <li>• City with the Rural: Resilience, quality of live and productive biodiversity</li> </ul>
<b>Literature</b>	<ul style="list-style-type: none"> <li>• 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</li> <li>• <a href="http://youtu.be/9hmkgn0nBgk">http://youtu.be/9hmkgn0nBgk</a> (Miracle Water Village, India, Integrated Rainwater Harvesting, Water Efficiency, Reforestation and Sanitation)</li> <li>• TEDx New Town Ralf Otterpohl: <a href="http://youtu.be/_M0J2u9BrbU">http://youtu.be/_M0J2u9BrbU</a></li> </ul>

<b>Course L0939: Water &amp; Wastewater Systems in a Global Context</b>	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	4
<b>Workload in Hours</b>	Independent Study Time 92, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Ralf Otterpohl
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Keynote lecture and video</li> <li>• Water &amp; Soil: Water availability as a consequence of healthy soils</li> <li>• Water and it's utilization, Integrated Urban Water Management</li> <li>• Water &amp; Energy, lecture and panel discussion pro and con for a specific big dam project</li> <li>• Rainwater Harvesting on Catchment level, Holistic Planned Grazing, Multi-Use-Reforestation</li> <li>• Sanitation and Reuse of water, nutrients and soil conditioners, Conventional and Innovative Approaches</li> <li>• Why are there excreta in water? Public Health, Awareness Campaigns</li> <li>• Rehearsal session, Q&amp;A</li> </ul>
<b>Literature</b>	<ul style="list-style-type: none"> <li>• Montgomery, David R. 2007: Dirt: The Erosion of Civilizations, University of California Press</li> <li>• Liu, John D.: <a href="http://eempc.org/hope-in-a-changing_climate/">http://eempc.org/hope-in-a-changing_climate/</a> (Integrated regeneration of the Loess Plateau, China, and sites in Ethiopia and Rwanda)</li> <li>• <a href="http://youtu.be/9hmkgn0nBgk">http://youtu.be/9hmkgn0nBgk</a> (Miracle Water Village, India, Integrated Rainwater Harvesting, Water Efficiency, Reforestation and Sanitation)</li> </ul>



Module M1702: Process Imaging				
<b>Courses</b>				
<b>Title</b>		<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
Process Imaging (L2723)		Lecture	2	3
Process Imaging (L2724)		Project-/problem-based Learning	2	3
<b>Module Responsible</b>	Prof. Alexander Penn			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>				
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b> <i>Knowledge</i> <i>Skills</i>				
<b>Personal Competence</b> <i>Social Competence</i> <i>Autonomy</i>				
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56			
<b>Credit points</b>	6			
<b>Course achievement</b>	None			
<b>Examination</b>	Written exam			
<b>Examination duration and scale</b>	120 min			
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory			

Course L2723: Process Imaging	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Alexander Penn
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	
<b>Literature</b>	

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<b>Course L2724: Process Imaging</b>	
<b>Typ</b>	Project-/problem-based Learning
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Alexander Penn
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	
<b>Literature</b>	

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
<b>Module Responsible</b>	Prof. Ralf Pörtner			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	Knowledge of bioprocess engineering and process engineering at bachelor level			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>				
<i>Knowledge</i>	After successful completion of the module the students <ul style="list-style-type: none"> <li>- know the basic principles of cell and tissue culture</li> <li>- know the relevant metabolic and physiological properties of animal and human cells</li> <li>- are able to explain and describe the basic underlying principles of bioreactors for cell and tissue cultures, in contrast to microbial fermentations</li> <li>- are able to explain the essential steps (unit operations) in downstream</li> <li>- are able to explain, analyze and describe the kinetic relationships and significant litigation strategies for cell culture reactors</li> </ul>			
<i>Skills</i>	The students are able <ul style="list-style-type: none"> <li>- to analyze and perform mathematical modeling to cellular metabolism at a higher level</li> <li>- are able to to develop process control strategies for cell culture systems</li> </ul>			
<b>Personal Competence</b>				
<i>Social Competence</i>	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.  The students can reflect their specific knowledge orally and discuss it with other students and teachers.			
<i>Autonomy</i>	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.			
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56			
<b>Credit points</b>	6			
<b>Course achievement</b>	None			
<b>Examination</b>	Written exam			
<b>Examination duration and scale</b>	120 min			
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory			

Course L0355: Fundamentals of Cell and Tissue Engineering	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Ralf Pörtner, Prof. An-Ping Zeng
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	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) Stoichiometry and kinetics of cell growth and product formation (growth of mammalian cells, quantitative description of cell growth & product formation, kinetics of growth)
<b>Literature</b>	Butler, M (2004) Animal Cell Culture Technology - The basics, 2 <sup>nd</sup> ed. Oxford University Press  Ozturk SS, Hu WS (eds) (2006) Cell Culture Technology For Pharmaceutical and Cell-Based Therapies. Taylor & Francis Group, New York  Eibl, R.; D. Eibl; R. Pörtner; G. Catapano and P. Czermak: Cell and Tissue Reaction Engineering, Springer (2008). ISBN 978-3-540-68175-5  Pörtner R (ed) (2013) Animal Cell Biotechnology - Methods and Protocols. Humana Press

Course L0356: Bioprocess Engineering for Medical Applications	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Ralf Pörtner
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	Requirements for cell culture processes, 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
<b>Literature</b>	Butler, M (2004) Animal Cell Culture Technology - The basics, 2 <sup>nd</sup> ed. Oxford University Press  Ozturk SS, Hu WS (eds) (2006) Cell Culture Technology For Pharmaceutical and Cell-Based Therapies. Taylor & Francis Group, New York  Eibl, R.; D. Eibl; R. Pörtner; G. Catapano and P. Czermak: Cell and Tissue Reaction Engineering, Springer (2008). ISBN 978-3-540-68175-5  Pörtner R (ed) (2013) Animal Cell Biotechnology - Methods and Protocols. Humana Press

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
<b>Module Responsible</b>	Prof. Daniel Ruprecht		
<b>Admission Requirements</b>	None		
<b>Recommended Previous Knowledge</b>	<ul style="list-style-type: none"> <li>Mathematik I, II, III für Ingenieurstudierende (deutsch oder englisch) oder Analysis &amp; Lineare Algebra I + II sowie Analysis III für Technomathematiker</li> <li>Basic MATLAB knowledge</li> </ul>		
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results		
<b>Professional Competence</b>	<p><i>Knowledge</i> Students are able to</p> <ul style="list-style-type: none"> <li>list numerical methods for the solution of ordinary differential equations and explain their core ideas,</li> <li>repeat convergence statements for the treated numerical methods (including the prerequisites tied to the underlying problem),</li> <li>explain aspects regarding the practical execution of a method.</li> <li>select the appropriate numerical method for concrete problems, implement the numerical algorithms efficiently and interpret the numerical results</li> </ul> <p><i>Skills</i> Students are able to</p> <ul style="list-style-type: none"> <li>implement (MATLAB), apply and compare numerical methods for the solution of ordinary differential equations,</li> <li>to justify the convergence behaviour of numerical methods with respect to the posed problem and selected algorithm,</li> <li>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.</li> </ul> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> Students are able to</p> <ul style="list-style-type: none"> <li>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.</li> </ul> <p><i>Autonomy</i> Students are capable</p> <ul style="list-style-type: none"> <li>to assess whether the supporting theoretical and practical exercises are better solved individually or in a team,</li> <li>to assess their individual progress and, if necessary, to ask questions and seek help.</li> </ul>		
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56		
<b>Credit points</b>	6		
<b>Course achievement</b>	None		
<b>Examination</b>	Written exam		
<b>Examination duration and scale</b>	90 min		
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Computer Science: Specialisation III. Mathematics: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Core qualification: Elective Compulsory Interdisciplinary Mathematics: Specialisation II. Numerical - Modelling Training: Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory		

Course L0576: Numerical Treatment of Ordinary Differential Equations	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Daniel Ruprecht
<b>Language</b>	DE/EN
<b>Cycle</b>	SoSe
<b>Content</b>	<p>Numerical methods for Initial Value Problems</p> <ul style="list-style-type: none"> <li>• single step methods</li> <li>• multistep methods</li> <li>• stiff problems</li> <li>• differential algebraic equations (DAE) of index 1</li> </ul> <p>Numerical methods for Boundary Value Problems</p> <ul style="list-style-type: none"> <li>• multiple shooting method</li> <li>• difference methods</li> <li>• variational methods</li> </ul>
<b>Literature</b>	<ul style="list-style-type: none"> <li>• E. Hairer, S. Noersett, G. Wanner: Solving Ordinary Differential Equations I: Nonstiff Problems</li> <li>• E. Hairer, G. Wanner: Solving Ordinary Differential Equations II: Stiff and Differential-Algebraic Problems</li> </ul>

Course L0582: Numerical Treatment of Ordinary Differential Equations	
<b>Typ</b>	Recitation Section (small)
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Daniel Ruprecht
<b>Language</b>	DE/EN
<b>Cycle</b>	SoSe
<b>Content</b>	See interlocking course
<b>Literature</b>	See interlocking course

Module M0906: Numerical Simulation and Lagrangian Transport			
<b>Courses</b>			
<b>Title</b>	<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
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
<b>Module Responsible</b>	Prof. Michael Schlüter		
<b>Admission Requirements</b>	None		
<b>Recommended Previous Knowledge</b>	<ul style="list-style-type: none"> <li>• Mathematics I-IV</li> <li>• Basic knowledge in Fluid Mechanics</li> <li>• Basic knowledge in chemical thermodynamics</li> </ul>		
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results		
<b>Professional Competence</b> <i>Knowledge</i>	After successful completion of the module the students are able to <ul style="list-style-type: none"> <li>• explain the the basic principles of statistical thermodynamics (ensembles, simple systems)</li> <li>• describe the main approaches in classical Molecular Modeling (Monte Carlo, Molecular Dynamics) in various ensembles</li> <li>• discuss examples of computer programs in detail,</li> <li>• evaluate the application of numerical simulations,</li> <li>• list the possible start and boundary conditions for a numerical simulation.</li> </ul>		
<i>Skills</i>	The students are able to: <ul style="list-style-type: none"> <li>• set up computer programs for solving simple problems by Monte Carlo or molecular dynamics,</li> <li>• solve problems by molecular modeling,</li> <li>• set up a numerical grid,</li> <li>• perform a simple numerical simulation with OpenFoam,</li> <li>• evaluate the result of a numerical simulation.</li> </ul>		
<b>Personal Competence</b> <i>Social Competence</i>	The students are able to <ul style="list-style-type: none"> <li>• develop joint solutions in mixed teams and present them in front of the other students,</li> <li>• to collaborate in a team and to reflect their own contribution toward it.</li> </ul>		
<i>Autonomy</i>	The students are able to: <ul style="list-style-type: none"> <li>• evaluate their learning progress and to define the following steps of learning on that basis,</li> <li>• evaluate possible consequences for their profession.</li> </ul>		
<b>Workload in Hours</b>	Independent Study Time 110, Study Time in Lecture 70		
<b>Credit points</b>	6		
<b>Course achievement</b>	None		
<b>Examination</b>	Oral exam		
<b>Examination duration and scale</b>	30 min		
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory		

Course L2301: Lagrangian transport in turbulent flows	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Alexandra von Kameke
<b>Language</b>	EN

Cycle	SoSe
<p><b>Content</b></p>	<p>Contents</p> <ul style="list-style-type: none"> <li>- Common variables and terms for characterizing turbulence (energy spectra, energy cascade, etc.)</li> <li>- An overview of Lagrange analysis methods and experiments in fluid mechanics</li> <li>- Critical examination of the concept of turbulence and turbulent structures.</li> <li>- Calculation of the transport of ideal fluid elements and associated analysis methods (absolute and relative diffusion, Lagrangian Coherent Structures, etc.)</li> <li>- Implementation of a Runge-Kutta 4th-order in Matlab</li> <li>- Introduction to particle integration using ODE solver from Matlab</li> <li>- Problems from turbulence research</li> <li>- Application analytical methods with Matlab.</li> </ul> <p>Structure:</p> <ul style="list-style-type: none"> <li>- 14 units a 2x45 min.</li> <li>- 10 units lecture</li> <li>- 4 Units Matlab Exercise- Go through the exercises Matlab, Peer2Peer? Explain solutions to your colleague</li> </ul> <p>Learning goals:</p> <p>Students receive very specific, in-depth knowledge from modern turbulence research and transport analysis. → Knowledge</p> <p>The students learn to classify the acquired knowledge, they study approaches to further develop the knowledge themselves and to relate different data sources to each other. → Knowledge, skills</p> <p>The students are trained in the personal competence to independently delve into and research a scientific topic. → Independence</p> <p>Matlab exercises in small groups during the lecture and guided Peer2Peer discussion rounds train communication skills in complex situations. The mixture of precise language and intuitive understanding is learnt. → Knowledge, social competence</p> <p>Required knowledge:</p> <p>Fluid mechanics 1 and 2 advantageous</p> <p>Programming knowledge advantageous</p>
<p><b>Literature</b></p>	<p>Bakunin, Oleg G. (2008): Turbulence and Diffusion. Scaling Versus Equations. Berlin [u. a.]: Springer Verlag.</p> <p>Bourgoin, Mickaël; Ouellette, Nicholas T.; Xu, Haitao; Berg, Jacob; Bodenschatz, Eberhard (2006): The role of pair dispersion in turbulent flow. In: Science (New York, N.Y.) 311 (5762), S. 835-838. DOI: 10.1126/science.1121726.</p> <p>Davidson, P. A. (2015): Turbulence. An introduction for scientists and engineers. Second edition. Oxford: Oxford Univ. Press.</p> <p>Graff, L. S.; Guttu, S.; LaCasce, J. H. (2015): Relative Dispersion in the Atmosphere from Reanalysis Winds. In: J. Atmos. Sci. 72 (7), S. 2769-2785. DOI: 10.1175/JAS-D-14-0225.1.</p> <p>Grigoriev, Roman (2011): Transport and Mixing in Laminar Flows. Weinheim, Germany: Wiley-VCH Verlag GmbH &amp; Co. KGaA.</p> <p>Haller, George (2015): Lagrangian Coherent Structures. In: Annu. Rev. Fluid Mech. 47 (1), S. 137-162. DOI: 10.1146/annurev-fluid-010313-141322.</p> <p>Kameke, A. von; Huhn, F.; Fernández-García, G.; Muñozuri, A. P.; Pérez-Muñozuri, V. (2010): Propagation of a chemical wave front in a quasi-two-dimensional superdiffusive flow. In: Physical review. E, Statistical, nonlinear, and soft matter physics 81 (6 Pt 2), S. 66211. DOI: 10.1103/PhysRevE.81.066211.</p> <p>Kameke, A. von; Huhn, F.; Fernández-García, G.; Muñozuri, A. P.; Pérez-Muñozuri, V. (2011): Double cascade turbulence and Richardson dispersion in a horizontal fluid flow induced by Faraday waves. In: Physical review letters 107 (7), S. 74502. DOI: 10.1103/PhysRevLett.107.074502.</p> <p>Kameke, A.v.; Kastens, S.; Rüttinger, S.; Herres-Pawlis, S.; Schlüter, M. (2019): How coherent structures dominate the residence time in a bubble wake: An experimental example. In: Chemical Engineering Science 207, S. 317-326. DOI: 10.1016/j.ces.2019.06.033.</p> <p>Klages, Rainer; Radons, Günter; Sokolov, Igor M. (2008): Anomalous Transport: Wiley.</p> <p>LaCasce, J. H. (2008): Statistics from Lagrangian observations. In: Progress in Oceanography 77 (1), S. 1-29. DOI:</p>



	<p>10.1016/j.pocean.2008.02.002.</p> <p>Neufeld, Zoltán; Hernández-García, Emilio (2009): Chemical and Biological Processes in Fluid Flows: PUBLISHED BY IMPERIAL COLLEGE PRESS AND DISTRIBUTED BY WORLD SCIENTIFIC PUBLISHING CO.</p> <p>Onu, K.; Huhn, F.; Haller, G. (2015): LCS Tool: A computational platform for Lagrangian coherent structures. In: Journal of Computational Science 7, S. 26-36. DOI: 10.1016/j.jocs.2014.12.002.</p> <p>Ouellette, Nicholas T.; Xu, Haitao; Bourgoin, Mickaël; Bodenschatz, Eberhard (2006): An experimental study of turbulent relative dispersion models. In: New J. Phys. 8 (6), S. 109. DOI: 10.1088/1367-2630/8/6/109.</p> <p>Pope, Stephen B. (2000): Turbulent Flows. Cambridge: Cambridge University Press.</p> <p>Rivera, M. K.; Ecke, R. E. (2005): Pair dispersion and doubling time statistics in two-dimensional turbulence. In: Physical review letters 95 (19), S. 194503. DOI: 10.1103/PhysRevLett.95.194503.</p> <p>Vallis, Geoffrey K. (2010): Atmospheric and oceanic fluid dynamics. Fundamentals and large-scale circulation. 5. printing. Cambridge: Cambridge Univ. Press.</p>
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Course L1375: Computational Fluid Dynamics - Exercises in OpenFoam	
<b>Typ</b>	Recitation Section (small)
<b>Hrs/wk</b>	1
<b>CP</b>	1
<b>Workload in Hours</b>	Independent Study Time 16, Study Time in Lecture 14
<b>Lecturer</b>	Prof. Michael Schlüter
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• generation of numerical grids with a common grid generator</li> <li>• selection of models and boundary conditions</li> <li>• basic numerical simulation with OpenFoam within the TUHH CIP-Pool</li> </ul>
<b>Literature</b>	OpenFoam Tutorials (StudIP)

Course L1052: Computational Fluid Dynamics in Process Engineering	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Michael Schlüter
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Introduction into partial differential equations</li> <li>• Basic equations</li> <li>• Boundary conditions and grids</li> <li>• Numerical methods</li> <li>• Finite difference method</li> <li>• Finite volume method</li> <li>• Time discretisation and stability</li> <li>• Population balance</li> <li>• Multiphase Systems</li> <li>• Modeling of Turbulent Flows</li> <li>• Exercises: Stability Analysis</li> <li>• Exercises: Example on CFD - analytically/numerically</li> </ul>
<b>Literature</b>	<p>Paschedag A.R.: CFD in der Verfahrenstechnik: Allgemeine Grundlagen und mehrphasige Anwendungen, Wiley-VCH, 2004 ISBN 3-527-30994-2.</p> <p>Ferziger, J.H.; Peric, M.: Numerische Strömungsmechanik. Springer-Verlag, Berlin, 2008, ISBN: 3540675868.</p> <p>Ferziger, J.H.; Peric, M.: Computational Methods for Fluid Dynamics. Springer, 2002, ISBN 3-540-42074-6</p>

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
<b>Module Responsible</b>	Prof. Martin Kaltschmitt		
<b>Admission Requirements</b>	None		
<b>Recommended Previous Knowledge</b>	Bachelor degree in Process Engineering, Bioprocess Engineering or Energy- and Environmental Engineering		
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results		
<b>Professional Competence</b>	<p><i>Knowledge</i> The students 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. Furthermore, they can describe the basics of the general procedure for the processing of modeling tasks, especially with ASPEN PLUS ® and ASPEN CUSTOM MODELER ®.</p> <p><i>Skills</i> Students are able to simulate and solve scientific task in the context of renewable energy technologies by:</p> <ul style="list-style-type: none"> <li>• development of modul-comprehensive approaches for the dimensioning and design of production processes</li> <li>• evaluating alternatives input parameter to solve the particular task even with incomplete information,</li> <li>• a systematic documentation of the work results in form of a written version, the presentation itself and the defense of contents.</li> </ul> <p>They can use the ASPEN PLUS ® and ASPEN CUSTOM MODELER ® for modeling energy systems and to evaluate the simulation solutions.</p> <p>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.</p>		
<b>Personal Competence</b>	<p><i>Social Competence</i> Students can</p> <ul style="list-style-type: none"> <li>• respectfully work together as a team with around 2-3 members,</li> <li>• participate in subject-specific and interdisciplinary discussions in the area of dimensioning and design of production processes, and can develop cooperated solutions,</li> <li>• defend their own work results in front of fellow students and</li> </ul> <p>assess the performance of fellow students in comparison to their own performance. Furthermore, they can accept professional constructive criticism.</p> <p><i>Autonomy</i> 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.</p>		
<b>Workload in Hours</b>	Independent Study Time 96, Study Time in Lecture 84		
<b>Credit points</b>	6		
<b>Course achievement</b>	None		
<b>Examination</b>	Written elaboration		
<b>Examination duration and scale</b>	Written report incl. presentation		
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Renewable Energies: Core qualification: Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory		

Course L1832: Biorefineries - Technical Design and Optimization	
<b>Typ</b>	Project-/problem-based Learning
<b>Hrs/wk</b>	3
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 48, Study Time in Lecture 42
<b>Lecturer</b>	Prof. Oliver Lüdtke
<b>Language</b>	DE
<b>Cycle</b>	SoSe
<b>Content</b>	<p><b>I. Repetition of engineering basics</b></p> <ol style="list-style-type: none"> <li>1. Shell and tube heat exchangers</li> <li>2. Steam generators and refrigerating machines</li> <li>3. Pumps and turbines</li> <li>4. Flow in piping networks</li> <li>5. Pumping and mixing of non-newtonian fluids</li> <li>6. Requirements to a detailed layout plan</li> </ol> <p><b>II. Calculation:</b></p> <ol style="list-style-type: none"> <li>1. Planning and design of a specific bio-refinery plant section, such as Ethanol distillation and fermentation. This is based on empirical value of a real, industrial plant. <ul style="list-style-type: none"> <li>◦ Mass and energy balances (Aspen)</li> <li>◦ Equipment design (heat exchangers, pumps, pipes, tanks, etc.) (</li> <li>◦ Isolation, wall thickness and material selection</li> <li>◦ Energy demand (electrical, heat or cooling), design of steam boilers and appliances</li> <li>◦ Selection of fittings, measuring instruments and safety equipment</li> <li>◦ Definition of main control loops</li> </ul> </li> <li>2. Hereby, the dependencies of transport phenomena between certain plant sections become evident and methods of calculation are introduced.</li> <li>3. In Detail Engineering , it is focused on aspects of plant engineering planning that are relevant for the subsequent construction of the plant.</li> <li>4. Depending of time requirement and group size a cost estimation and preparation of a complete R&amp;I flow chart can be implemented as well.</li> </ol>
<b>Literature</b>	<p>Perry, R.;Green, R.: Perry's Chemical Engineers' Handbook, 8<sup>th</sup> Edition, McGraw Hill Professional, 2007</p> <p>Sinnot, R. K.: Chemical Engineering Design, Elsevier, 2014</p>

Course L0022: CAPE in Energy Engineering	
<b>Typ</b>	Projection Course
<b>Hrs/wk</b>	3
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 48, Study Time in Lecture 42
<b>Lecturer</b>	Prof. Martin Kaltschmitt
<b>Language</b>	DE
<b>Cycle</b>	SoSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• CAPE = <i>Computer-Aided-Project-Engineering</i></li> <li>• INTRODUCTION TO THE THEORY <ul style="list-style-type: none"> <li>◦ Classes of simulation programs</li> <li>◦ Sequential modular approach</li> <li>◦ Equation-oriented approach</li> <li>◦ Simultaneous modular approach</li> <li>◦ General procedure for the processing of modeling tasks</li> <li>◦ Special procedure for solving models with repatriations</li> </ul> </li> <li>• COMPUTER EXERCISES renewable energy projects WITH ASPEN PLUS ® AND ASPEN CUSTOM MODELER ® <ul style="list-style-type: none"> <li>◦ Scope, potential and limitations of Aspen Plus ® and Aspen Custom Modeler ®</li> <li>◦ Use of integrated databases for material data</li> <li>◦ Methods for estimating non-existent physical property data</li> <li>◦ Use of model libraries and Process Synthesis</li> <li>◦ Application of design specifications and sensitivity analyzes</li> <li>◦ Solving optimization problems</li> </ul> </li> </ul> <p>Within the seminar, the various tasks are actively discussed and applied to various cases of application.</p>
<b>Literature</b>	<ul style="list-style-type: none"> <li>• Aspen Plus® - Aspen Plus User Guide</li> <li>• William L. Luyben; Distillation Design and Control Using Aspen Simulation; ISBN-10: 0-471-77888-5</li> </ul>

Module M0617: High Pressure Chemical Engineering				
<b>Courses</b>				
<b>Title</b>		<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
High pressure plant and vessel design (L1278)		Lecture	2	2
Industrial Processes Under High Pressure (L0116)		Lecture	2	2
Advanced Separation Processes (L0094)		Lecture	2	2
<b>Module Responsible</b>	Dr. Monika Johannsen			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	Fundamentals of Chemistry, Chemical Engineering, Fluid Process Engineering, Thermal Separation Processes, Thermodynamics, Heterogeneous Equilibria			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>	<p><i>Knowledge</i> After a successful completion of this module, students can:</p> <ul style="list-style-type: none"> <li>explain the influence of pressure on the properties of compounds, phase equilibria, and production processes,</li> <li>describe the thermodynamic fundamentals of separation processes with supercritical fluids,</li> <li>exemplify models for the description of solid extraction and countercurrent extraction,</li> <li>discuss parameters for optimization of processes with supercritical fluids.</li> </ul> <p><i>Skills</i> After successful completion of this module, students are able to:</p> <ul style="list-style-type: none"> <li>compare separation processes with supercritical fluids and conventional solvents,</li> <li>assess the application potential of high-pressure processes at a given separation task,</li> <li>include high pressure methods in a given multistep industrial application,</li> <li>estimate economics of high-pressure processes in terms of investment and operating costs,</li> <li>perform an experiment with a high pressure apparatus under guidance,</li> <li>evaluate experimental results,</li> <li>prepare an experimental protocol.</li> </ul> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> After successful completion of this module, students are able to:</p> <ul style="list-style-type: none"> <li>present a scientific topic from an original publication in teams of 2 and defend the contents together.</li> </ul> <p><i>Autonomy</i></p>			
<b>Workload in Hours</b>	Independent Study Time 96, Study Time in Lecture 84			
<b>Credit points</b>	6			
<b>Course achievement</b>	<b>Compulsory</b>	<b>Bonus</b>	<b>Form</b>	<b>Description</b>
	Yes	15 %	Presentation	
<b>Examination</b>	Written exam			
<b>Examination duration and scale</b>	120 min			
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory			

<b>Course L1278: High pressure plant and vessel design</b>	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Arne Pietsch
<b>Language</b>	DE/EN
<b>Cycle</b>	SoSe
<b>Content</b>	<ol style="list-style-type: none"> <li>1. Basic laws and certification standards</li> <li>2. Basics for calculations of pressurized vessels</li> <li>3. Stress hypothesis</li> <li>4. Selection of materials and fabrication processes</li> <li>5. vessels with thin walls</li> <li>6. vessels with thick walls</li> <li>7. Safety installations</li> <li>8. Safety analysis</li> </ol> <p>Applications:</p> <ul style="list-style-type: none"> <li>- subsea technology (manned and unmanned vessels)</li> <li>- steam vessels</li> <li>- heat exchangers</li> <li>- LPG, LEG transport vessels</li> </ul>
<b>Literature</b>	<p>Apparate und Armaturen in der chemischen Hochdrucktechnik, Springer Verlag</p> <p>Spain and Paauwe: High Pressure Technology, Vol. I und II, M. Dekker Verlag</p> <p>AD-Merkblätter, Heumanns Verlag</p> <p>Bertucco; Vetter: High Pressure Process Technology, Elsevier Verlag</p> <p>Sherman; Stadtmüller: Experimental Techniques in High-Pressure Research, Wiley &amp; Sons Verlag</p> <p>Klapp: Apparate- und Anlagentechnik, Springer Verlag</p>

Course L0116: Industrial Processes Under High Pressure	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Carsten Zetzl
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	<p>Part I : Physical Chemistry and Thermodynamics</p> <ol style="list-style-type: none"> <li>1. Introduction: Overview, achieving high pressure, range of parameters.</li> <li>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.</li> <li>3. Influence of pressure on heterogeneous equilibria: Phenomenology of phase equilibria</li> <li>4. Overview on calculation methods for (high pressure) phase equilibria). Influence of pressure on transport processes, heat and mass transfer.</li> </ol> <p>Part II : High Pressure Processes</p> <ol style="list-style-type: none"> <li>5. Separation processes at elevated pressures: Absorption, adsorption (pressure swing adsorption), distillation (distillation of air), condensation (liquefaction of gases)</li> <li>6. Supercritical fluids as solvents: Gas extraction, cleaning, solvents in reacting systems, dyeing, impregnation, particle formation (formulation)</li> <li>7. Reactions at elevated pressures. Influence of elevated pressure on biochemical systems: Resistance against pressure</li> </ol> <p><b>Part III : Industrial production</b></p> <ol style="list-style-type: none"> <li>8. Reaction : Haber-Bosch-process, methanol-synthesis, polymerizations; Hydrations, pyrolysis, hydrocracking; Wet air oxidation, supercritical water oxidation (SCWO)</li> <li>9. Separation : Linde Process, De-Caffeination, Petrol and Bio-Refinery</li> <li>10. Industrial High Pressure Applications in Biofuel and Biodiesel Production</li> <li>11. Sterilization and Enzyme Catalysis</li> <li>12. Solids handling in high pressure processes, feeding and removal of solids, transport within the reactor.</li> <li>13. Supercritical fluids for materials processing.</li> <li>14. Cost Engineering</li> </ol> <p>Learning Outcomes: After a successful completion of this module, the student should be able to</p> <ul style="list-style-type: none"> <li>- understand of the influences of pressure on properties of compounds, phase equilibria, and production processes.</li> <li>- Apply high pressure approaches in the complex process design tasks</li> <li>- Estimate Efficiency of high pressure alternatives with respect to investment and operational costs</li> </ul> <p>Performance Record:</p> <ol style="list-style-type: none"> <li>1. Presence (28 h)</li> <li>2. Oral presentation of original scientific article (15 min) with written summary</li> <li>3. Written examination and Case study ( 2+3 : 32 h Workload)</li> </ol> <p>Workload: 60 hours total</p>
<b>Literature</b>	<p>Literatur:</p> <p>Script: High Pressure Chemical Engineering. G. Brunner: Gas Extraction. An Introduction to Fundamentals of Supercritical Fluids and the Application to Separation Processes. Steinkopff, Darmstadt, Springer, New York, 1994.</p>

<b>Course L0094: Advanced Separation Processes</b>	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Monika Johannsen
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Introduction/Overview on Properties of Supercritical Fluids (SCF) and their Application in Gas Extraction Processes</li> <li>• Solubility of Compounds in Supercritical Fluids and Phase Equilibrium with SCF</li> <li>• Extraction from Solid Substrates: Fundamentals, Hydrodynamics and Mass Transfer</li> <li>• Extraction from Solid Substrates: Applications and Processes (including Supercritical Water)</li> <li>• Countercurrent Multistage Extraction: Fundamentals and Methods, Hydrodynamics and Mass Transfer</li> <li>• Countercurrent Multistage Extraction: Applications and Processes</li> <li>• Solvent Cycle, Methods for Precipitation</li> <li>• Supercritical Fluid Chromatography (SFC): Fundamentals and Application</li> <li>• Simulated Moving Bed Chromatography (SMB)</li> <li>• Membrane Separation of Gases at High Pressures</li> <li>• Separation by Reactions in Supercritical Fluids (Enzymes)</li> </ul>
<b>Literature</b>	G. Brunner: Gas Extraction. An Introduction to Fundamentals of Supercritical Fluids and the Application to Separation Processes. Steinkopff, Darmstadt, Springer, New York, 1994.

Module M1709: Applied optimization in energy and process engineering				
<b>Courses</b>				
<b>Title</b>		<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
Applied optimization in energy and process engineering (L2693)		Integrated Lecture	2	3
Applied optimization in energy and process engineering (L2695)		Recitation Section (small)	2	3
<b>Module Responsible</b>	Prof. Mirko Skiborowski			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	Fundamentals in the field of mathematical modeling and numerical mathematics, as well as a basic understanding of process engineering processes.  In particular the contents of the module Process and Plant Engineering II			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>	<p><i>Knowledge</i> The module provides a general introduction to the basics of applied mathematical optimization and deals with application areas on different scales from the identification of kinetic models, to the optimal design of unit operations and the optimization of entire (sub)processes, as well as production planning. In addition to the basic classification and formulation of optimization problems, different solution approaches are discussed and tested during the exercises. Besides deterministic gradient-based methods, metaheuristics such as evolutionary and genetic algorithms and their application are discussed as well.</p> <ul style="list-style-type: none"> <li>• Introduction to Applied Optimization</li> <li>• Formulation of optimization problems</li> <li>• Linear Optimization</li> <li>• Nonlinear Optimization</li> <li>• Mixed-integer (non)linear optimization</li> <li>• Multi-objective optimization</li> <li>• Global optimization</li> </ul> <p><i>Skills</i> After successful participation in the module "Applied Optimization in Energy and Process Engineering", students are able to formulate the different types of optimization problems and to select appropriate solution methods in suitable software such as Matlab and GAMS and to develop improved solution strategies. Furthermore, students will be able to interpret and critically examine the results accordingly.</p> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> Students are capable of:</p> <ul style="list-style-type: none"> <li>•develop solutions in heterogeneous small groups</li> </ul> <p><i>Autonomy</i> Students are capable of:</p> <ul style="list-style-type: none"> <li>•taping new knowledge on a special subject by literature research</li> </ul>			
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56			
<b>Credit points</b>	6			
<b>Course achievement</b>	None			
<b>Examination</b>	Oral exam			
<b>Examination duration and scale</b>	35 min			
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory			



<b>Course L2693: Applied optimization in energy and process engineering</b>	
<b>Typ</b>	Integrated Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Mirko Skiborowski
<b>Language</b>	DE/EN
<b>Cycle</b>	SoSe
<b>Content</b>	<p>The lecture offers a general introduction to the basics and possibilities of applied mathematical optimization and deals with application areas on different scales from kinetics identification, optimal design of unit operations to the optimization of entire (sub)processes, and production planning. In addition to the basic classification and formulation of optimization problems, different solution approaches are discussed. Besides deterministic gradient-based methods, metaheuristics such as evolutionary and genetic algorithms and their application are discussed as well.</p> <ul style="list-style-type: none"> <li>- Introduction to Applied Optimization</li> <li>- Formulation of optimization problems</li> <li>- Linear Optimization</li> <li>- Nonlinear Optimization</li> <li>- Mixed-integer (non)linear optimization</li> <li>- Multi-objective optimization</li> <li>- Global optimization</li> </ul>
<b>Literature</b>	<p>Weicker, K., Evolutionäre Algorithmen, Springer, 2015</p> <p>Edgar, T. F., Himmelblau D. M., Lasdon, L. S., Optimization of Chemical Processes, McGraw Hill, 2001</p> <p>Biegler, L. Nonlinear Programming - Concepts, Algorithms, and Applications to Chemical Processes, 2010</p> <p>Kallrath, J. Gemischt-ganzzahlige Optimierung: Modellierung in der Praxis, Vieweg, 2002</p>

<b>Course L2695: Applied optimization in energy and process engineering</b>	
<b>Typ</b>	Recitation Section (small)
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Mirko Skiborowski
<b>Language</b>	DE/EN
<b>Cycle</b>	SoSe
<b>Content</b>	See interlocking course
<b>Literature</b>	See interlocking course

Module M0633: Industrial Process Automation				
<b>Courses</b>				
<b>Title</b>		<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
Industrial Process Automation (L0344)		Lecture	2	3
Industrial Process Automation (L0345)		Recitation Section (small)	2	3
<b>Module Responsible</b>	Prof. Alexander Schlaefer			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	mathematics and optimization methods principles of automata principles of algorithms and data structures programming skills			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>				
<i>Knowledge</i>	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'.			
<i>Skills</i>	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.			
<b>Personal Competence</b>				
<i>Social Competence</i>	The students work in teams to solve problems.			
<i>Autonomy</i>	The students can reflect their knowledge and document the results of their work.			
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56			
<b>Credit points</b>	6			
<b>Course achievement</b>	<b>Compulsory</b>	<b>Bonus</b>	<b>Form</b>	<b>Description</b>
	No	10 %	Exercises	
<b>Examination</b>	Written exam			
<b>Examination duration and scale</b>	90 minutes			
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory			

Course L0344: Industrial Process Automation	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Alexander Schlaefer
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>- foundations of problem solving and system modeling, discrete event systems</li> <li>- properties of processes, modeling using automata and Petri-nets</li> <li>- design considerations for processes (mutex, deadlock avoidance, liveness)</li> <li>- optimal scheduling for processes</li> <li>- optimal decisions when planning manufacturing systems, decisions under uncertainty</li> <li>- software design and software architectures for automation, PLCs</li> </ul>
<b>Literature</b>	<p>J. Lunze: „Automatisierungstechnik“, Oldenbourg Verlag, 2012</p> <p>Reisig: Petrinetze: Modellierungstechnik, Analysemethoden, Fallstudien; Vieweg+Teubner 2010</p> <p>Hrúz, Zhou: Modeling and Control of Discrete-event Dynamic Systems; Springer 2007</p> <p>Li, Zhou: Deadlock Resolution in Automated Manufacturing Systems, Springer 2009</p> <p>Pinedo: Planning and Scheduling in Manufacturing and Services, Springer 2009</p>

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

Module M0902: Wastewater Treatment and Air Pollution Abatement			
<b>Courses</b>			
<b>Title</b>	<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
Biological Wastewater Treatment (L0517)	Lecture	2	3
Air Pollution Abatement (L0203)	Lecture	2	3
<b>Module Responsible</b>	Dr. Swantje Pietsch		
<b>Admission Requirements</b>	None		
<b>Recommended Previous Knowledge</b>	Basic knowledge of biology and chemistry Basic knowledge of solids process engineering and separation technology		
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results		
<b>Professional Competence</b>	After successful completion of the module students are able to		
<i>Knowledge</i>	<ul style="list-style-type: none"> <li>name and explain biological processes for waste water treatment,</li> <li>characterize waste water and sewage sludge,</li> <li>discuss legal regulations in the area of emissions and air quality</li> <li>explain the effects of air pollutants on the environment,</li> <li>name and explain off gas treatment processes and to define their area of application</li> </ul>		
<i>Skills</i>	Students are able to		
<b>Personal Competence</b>	<ul style="list-style-type: none"> <li>choose and design process steps for the biological waste water treatment</li> <li>combine processes for cleaning of off-gases depending on the pollutants contained in the gases</li> </ul>		
<i>Social Competence</i>			
<i>Autonomy</i>			
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56		
<b>Credit points</b>	6		
<b>Course achievement</b>	None		
<b>Examination</b>	Written exam		
<b>Examination duration and scale</b>	90 min		
<b>Assignment for the Following Curricula</b>	Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Energy and Environmental Engineering: Specialisation Environmental Engineering: Elective Compulsory Environmental Engineering: Specialisation Waste and Energy: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Joint European Master in Environmental Studies - Cities and Sustainability: Specialisation Water: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Compulsory Water and Environmental Engineering: Specialisation Cities: Compulsory		

Course L0517: Biological Wastewater Treatment	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Joachim Behrendt
<b>Language</b>	DE/EN
<b>Cycle</b>	WiSe
<b>Content</b>	Charaterisation of Wastewater Metabolism of Microorganisms Kinetic of microbiotic processes Calculation of bioreactor for wastewater treatment Concepts of Wastewater treatment Design of WWTP Excursion to a WWTP Biofilms Biofim Reactors Anaerobic Wastewater and sldge treatment resources oriented sanitation technology

	Future challenges of wastewater treatment
<b>Literature</b>	<p><b>Gujer, Willi</b> Siedlungswasserwirtschaft : mit 84 Tabellen ISBN: 3540343296 (Gb.) URL: <a href="http://www.gbv.de/dms/bs/toc/516261924.pdf">http://www.gbv.de/dms/bs/toc/516261924.pdf</a> URL: <a href="http://deposit.d-nb.de/cgi-bin/dokserv?id=2842122&amp;prov=M&amp;dok_var=1&amp;dok_ext=htm">http://deposit.d-nb.de/cgi-bin/dokserv?id=2842122&amp;prov=M&amp;dok_var=1&amp;dok_ext=htm</a> Berlin [u.a.] : Springer, 2007 TUB_HH_Katalog</p> <p><b>Henze, Mogens</b> Wastewater treatment : biological and chemical processes ISBN: 3540422285 (Pp.) Berlin [u.a.] : Springer, 2002 TUB_HH_Katalog</p> <p><b>Imhoff, Karl</b> (Imhoff, Klaus R.) Taschenbuch der Stadtentwässerung : mit 10 Tafeln ISBN: 3486263331 ((Gb.)) München [u.a.] : Oldenbourg, 1999 TUB_HH_Katalog</p> <p><b>Lange, Jörg</b> (Otterpohl, Ralf; Steger-Hartmann, Thomas;) Abwasser : Handbuch zu einer zukunftsfähigen Wasserwirtschaft ISBN: 3980350215 (kart.) URL: <a href="http://www.gbv.de/du/services/agi/52567E5D44DA0809C12570220050BF25/000000700334">http://www.gbv.de/du/services/agi/52567E5D44DA0809C12570220050BF25/000000700334</a> Donaueschingen-Pföhrn : Mall-Beton-Verl., 2000 TUB_HH_Katalog</p> <p><b>Mudrack, Klaus</b> (Kunst, Sabine;) Biologie der Abwasserreinigung : 18 Tabellen ISBN: 382741427X URL: <a href="http://www.gbv.de/du/services/agi/94B581161B6EC747C1256E3F005A8143/420000114903">http://www.gbv.de/du/services/agi/94B581161B6EC747C1256E3F005A8143/420000114903</a> Heidelberg [u.a.] : Spektrum, Akad. Verl., 2003 TUB_HH_Katalog</p> <p><b>Tchobanoglous, George</b> (Metcalf &amp; Eddy, Inc., ;) Wastewater engineering : treatment and reuse ISBN: 0070418780 (alk. paper) ISBN: 0071122508 (ISE (*pbk)) Boston [u.a.] : McGraw-Hill, 2003 TUB_HH_Katalog</p> <p><b>Henze, Mogens</b> Activated sludge models ASM1, ASM2, ASM2d and ASM3 ISBN: 1900222248 London : IWA Publ., 2002 TUB_HH_Katalog</p> <p><b>Kunz, Peter</b> Umwelt-Bioverfahrenstechnik Vieweg, 1992</p> <p><b>Bauhaus-Universität., Arbeitsgruppe Weiterbildendes Studium Wasser und Umwelt</b> (Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall, ;) Abwasserbehandlung : Gewässerbelastung, Bemessungsgrundlagen, Mechanische Verfahren, Biologische Verfahren, Reststoffe aus der Abwasserbehandlung, Kleinkläranlagen ISBN: 3860682725 URL: <a href="http://www.gbv.de/dms/weimar/toc/513989765_toc.pdf">http://www.gbv.de/dms/weimar/toc/513989765_toc.pdf</a> URL: <a href="http://www.gbv.de/dms/weimar/abs/513989765_abs.pdf">http://www.gbv.de/dms/weimar/abs/513989765_abs.pdf</a> Weimar : Universitätsverl, 2006 TUB_HH_Katalog</p> <p><b>Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall</b> DWA-Regelwerk Hennef : DWA, 2004 TUB_HH_Katalog</p> <p><b>Wiesmann, Udo</b> (Choi, In Su; Dombrowski, Eva-Maria;) Fundamentals of biological wastewater treatment ISBN: 3527312196 (Gb.) URL: <a href="http://deposit.ddb.de/cgi-bin/dokserv?id=2774611&amp;prov=M&amp;dok_var=1&amp;dok_ext=htm">http://deposit.ddb.de/cgi-bin/dokserv?id=2774611&amp;prov=M&amp;dok_var=1&amp;dok_ext=htm</a> Weinheim : WILEY-VCH, 2007 TUB_HH_Katalog</p>

<b>Course L0203: Air Pollution Abatement</b>	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Swantje Pietsch
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	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.
<b>Literature</b>	Handbook of air pollution prevention and control, Nicholas P. Cheremisinoff. - Amsterdam [u.a.] : Butterworth-Heinemann, 2002 Atmospheric pollution : history, science, and regulation, Mark Zachary Jacobson. - Cambridge [u.a.] : Cambridge Univ. Press, 2002 Air pollution control technology handbook, Karl B. Schnelle. - Boca Raton [u.a.] : CRC Press, c 2002 Air pollution, Jeremy Colls. - 2. ed. - London [u.a.] : Spon, 2002

Module M0949: Rural Development and Resources Oriented Sanitation for different Climate Zones				
<b>Courses</b>				
<b>Title</b>		<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
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
<b>Module Responsible</b>	Prof. Ralf Otterpohl			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	Basic knowledge of the global situation with rising poverty, soil degradation, lack of water resources and sanitation			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>				
<i>Knowledge</i>	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.			
	Students are able to discuss a wide range of proven approaches in Rural Development from and for many regions of the world.			
<i>Skills</i>	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 "Holistic Planned Grazing" as developed by Allan Savory.			
<b>Personal Competence</b>				
<i>Social Competence</i>	The students are able to develop a specific topic in a team and to work out milestones according to a given plan.			
<i>Autonomy</i>	Students are in a position to work on a subject and to organize their work flow independently. They can also present on this subject.			
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56			
<b>Credit points</b>	6			
<b>Course achievement</b>	None			
<b>Examination</b>	Subject theoretical and practical work			
<b>Examination duration and scale</b>	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 semester.			
<b>Assignment for the Following Curricula</b>	Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory Environmental Engineering: Specialisation Water: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Joint European Master in Environmental Studies - Cities and Sustainability: Specialisation Water: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory			

<b>Course L0942: Rural Development and Resources Oriented Sanitation for different Climate Zones</b>	
<b>Typ</b>	Seminar
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Ralf Otterpohl
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• 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.</li> <li>• 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.</li> </ul>
<b>Literature</b>	<ul style="list-style-type: none"> <li>• J. Lange, R. Otterpohl 2000: Abwasser - Handbuch zu einer zukunftsfähigen Abwasserwirtschaft. Mallbeton Verlag (TUHH Bibliothek)</li> <li>• Winblad, Uno and Simpson-Hébert, Mayling 2004: Ecological Sanitation, EcoSanRes, Sweden (free download)</li> <li>• Schober, Sabine: WTO/TUHH Award winning Terra Preta Toilet Design: <a href="http://youtu.be/w_R09cYq6ys">http://youtu.be/w_R09cYq6ys</a></li> </ul>

<b>Course L0941: Rural Development and Resources Oriented Sanitation for different Climate Zones</b>	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Ralf Otterpohl
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Living Soil - THE key element of Rural Development</li> <li>• Participatory Approaches</li> <li>• Rainwater Harvesting</li> <li>• Ecological Sanitation Principles and practical examples</li> <li>• Permaculture Principles of Rural Development</li> <li>• Performance and Resilience of Organic Small Farms</li> <li>• Going Further: The TUHH Toolbox for Rural Development</li> <li>• EMAS Technologies, Low cost drinking water supply</li> </ul>
<b>Literature</b>	<ul style="list-style-type: none"> <li>• Miracle Water Village, India, Integrated Rainwater Harvesting, Water Efficiency, Reforestation and Sanitation: <a href="http://youtu.be/9hmkgn0nBgk">http://youtu.be/9hmkgn0nBgk</a></li> <li>• Montgomery, David R. 2007: Dirt: The Erosion of Civilizations, University of California Press</li> </ul>



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
<b>Module Responsible</b>	Prof. An-Ping Zeng			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	Knowledge of bioprocess engineering and process engineering at bachelor level			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>				
<i>Knowledge</i>	After successful completion of the module <ul style="list-style-type: none"> <li>• the students can outline the current status of research on the specific topics discussed</li> <li>• the students can explain the basic underlying principles of the respective biotechnological production processes</li> </ul>			
<i>Skills</i>	After successful completion of the module students are able to <ul style="list-style-type: none"> <li>• analyzing and evaluate current research approaches</li> <li>• Lay-out biotechnological production processes basically</li> </ul>			
<b>Personal Competence</b>				
<i>Social Competence</i>	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.			
<i>Autonomy</i>	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.			
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56			
<b>Credit points</b>	6			
<b>Course achievement</b>	None			
<b>Examination</b>	Presentation			
<b>Examination duration and scale</b>	oral presentation + discussion (45 min) + Written report (10 pages)			
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory			

Course L1065: Biotechnical Processes	
<b>Typ</b>	Project-/problem-based Learning
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Willfried Blümke
<b>Language</b>	DE/EN
<b>Cycle</b>	WiSe
<b>Content</b>	<p>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:</p> <ul style="list-style-type: none"> <li>• Asset Lifecycle</li> <li>• Digitization in the bioprocess industry</li> <li>• Basic principles of industrial bioprocess development</li> <li>• Sustainability aspects in the development of bioprocess engineering processes</li> </ul>
<b>Literature</b>	<p>Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1</p> <p>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.</p> <p>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. <a href="http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract">http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract</a></p> <p>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003</p> <p>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage</p> <p>Krahe M (2003) Biochemical Engineering. Ullmann's Encyclopedia of Industrial Chemistry. <a href="http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html">http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html</a></p> <p>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts</p>

Course L1172: Development of bioprocess engineering processes in industrial practice	
<b>Typ</b>	Seminar
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Stephan Freyer
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<p>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.</p>
<b>Literature</b>	<p>Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen]</p> <p>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.</p> <p>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. <a href="http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract">http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract</a></p> <p>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003</p> <p>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage</p> <p>Krahe M (2003) Biochemical Engineering. Ullmann's Encyclopedia of Industrial Chemistry. <a href="http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html">http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html</a></p> <p>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts</p>

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	
<b>Module Responsible</b>	Prof. Mathias Ernst			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	Basic knowledge of water chemistry. Knowledge of the core processes involved in water, gas and steam treatment			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>	<p><i>Knowledge</i> 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.</p> <p><i>Skills</i> 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.</p> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> 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.</p> <p><i>Autonomy</i> 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.</p>			
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56			
<b>Credit points</b>	6			
<b>Course achievement</b>	None			
<b>Examination</b>	Written exam			
<b>Examination duration and scale</b>	90 min			
<b>Assignment for the Following Curricula</b>	Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory Environmental Engineering: Specialisation Water: Elective Compulsory Joint European Master in Environmental Studies - Cities and Sustainability: Specialisation Water: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory			

Course L0399: Membrane Technology	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Mathias Ernst
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<p>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 electrodialysis, 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.</p> <p>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.</p> <p>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.</p>
<b>Literature</b>	<ul style="list-style-type: none"> <li>• T. Melin, R. Rautenbach: Membranverfahren: Grundlagen der Modul- und Anlagenauslegung (2., erweiterte Auflage), Springer-Verlag, Berlin 2004.</li> <li>• Marcel Mulder, Basic Principles of Membrane Technology, Kluwer Academic Publishers, Dordrecht, The Netherlands</li> <li>• Richard W. Baker, Membrane Technology and Applications, Second Edition, John Wiley &amp; Sons, Ltd., 2004</li> </ul>

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

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

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
<b>Module Responsible</b>	Prof. Martin Kaltschmitt		
<b>Admission Requirements</b>	None		
<b>Recommended Previous Knowledge</b>	none		
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results		
<b>Professional Competence</b>	<p><i>Knowledge</i> 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.</p> <p><i>Skills</i> Students are able to solve scientific problems in the context of heat and electricity supply using renewable energy systems by:</p> <ul style="list-style-type: none"> <li>• using module-comprehensive knowledge for different applications,</li> <li>• evaluating alternative input parameter regarding the solution of the task in the case of incomplete information (technical, economical and ecological parameter),</li> <li>• a systematic documentation of the work results in form of a written version, the presentation itself and the defense of contents.</li> </ul> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> Students can</p> <ul style="list-style-type: none"> <li>• respectfully work together as a team with around 2-3 members,</li> <li>• participate in subject-specific and interdisciplinary discussions in the area of dimensioning and analysis of potentials of heat and electricity supply using renewable energy, and can develop cooperated solutions,</li> <li>• defend their own work results in front of fellow students and</li> <li>• assess the performance of fellow students in comparison to their own performance. Furthermore, they can accept professional constructive criticism.</li> </ul> <p><i>Autonomy</i> 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.</p>		
<b>Workload in Hours</b>	Independent Study Time 96, Study Time in Lecture 84		
<b>Credit points</b>	6		
<b>Course achievement</b>	None		
<b>Examination</b>	Written elaboration		
<b>Examination duration and scale</b>	per course: 20 minutes presentation + written report		
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Renewable Energies: Core qualification: Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory		

<b>Course L0137: Environmental Technology and Energy Economics</b>	
<b>Typ</b>	Project-/problem-based Learning
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Martin Kaltschmitt
<b>Language</b>	DE
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Preliminary discussion with the rules of the lecture</li> <li>• 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)</li> <li>• "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</li> <li>• Submission of a written solution of the task and distribution to the participants by the student / group of students</li> <li>• Presentation of the edited theme (20 min) with PPT presentation and subsequent discussion (20 minutes)</li> <li>• Attendance is mandatory for all seminars</li> </ul>
<b>Literature</b>	Eigenständiges Literaturstudium in der Bibliothek und aus anderen Quellen.

<b>Course L0046: Electricity Generation from Renewable Sources of Energy</b>	
<b>Typ</b>	Seminar
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Martin Kaltschmitt
<b>Language</b>	DE
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Preliminary discussion with the seminar rules</li> <li>• Distribution of the topics related to the subject of the seminar to individual students / groups of students (depending on the number of participating students)</li> <li>• Delivery of a five-page summary of the seminar topic and distribution to the participants by the student / group of students</li> <li>• Presentation of the processed topic (30 min) with PPT presentation and subsequent discussion (20 minutes)</li> <li>• Attendance is mandatory for all seminars</li> </ul>
<b>Literature</b>	<ul style="list-style-type: none"> <li>• Eigenständiges Literaturstudium in der Bibliothek und aus anderen Quellen.</li> </ul>

<b>Course L0045: Heat Provision from Renewable Sources of Energy</b>	
<b>Typ</b>	Seminar
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Martin Kaltschmitt
<b>Language</b>	DE
<b>Cycle</b>	SoSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Preliminary discussion with the seminar rules</li> <li>• Distribution of the topics related to the subject of the seminar to individual students / groups of students (depending on the number of participating students)</li> <li>• Delivery of a five-page summary of the seminar topic and distribution to the participants by the student / group of students</li> <li>• Presentation of the processed topic (30 min) with PPT presentation and subsequent discussion (20 minutes)</li> <li>• Attendance is mandatory for all seminars</li> </ul>
<b>Literature</b>	Eigenständiges Literaturstudium in der Bibliothek und aus anderen Quellen.

Module M1327: Modeling of Granular Materials				
Courses				
Title	Typ	Hrs/wk	CP	
Multiscale simulation of granular materials (L1858)	Lecture	2	2	
Multiscale simulation of granular materials (L1860)	Recitation Section (small)	2	2	
Thermodynamic and kinetic modeling of the solid state (L1859)	Lecture	2	2	
<b>Module Responsible</b>	Prof. Maksym Dosta			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	Fundamentals in Mathematics, Physics and Mechanics			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>	<p><i>Knowledge</i></p> <p>After successful completion of the module the students are able to:</p> <ul style="list-style-type: none"> <li>describe modern modeling approaches which can be applied for simulation of granular materials</li> <li>analyze and evaluate possibility to apply numerical simulations on different time and length scales: from description of single particle properties on micro scale up to process simulation on macro scale</li> <li>list modern simulation system and discuss possibility of their application</li> <li>explain fundamentals of main numerical methods which are used for modeling of particulate materials</li> <li>list experimental methods to characterize granular materials</li> <li>explain fundamental thermodynamic and kinetic relations for the processes with solids</li> <li>explain theoretical background and limitations of the discrete models for the processes with solids</li> </ul> <p><i>Skills</i></p> <p>After successful completion of the module the students are able to,</p> <ul style="list-style-type: none"> <li>perform flowsheet simulation of solids processes and analyze steady-state or dynamic process behavior</li> <li>simulate behavior of granular materials on the micro scale with Discrete Element Method (DEM)</li> <li>optimize processes of mechanical process engineering (mixing, separation, crushing, ...) with DEM</li> <li>apply multiscale simulations for modeling of particulate materials</li> <li>evaluate results of numerical simulations</li> <li>select and apply appropriate thermodynamic and kinetic models for processes with solids</li> <li>select and apply appropriate discrete models for the processes with solids.</li> </ul>			
<i>Knowledge</i>				
<i>Skills</i>				
<b>Personal Competence</b>	<p><i>Social Competence</i></p> <p>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.</p> <p><i>Autonomy</i></p> <p>After completion of this module, participants will be able to solve a technical problem independently including a presentation of the results. 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.</p>			
<b>Workload in Hours</b>	Independent Study Time 96, Study Time in Lecture 84			
<b>Credit points</b>	6			
<b>Course achievement</b>	None			
<b>Examination</b>	Written exam			
<b>Examination duration and scale</b>	90 min			
<b>Assignment for the Following Curricula</b>	Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory			

<b>Course L1858: Multiscale simulation of granular materials</b>	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Maksym Dosta
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Steady-state flowsheet simulation of solids processes</li> <li>• Dynamic flowsheet simulation of solids processes</li> <li>• Introduction to Discrete Element Method (DEM)</li> <li>• Contact and breakage mechanics of granular materials</li> <li>• Extension of DEM</li> <li>• Modeling of Gas/Solid streams with coupled DEM and CFD methods</li> <li>• Population balance modelling of solids processes</li> <li>• Multiscale simulation of particulate materials</li> </ul>
<b>Literature</b>	<p>B.V. Babu (2004). Process plant simulation, Oxford Univ. Press, New York.</p> <p>S.J. Antony, W. Hoyle, Y. Ding (Eds.) (2004). Granular materials: Fundamentals and Applications, RSC, Cambridge.</p> <p>T. Pöschel (2010). Computational Granular Dynamics: Models and Algorithms, Springer Verl. Berlin.</p> <p>Other lecture materials to be distributed</p>

<b>Course L1860: Multiscale simulation of granular materials</b>	
<b>Typ</b>	Recitation Section (small)
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Maksym Dosta
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Introduction into simulation frameworks: Aspen Plus (Solids), Dyssol, MUSEN</li> <li>• Steady-state flowsheet simulation of solids processes (Aspen Plus)</li> <li>• Dynamic flowsheet simulation of solids processes (Dyssol)</li> <li>• Implementation of new contact laws and calculation of particle interactions (Matlab)</li> <li>• Simulation of granular materials with population balance models (Matlab)</li> <li>• Simulation of granular materials with discrete element method (MUSEN)</li> <li>• Optimization of several processes with discrete element method (MUSEN)</li> </ul>
<b>Literature</b>	<p>M. Dosta: Lecture notes.</p> <p>S. Attaway (2013). Matlab: A Practical Introduction to Programming and Problem Solving, Third Ed.</p> <p>Other lecture materials to be distributed</p>



<b>Course L1859: Thermodynamic and kinetic modeling of the solid state</b>	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Pavel Gurikov
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Thermodynamics of pure solids: melting/crystallization; glassy and amorphous state.</li> <li>• Thermodynamics of solid-gas equilibria: adsorption and sublimation.</li> <li>• Thermodynamics of solid-liquid equilibria: solubility in aqueous and non-aqueous systems; solid solutions; supercritical fluids as solvents.</li> <li>• Kinetics of dissolution/precipitation processes: chemical vapor deposition; drug release; hydrothermal processes.</li> <li>• Characterization of solids: contact angle, adsorption techniques, IR spectroscopy, electron microscopy.</li> <li>• Discrete models of dissolution/precipitation processes: diffusion limited aggregation; random-like and ballistic-like deposition models</li> <li>• Advanced discrete models: surface wettability; adsorption and precipitation of (bio)polymers.</li> </ul>
<b>Literature</b>	<p>Prausnitz, J.M., Lichtenthaler, R.N., and Azevedo, E.G. de (1998). Molecular Thermodynamics of Fluid-Phase Equilibria, Pearson Education.</p> <p>Elliott, S., and Elliott, S.R. (1998). The Physics and Chemistry of Solids, Wiley.</p> <p>Chopard, B., and Droz, M. (2005). Cellular Automata Modeling of Physical Systems, Cambridge University Press.</p>

Module M1736: Industrial homogeneous catalysis			
<b>Courses</b>			
<b>Title</b>	<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
Homogeneous catalysis in application (L2804)	Practical Course	1	2
Industrial homogeneous catalysis (L2802)	Lecture	2	2
Industrial homogeneous catalysis (L2803)	Recitation Section (large)	1	2
<b>Module Responsible</b>	Prof. Jakob Albert		
<b>Admission Requirements</b>	None		
<b>Recommended Previous Knowledge</b>	<ul style="list-style-type: none"> <li>• Basic knowledge from the Bachelor's degree course in process engineering</li> <li>• Chemical reaction engineering</li> <li>• Process and plant engineering</li> </ul>		
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results		
<b>Professional Competence</b>	<p><i>Knowledge</i> Students can:</p> <ul style="list-style-type: none"> <li>• explain the principle of homogeneous catalysis,</li> <li>• give an overview of the versatile applications of homogeneous catalysis in industry</li> <li>• evaluate different homogeneously catalysed reactions with regard to their technical challenges and economic significance.</li> </ul> <p><i>Skills</i> The students are able to</p> <ul style="list-style-type: none"> <li>• develop concepts for the technical implementation of homogeneously catalysed reactions,</li> <li>• evaluate practical aspects of homogeneous catalysis using laboratory experiments,</li> <li>• apply the acquired knowledge to different homogeneously catalysed reactions.</li> </ul> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> The students:</p> <ul style="list-style-type: none"> <li>• are able to work out the practical aspects of homogeneous catalysis on the basis of laboratory experiments, to carry out and evaluate the analytics of the products and to precisely summarise the results of the experiments in a protocol.</li> <li>• are able to independently discuss approaches to solutions and problems in the field of homogeneous catalysis in an interdisciplinary small group,</li> <li>• are able to work together in small groups on subject-specific tasks, Translated with <a href="http://www.DeepL.com/Translator">www.DeepL.com/Translator</a> (free version)</li> </ul> <p><i>Autonomy</i> The students</p> <ul style="list-style-type: none"> <li>• are able to independently obtain extensive literature on the topic and to gain knowledge from it,</li> <li>• are able to independently solve tasks on the topic and assess their learning status based on the feedback given,</li> <li>• are able to independently conduct experimental studies on the topic.</li> </ul>		
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56		
<b>Credit points</b>	6		
<b>Course achievement</b>	None		
<b>Examination</b>	Oral exam		
<b>Examination duration and scale</b>	30 min		
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory		

<b>Course L2804: Homogeneous catalysis in application</b>	
<b>Typ</b>	Practical Course
<b>Hrs/wk</b>	1
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 46, Study Time in Lecture 14
<b>Lecturer</b>	Prof. Jakob Albert
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	In the laboratory practical course, practical experiments are carried out with reference to industrial application of homogeneous catalysis. The hurdles to the technical implementation of homogeneously catalysed reactions are made clear to the students. The associated analysis of the experimental samples is also part of the laboratory practical course and is carried out and evaluated by the students themselves. The results are precisely summarised and scientifically presented in an experimental protocol.
<b>Literature</b>	<ol style="list-style-type: none"> <li>1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013</li> <li>2. A. Behr, „Angewandte homogene Katalyse“, Wiley-VCH, 2008</li> </ol>

<b>Course L2802: Industrial homogeneous catalysis</b>	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Jakob Albert
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Introduction to homogeneous catalysis</li> <li>• Elementary steps of catalysis</li> <li>• Homogeneous transition metal catalysis</li> <li>• Hydroformylation</li> <li>• Wacker process</li> <li>• Monsanto process</li> <li>• Shell higher olefin process (SHOP)</li> <li>• Extractive-oxidative desulphurisation (ECODS)</li> <li>• Phase transfer catalysis</li> <li>• Liquid-liquid two-phase catalysis</li> <li>• Catalyst recycling</li> <li>• Reactor concepts</li> </ul>
<b>Literature</b>	<ol style="list-style-type: none"> <li>1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013</li> <li>2. A. Behr, „Angewandte homogene Katalyse“, Wiley-VCH, 2008</li> </ol>

<b>Course L2803: Industrial homogeneous catalysis</b>	
<b>Typ</b>	Recitation Section (large)
<b>Hrs/wk</b>	1
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 46, Study Time in Lecture 14
<b>Lecturer</b>	Prof. Jakob Albert
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	In this exercise the contents of the lecture are further deepened and transferred into practical application. This is done using example tasks from practice, which are made available to the students. The students are to solve these tasks independently or in groups with the help of the lecture material. The solution is then discussed with students under scientific guidance, with parts of the task being presented on the blackboard.
<b>Literature</b>	<ol style="list-style-type: none"> <li>1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013</li> <li>2. A. Behr, „Angewandte homogene Katalyse“, Wiley-VCH, 2008</li> </ol>

## Specialization Bioprocess Engineering

In this study programm direction the emphasis is on the area of Bioprocess and Biotechnology Engineering.

For students with correspondingly good German language levels the modules in German language from the Master Biotechnology are available as well.

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
<b>Module Responsible</b>	Prof. Ralf Pörtner		
<b>Admission Requirements</b>	None		
<b>Recommended Previous Knowledge</b>	Knowledge of bioprocess engineering and process engineering at bachelor level		
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results		
<b>Professional Competence</b>	<p><i>Knowledge</i></p> <p>After successful completion of the module the students</p> <ul style="list-style-type: none"> <li>- know the basic principles of cell and tissue culture</li> <li>- know the relevant metabolic and physiological properties of animal and human cells</li> <li>- are able to explain and describe the basic underlying principles of bioreactors for cell and tissue cultures, in contrast to microbial fermentations</li> <li>- are able to explain the essential steps (unit operations) in downstream</li> <li>- are able to explain, analyze and describe the kinetic relationships and significant litigation strategies for cell culture reactors</li> </ul> <p><i>Skills</i></p> <p>The students are able</p> <ul style="list-style-type: none"> <li>- to analyze and perform mathematical modeling to cellular metabolism at a higher level</li> <li>- are able to develop process control strategies for cell culture systems</li> </ul> <p><b>Personal Competence</b></p> <p><i>Social Competence</i></p> <p>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.</p> <p>The students can reflect their specific knowledge orally and discuss it with other students and teachers.</p> <p><i>Autonomy</i></p> <p>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.</p>		
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56		
<b>Credit points</b>	6		
<b>Course achievement</b>	None		
<b>Examination</b>	Written exam		
<b>Examination duration and scale</b>	120 min		
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory		

Course L0355: Fundamentals of Cell and Tissue Engineering	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Ralf Pörtner, Prof. An-Ping Zeng
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	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) Stoichiometry and kinetics of cell growth and product formation (growth of mammalian cells, quantitative description of cell growth & product formation, kinetics of growth)
<b>Literature</b>	Butler, M (2004) Animal Cell Culture Technology - The basics, 2 <sup>nd</sup> ed. Oxford University Press  Ozturk SS, Hu WS (eds) (2006) Cell Culture Technology For Pharmaceutical and Cell-Based Therapies. Taylor & Francis Group, New York  Eibl, R.; D. Eibl; R. Pörtner; G. Catapano and P. Czermak: Cell and Tissue Reaction Engineering, Springer (2008). ISBN 978-3-540-68175-5  Pörtner R (ed) (2013) Animal Cell Biotechnology - Methods and Protocols. Humana Press

Course L0356: Bioprocess Engineering for Medical Applications	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Ralf Pörtner
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	Requirements for cell culture processes, 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
<b>Literature</b>	Butler, M (2004) Animal Cell Culture Technology - The basics, 2 <sup>nd</sup> ed. Oxford University Press  Ozturk SS, Hu WS (eds) (2006) Cell Culture Technology For Pharmaceutical and Cell-Based Therapies. Taylor & Francis Group, New York  Eibl, R.; D. Eibl; R. Pörtner; G. Catapano and P. Czermak: Cell and Tissue Reaction Engineering, Springer (2008). ISBN 978-3-540-68175-5  Pörtner R (ed) (2013) Animal Cell Biotechnology - Methods and Protocols. Humana Press

Module M1702: Process Imaging				
<b>Courses</b>				
<b>Title</b>		<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
Process Imaging (L2723)		Lecture	2	3
Process Imaging (L2724)		Project-/problem-based Learning	2	3
<b>Module Responsible</b>	Prof. Alexander Penn			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>				
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b> <i>Knowledge</i> <i>Skills</i>				
<b>Personal Competence</b> <i>Social Competence</i> <i>Autonomy</i>				
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56			
<b>Credit points</b>	6			
<b>Course achievement</b>	None			
<b>Examination</b>	Written exam			
<b>Examination duration and scale</b>	120 min			
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory			

Course L2723: Process Imaging	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Alexander Penn
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	
<b>Literature</b>	

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<b>Course L2724: Process Imaging</b>	
<b>Typ</b>	Project-/problem-based Learning
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Alexander Penn
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	
<b>Literature</b>	

Module M0975: Industrial Bioprocesses in Practice				
<b>Courses</b>				
<b>Title</b>		<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
Industrial biotechnology in Chemical Industry (L2276)		Seminar	2	3
Practice in bioprocess engineering (L2275)		Seminar	2	3
<b>Module Responsible</b>	Prof. Andreas Liese			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	Knowledge of bioprocess engineering and process engineering at bachelor level			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>				
<i>Knowledge</i>	After successful completion of the module <ul style="list-style-type: none"> <li>the students can outline the current status of research on the specific topics discussed</li> <li>the students can explain the basic underlying principles of the respective industrial biotransformations</li> </ul>			
<i>Skills</i>	After successful completion of the module students are able to <ul style="list-style-type: none"> <li>analyze and evaluate current research approaches</li> <li>plan industrial biotransformations basically</li> </ul>			
<b>Personal Competence</b>				
<i>Social Competence</i>	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.			
<i>Autonomy</i>	The students are able independently to present the results of their subtasks in a presentation			
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56			
<b>Credit points</b>	6			
<b>Course achievement</b>	None			
<b>Examination</b>	Presentation			
<b>Examination duration and scale</b>	each seminar 15 min lecture and 15 min discussion			
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Management and Controlling: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory			



<b>Course L2276: Industrial biotechnology in Chemical Industry</b>	
<b>Typ</b>	Seminar
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Stephan Freyer
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	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.
<b>Literature</b>	<p>Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen]</p> <p>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.</p> <p>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. <a href="http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract">http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract</a></p> <p>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003</p> <p>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage</p> <p>Krahe M (2003) Biochemical Engineering. Ullmann's Encyclopedia of Industrial Chemistry. <a href="http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html">http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html</a></p> <p>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts</p>

<b>Course L2275: Practice in bioprocess engineering</b>	
<b>Typ</b>	Seminar
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Willfried Blümke
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	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.
<b>Literature</b>	<p>Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen]</p> <p>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.</p> <p>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. <a href="http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract">http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract</a></p> <p>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003</p> <p>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage</p> <p>Krahe M (2003) Biochemical Engineering. Ullmann's Encyclopedia of Industrial Chemistry. <a href="http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html">http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html</a></p> <p>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts</p>

Module M1709: Applied optimization in energy and process engineering				
Courses				
Title	Typ	Hrs/wk	CP	
Applied optimization in energy and process engineering (L2693)	Integrated Lecture	2	3	
Applied optimization in energy and process engineering (L2695)	Recitation Section (small)	2	3	
<b>Module Responsible</b>	Prof. Mirko Skiborowski			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	Fundamentals in the field of mathematical modeling and numerical mathematics, as well as a basic understanding of process engineering processes.  In particular the contents of the module Process and Plant Engineering II			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>	<p><i>Knowledge</i> The module provides a general introduction to the basics of applied mathematical optimization and deals with application areas on different scales from the identification of kinetic models, to the optimal design of unit operations and the optimization of entire (sub)processes, as well as production planning. In addition to the basic classification and formulation of optimization problems, different solution approaches are discussed and tested during the exercises. Besides deterministic gradient-based methods, metaheuristics such as evolutionary and genetic algorithms and their application are discussed as well.</p> <ul style="list-style-type: none"> <li>• Introduction to Applied Optimization</li> <li>• Formulation of optimization problems</li> <li>• Linear Optimization</li> <li>• Nonlinear Optimization</li> <li>• Mixed-integer (non)linear optimization</li> <li>• Multi-objective optimization</li> <li>• Global optimization</li> </ul> <p><i>Skills</i> After successful participation in the module "Applied Optimization in Energy and Process Engineering", students are able to formulate the different types of optimization problems and to select appropriate solution methods in suitable software such as Matlab and GAMS and to develop improved solution strategies. Furthermore, students will be able to interpret and critically examine the results accordingly.</p> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> Students are capable of:</p> <ul style="list-style-type: none"> <li>•develop solutions in heterogeneous small groups</li> </ul> <p><i>Autonomy</i> Students are capable of:</p> <ul style="list-style-type: none"> <li>•taping new knowledge on a special subject by literature research</li> </ul>			
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56			
<b>Credit points</b>	6			
<b>Course achievement</b>	None			
<b>Examination</b>	Oral exam			
<b>Examination duration and scale</b>	35 min			
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory			

<b>Course L2693: Applied optimization in energy and process engineering</b>	
<b>Typ</b>	Integrated Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Mirko Skiborowski
<b>Language</b>	DE/EN
<b>Cycle</b>	SoSe
<b>Content</b>	<p>The lecture offers a general introduction to the basics and possibilities of applied mathematical optimization and deals with application areas on different scales from kinetics identification, optimal design of unit operations to the optimization of entire (sub)processes, and production planning. In addition to the basic classification and formulation of optimization problems, different solution approaches are discussed. Besides deterministic gradient-based methods, metaheuristics such as evolutionary and genetic algorithms and their application are discussed as well.</p> <ul style="list-style-type: none"> <li>- Introduction to Applied Optimization</li> <li>- Formulation of optimization problems</li> <li>- Linear Optimization</li> <li>- Nonlinear Optimization</li> <li>- Mixed-integer (non)linear optimization</li> <li>- Multi-objective optimization</li> <li>- Global optimization</li> </ul>
<b>Literature</b>	<p>Weicker, K., Evolutionäre Algorithmen, Springer, 2015</p> <p>Edgar, T. F., Himmelblau D. M., Lasdon, L. S., Optimization of Chemical Processes, McGraw Hill, 2001</p> <p>Biegler, L. Nonlinear Programming - Concepts, Algorithms, and Applications to Chemical Processes, 2010</p> <p>Kallrath, J. Gemischt-ganzzahlige Optimierung: Modellierung in der Praxis, Vieweg, 2002</p>

<b>Course L2695: Applied optimization in energy and process engineering</b>	
<b>Typ</b>	Recitation Section (small)
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Mirko Skiborowski
<b>Language</b>	DE/EN
<b>Cycle</b>	SoSe
<b>Content</b>	See interlocking course
<b>Literature</b>	See interlocking course

Module M1125: Bioresources and Biorefineries			
Courses			
Title	Typ	Hrs/wk	CP
Biorefinery Technology (L0895)	Lecture	2	2
Biorefinery Technologie (L0974)	Recitation Section (small)	1	1
Bioresource Management (L0892)	Lecture	2	2
Bioresource Management (L0893)	Recitation Section (small)	1	1
<b>Module Responsible</b>	Dr. Ina Körner		
<b>Admission Requirements</b>	None		
<b>Recommended Previous Knowledge</b>	Basics on engineering; Basics of waste and energy management		
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results		
<b>Professional Competence</b>			
<i>Knowledge</i>	Students can give an overview on principles and theories in the field's bioresource management and biorefinery technology and can explain specialized terms and technologies.		
<i>Skills</i>	Students are capable of applying knowledge and know-how in the field's bioresource management and biorefinery technology in order to perform technical and regional-planning tasks. They are also able to discuss the links to waste management, energy management and biotechnology.		
<b>Personal Competence</b>			
<i>Social Competence</i>	Students can work goal-oriented with others and communicate and document their interests and knowledge in an acceptable way.		
<i>Autonomy</i>	Students are able to solve independently, with the aid of pointers, practice-related tasks bearing in mind possible societal consequences.		
<b>Workload in Hours</b>	Independent Study Time 96, Study Time in Lecture 84		
<b>Credit points</b>	6		
<b>Course achievement</b>	None		
<b>Examination</b>	Written exam		
<b>Examination duration and scale</b>	90 min		
<b>Assignment for the Following Curricula</b>	Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Environmental Engineering: Specialisation Waste and Energy: Elective Compulsory Environmental Engineering: Specialisation Biotechnology: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Joint European Master in Environmental Studies - Cities and Sustainability: Specialisation Energy: Elective Compulsory		

Course L0895: Biorefinery Technology	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Ina Körner
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<p>The Europe 2020 strategy calls for bioeconomy as the key for smart and green growth of today. Biorefineries are the fundamental part on the way to convert the use of fossil-based society to bio-based society. For this reason, agriculture and forestry sectors are increasingly deliver bioresources. It is not only for their traditional applications in the food and feed sectors such as pulp or paper and construction material productions, but also to produce bioenergy and bio-based products such as bio-plastics. However although bioresources are renewable, they are considered as limited resources as well. The bioeconomy's limitation factor is the availability land on our world. In the context of the development of the bioeconomy, the sustainable and reliable supply of non-food biomass feedstock is a critical success factor for the long-term perspective of bioenergy and other bio-based products production. Biorefineries are complex of technologies and process cascades using the available primary, secondary and tertiary bioresources to produce a multitude of products - a product mix from material and energy products.</p> <p>The lecture gives an overview on biorefinery technology and shall contribute to promotion of international biorefinery developments.</p> <p>Lectures:</p> <ul style="list-style-type: none"> <li>• What is a biorefinery: Overview on basic organic substrates and processes which lead to material and energy products</li> <li>• The way from a fossil based to a biobased economy in the 21st century</li> <li>• The worlds most advanced biorefinery</li> <li>• Presentation of various biorefinery systems and their products (e.g. lignocellulose biorefinery, green biorefinery, whole plant biorefinery, civilization biorefinery)</li> <li>• Example projects (e.g. combination of anaerobic digestion and composting in practice; demonstration project in Hamburgs city quarter Jenfelder Au)</li> </ul> <p>The lectures will be accompanied by technical tours. Optional it is also possible to visit more biorefinery lectures in the University of Hamburg (lectures in German only).</p> <p>In the exercise students have the possibility to work in groups on a biorefinery project or to work on a student-specific task.</p>
<b>Literature</b>	<p>Biorefineries - Industrial Process and Products - Status Qua and Future directions by Kamm, Gruber and Kamm (2010); Wiley VCH, available on-line in TUHH-library</p> <p>Powerpoint-Präsentations / selected Publications / further recommendations depending on the actual developments</p> <p>Industrial Biorefineries and White Biorefinery, by Pandey, Höfer, Larroche, Taherzadeh, Nampoothiri (Eds.); (2014 book development in progress)</p>

Course L0974: Biorefinery Technologie	
<b>Typ</b>	Recitation Section (small)
<b>Hrs/wk</b>	1
<b>CP</b>	1
<b>Workload in Hours</b>	Independent Study Time 16, Study Time in Lecture 14
<b>Lecturer</b>	Dr. Ina Körner
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<p>1. ) Selection of a topic within the thematic area "Biorefinery Technologie" from a given list or self-selected.</p> <p>2.) Self-dependent recherches to the topic.</p> <p>3.) Preparation of a written elaboration.</p> <p>4.) Presentation of the results in the group.</p>
<b>Literature</b>	<p>Vom Thema abhängig. Eigene Recherchen nötig.</p> <p>Depending on the topic. Own recheches necessary.</p>

Course L0892: Bioresource Management	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Ina Körner
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<p>In the context of limited fossil resources, climate change mitigation and increasing population growth, Bioresources has a special role. They have to feed the population and in the same time they are important for material production such as pulp and paper or construction materials. Moreover they become more and more important in chemical industry and in energy provision as fossil substitution. Although Bioresources are renewable, they are also considered as limited resources. The availability of land on our planet is the main limitation factor. The sustainable and reliable supply of non-food biomass feedstock is a critical for successful and long term perspective on production of bioenergy and other bio-based products. As the consequence, the increasing competition and shortages continue to happen at the traditional sectors. On the other side, huge unused but potentials residue on waste and wastewater sector exist. Nowadays, a lot of activities to develop better processes, to create new bio-based products in order to become more efficient, the inclusion of secondary and tertiary bio-resources in the valorisation chain are going on.</p> <p>The lecture deals with the current state-of-the-art of bioresource management. It shows deficits and potentials for improvement especially in the sector of utilization of organic residues for material and energy generation:</p> <p><i>Lectures on:</i></p> <ul style="list-style-type: none"> <li>• Bioresource generation and utilization including lost potentials today</li> <li>• Basic biological, mechanical, physico-chemical and logistical processes</li> <li>• The conflict of material vs. energy generation from wood / waste wood</li> <li>• The basics of pulp &amp; paper production including waste paper recycling</li> <li>• The Pros and Cons from biogas and compost production</li> </ul> <p><i>Special lectures by invited guests from research and practice:</i></p> <ul style="list-style-type: none"> <li>• Pathways of waste organics on the example of Hamburg's City Cleaning Company</li> <li>• Utilization options of landscaping materials on the example of grass</li> <li>• Increase of process efficiency of anaerobic digestions</li> <li>• Decision support tools on the example of an municipality in Indonesia</li> </ul> <p><i>Optional: Technical visits</i></p>
<b>Literature</b>	Power-Point presentations in STUD-IP

Course L0893: Bioresource Management	
<b>Typ</b>	Recitation Section (small)
<b>Hrs/wk</b>	1
<b>CP</b>	1
<b>Workload in Hours</b>	Independent Study Time 16, Study Time in Lecture 14
<b>Lecturer</b>	Dr. Ina Körner
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	See interlocking course
<b>Literature</b>	See interlocking course

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
<b>Module Responsible</b>	Prof. An-Ping Zeng			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	Knowledge of bioprocess engineering and process engineering at bachelor level			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>				
<i>Knowledge</i>	After successful completion of the module <ul style="list-style-type: none"> <li>• the students can outline the current status of research on the specific topics discussed</li> <li>• the students can explain the basic underlying principles of the respective biotechnological production processes</li> </ul>			
<i>Skills</i>	After successful completion of the module students are able to <ul style="list-style-type: none"> <li>• analyzing and evaluate current research approaches</li> <li>• Lay-out biotechnological production processes basically</li> </ul>			
<b>Personal Competence</b>				
<i>Social Competence</i>	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.			
<i>Autonomy</i>	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.			
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56			
<b>Credit points</b>	6			
<b>Course achievement</b>	None			
<b>Examination</b>	Presentation			
<b>Examination duration and scale</b>	oral presentation + discussion (45 min) + Written report (10 pages)			
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory			

Course L1065: Biotechnical Processes	
<b>Typ</b>	Project-/problem-based Learning
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Willfried Blümke
<b>Language</b>	DE/EN
<b>Cycle</b>	WiSe
<b>Content</b>	<p>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:</p> <ul style="list-style-type: none"> <li>• Asset Lifecycle</li> <li>• Digitization in the bioprocess industry</li> <li>• Basic principles of industrial bioprocess development</li> <li>• Sustainability aspects in the development of bioprocess engineering processes</li> </ul>
<b>Literature</b>	<p>Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1</p> <p>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.</p> <p>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. <a href="http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract">http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract</a></p> <p>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003</p> <p>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage</p> <p>Krahe M (2003) Biochemical Engineering. Ullmann's Encyclopedia of Industrial Chemistry. <a href="http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html">http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html</a></p> <p>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts</p>

Course L1172: Development of bioprocess engineering processes in industrial practice	
<b>Typ</b>	Seminar
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Stephan Freyer
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<p>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.</p>
<b>Literature</b>	<p>Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen]</p> <p>Bailey, James and David F. Ollis: Biochemical Engineering Fundamentals. -2nd ed.; New York: McGraw Hill, 1986.</p> <p>Becker, Th. et al. (2008) Biotechnology. Ullmann's Encyclopedia of Industrial Chemistry. <a href="http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract">http://www.mrw.interscience.wiley.com/emrw/9783527306732/ueic/article/a04_107/current/abstract</a></p> <p>Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2003</p> <p>Hass, V. und R. Pörtner: Praxis der Bioprozesstechnik. Spektrum Akademischer Verlag (2011), 2. Auflage</p> <p>Krahe M (2003) Biochemical Engineering. Ullmann's Encyclopedia of Industrial Chemistry. <a href="http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html">http://www.mrw.interscience.wiley.com/ueic/articles/b04_381/frame.html</a></p> <p>Schuler, M.L. / Kargi, F.: Bioprocess Engineering - Basic concepts</p>



Module M1736: Industrial homogeneous catalysis			
<b>Courses</b>			
<b>Title</b>	<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
Homogeneous catalysis in application (L2804)	Practical Course	1	2
Industrial homogeneous catalysis (L2802)	Lecture	2	2
Industrial homogeneous catalysis (L2803)	Recitation Section (large)	1	2
<b>Module Responsible</b>	Prof. Jakob Albert		
<b>Admission Requirements</b>	None		
<b>Recommended Previous Knowledge</b>	<ul style="list-style-type: none"> <li>• Basic knowledge from the Bachelor's degree course in process engineering</li> <li>• Chemical reaction engineering</li> <li>• Process and plant engineering</li> </ul>		
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results		
<b>Professional Competence</b>	<p><i>Knowledge</i> Students can:</p> <ul style="list-style-type: none"> <li>• explain the principle of homogeneous catalysis,</li> <li>• give an overview of the versatile applications of homogeneous catalysis in industry</li> <li>• evaluate different homogeneously catalysed reactions with regard to their technical challenges and economic significance.</li> </ul> <p><i>Skills</i> The students are able to</p> <ul style="list-style-type: none"> <li>• develop concepts for the technical implementation of homogeneously catalysed reactions,</li> <li>• evaluate practical aspects of homogeneous catalysis using laboratory experiments,</li> <li>• apply the acquired knowledge to different homogeneously catalysed reactions.</li> </ul> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> The students:</p> <ul style="list-style-type: none"> <li>• are able to work out the practical aspects of homogeneous catalysis on the basis of laboratory experiments, to carry out and evaluate the analytics of the products and to precisely summarise the results of the experiments in a protocol.</li> <li>• are able to independently discuss approaches to solutions and problems in the field of homogeneous catalysis in an interdisciplinary small group,</li> <li>• are able to work together in small groups on subject-specific tasks, Translated with <a href="http://www.DeepL.com/Translator">www.DeepL.com/Translator</a> (free version)</li> </ul> <p><i>Autonomy</i> The students</p> <ul style="list-style-type: none"> <li>• are able to independently obtain extensive literature on the topic and to gain knowledge from it,</li> <li>• are able to independently solve tasks on the topic and assess their learning status based on the feedback given,</li> <li>• are able to independently conduct experimental studies on the topic.</li> </ul>		
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56		
<b>Credit points</b>	6		
<b>Course achievement</b>	None		
<b>Examination</b>	Oral exam		
<b>Examination duration and scale</b>	30 min		
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory		

<b>Course L2804: Homogeneous catalysis in application</b>	
<b>Typ</b>	Practical Course
<b>Hrs/wk</b>	1
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 46, Study Time in Lecture 14
<b>Lecturer</b>	Prof. Jakob Albert
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	In the laboratory practical course, practical experiments are carried out with reference to industrial application of homogeneous catalysis. The hurdles to the technical implementation of homogeneously catalysed reactions are made clear to the students. The associated analysis of the experimental samples is also part of the laboratory practical course and is carried out and evaluated by the students themselves. The results are precisely summarised and scientifically presented in an experimental protocol.
<b>Literature</b>	<ol style="list-style-type: none"> <li>1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013</li> <li>2. A. Behr, „Angewandte homogene Katalyse“, Wiley-VCH, 2008</li> </ol>

<b>Course L2802: Industrial homogeneous catalysis</b>	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Jakob Albert
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Introduction to homogeneous catalysis</li> <li>• Elementary steps of catalysis</li> <li>• Homogeneous transition metal catalysis</li> <li>• Hydroformylation</li> <li>• Wacker process</li> <li>• Monsanto process</li> <li>• Shell higher olefin process (SHOP)</li> <li>• Extractive-oxidative desulphurisation (ECODS)</li> <li>• Phase transfer catalysis</li> <li>• Liquid-liquid two-phase catalysis</li> <li>• Catalyst recycling</li> <li>• Reactor concepts</li> </ul>
<b>Literature</b>	<ol style="list-style-type: none"> <li>1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013</li> <li>2. A. Behr, „Angewandte homogene Katalyse“, Wiley-VCH, 2008</li> </ol>

<b>Course L2803: Industrial homogeneous catalysis</b>	
<b>Typ</b>	Recitation Section (large)
<b>Hrs/wk</b>	1
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 46, Study Time in Lecture 14
<b>Lecturer</b>	Prof. Jakob Albert
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	In this exercise the contents of the lecture are further deepened and transferred into practical application. This is done using example tasks from practice, which are made available to the students. The students are to solve these tasks independently or in groups with the help of the lecture material. The solution is then discussed with students under scientific guidance, with parts of the task being presented on the blackboard.
<b>Literature</b>	<ol style="list-style-type: none"> <li>1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013</li> <li>2. A. Behr, „Angewandte homogene Katalyse“, Wiley-VCH, 2008</li> </ol>

## Specialization Chemical Process Engineering

Here the qualification in process/chemical engineering should be obtained.

For students with correspondingly good German language levels the modules in German language from the Master Process Engineering are available as well.

Module M0617: High Pressure Chemical Engineering			
<b>Courses</b>			
<b>Title</b>		<b>Typ</b>	<b>Hrs/wk</b> <b>CP</b>
High pressure plant and vessel design (L1278)		Lecture	2                  2
Industrial Processes Under High Pressure (L0116)		Lecture	2                  2
Advanced Separation Processes (L0094)		Lecture	2                  2
<b>Module Responsible</b>	Dr. Monika Johannsen		
<b>Admission Requirements</b>	None		
<b>Recommended Previous Knowledge</b>	Fundamentals of Chemistry, Chemical Engineering, Fluid Process Engineering, Thermal Separation Processes, Thermodynamics, Heterogeneous Equilibria		
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results		
<b>Professional Competence</b>			
<i>Knowledge</i>	After a successful completion of this module, students can: <ul style="list-style-type: none"> <li>• explain the influence of pressure on the properties of compounds, phase equilibria, and production processes,</li> <li>• describe the thermodynamic fundamentals of separation processes with supercritical fluids,</li> <li>• exemplify models for the description of solid extraction and countercurrent extraction,</li> <li>• discuss parameters for optimization of processes with supercritical fluids.</li> </ul>		
<i>Skills</i>	After successful completion of this module, students are able to: <ul style="list-style-type: none"> <li>• compare separation processes with supercritical fluids and conventional solvents,</li> <li>• assess the application potential of high-pressure processes at a given separation task,</li> <li>• include high pressure methods in a given multistep industrial application,</li> <li>• estimate economics of high-pressure processes in terms of investment and operating costs,</li> <li>• perform an experiment with a high pressure apparatus under guidance,</li> <li>• evaluate experimental results,</li> <li>• prepare an experimental protocol.</li> </ul>		
<b>Personal Competence</b>			
<i>Social Competence</i>	After successful completion of this module, students are able to: <ul style="list-style-type: none"> <li>• present a scientific topic from an original publication in teams of 2 and defend the contents together.</li> </ul>		
<i>Autonomy</i>			
<b>Workload in Hours</b>	Independent Study Time 96, Study Time in Lecture 84		
<b>Credit points</b>	6		
<b>Course achievement</b>	<b>Compulsory</b>	<b>Bonus</b>	<b>Form</b> <b>Description</b>
	Yes	15 %	Presentation
<b>Examination</b>	Written exam		
<b>Examination duration and scale</b>	120 min		
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory		

<b>Course L1278: High pressure plant and vessel design</b>	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Arne Pietsch
<b>Language</b>	DE/EN
<b>Cycle</b>	SoSe
<b>Content</b>	<ol style="list-style-type: none"> <li>1. Basic laws and certification standards</li> <li>2. Basics for calculations of pressurized vessels</li> <li>3. Stress hypothesis</li> <li>4. Selection of materials and fabrication processes</li> <li>5. vessels with thin walls</li> <li>6. vessels with thick walls</li> <li>7. Safety installations</li> <li>8. Safety analysis</li> </ol> <p>Applications:</p> <ul style="list-style-type: none"> <li>- subsea technology (manned and unmanned vessels)</li> <li>- steam vessels</li> <li>- heat exchangers</li> <li>- LPG, LEG transport vessels</li> </ul>
<b>Literature</b>	<p>Apparate und Armaturen in der chemischen Hochdrucktechnik, Springer Verlag</p> <p>Spain and Paauwe: High Pressure Technology, Vol. I und II, M. Dekker Verlag</p> <p>AD-Merkblätter, Heumanns Verlag</p> <p>Bertucco; Vetter: High Pressure Process Technology, Elsevier Verlag</p> <p>Sherman; Stadtmüller: Experimental Techniques in High-Pressure Research, Wiley &amp; Sons Verlag</p> <p>Klapp: Apparate- und Anlagentechnik, Springer Verlag</p>

Course L0116: Industrial Processes Under High Pressure	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Carsten Zetzl
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	<p>Part I : Physical Chemistry and Thermodynamics</p> <ol style="list-style-type: none"> <li>1. Introduction: Overview, achieving high pressure, range of parameters.</li> <li>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.</li> <li>3. Influence of pressure on heterogeneous equilibria: Phenomenology of phase equilibria</li> <li>4. Overview on calculation methods for (high pressure) phase equilibria). Influence of pressure on transport processes, heat and mass transfer.</li> </ol> <p>Part II : High Pressure Processes</p> <ol style="list-style-type: none"> <li>5. Separation processes at elevated pressures: Absorption, adsorption (pressure swing adsorption), distillation (distillation of air), condensation (liquefaction of gases)</li> <li>6. Supercritical fluids as solvents: Gas extraction, cleaning, solvents in reacting systems, dyeing, impregnation, particle formation (formulation)</li> <li>7. Reactions at elevated pressures. Influence of elevated pressure on biochemical systems: Resistance against pressure</li> </ol> <p><b>Part III : Industrial production</b></p> <ol style="list-style-type: none"> <li>8. Reaction : Haber-Bosch-process, methanol-synthesis, polymerizations; Hydrations, pyrolysis, hydrocracking; Wet air oxidation, supercritical water oxidation (SCWO)</li> <li>9. Separation : Linde Process, De-Caffeination, Petrol and Bio-Refinery</li> <li>10. Industrial High Pressure Applications in Biofuel and Biodiesel Production</li> <li>11. Sterilization and Enzyme Catalysis</li> <li>12. Solids handling in high pressure processes, feeding and removal of solids, transport within the reactor.</li> <li>13. Supercritical fluids for materials processing.</li> <li>14. Cost Engineering</li> </ol> <p>Learning Outcomes: After a successful completion of this module, the student should be able to</p> <ul style="list-style-type: none"> <li>- understand of the influences of pressure on properties of compounds, phase equilibria, and production processes.</li> <li>- Apply high pressure approaches in the complex process design tasks</li> <li>- Estimate Efficiency of high pressure alternatives with respect to investment and operational costs</li> </ul> <p>Performance Record:</p> <ol style="list-style-type: none"> <li>1. Presence (28 h)</li> <li>2. Oral presentation of original scientific article (15 min) with written summary</li> <li>3. Written examination and Case study ( 2+3 : 32 h Workload)</li> </ol> <p>Workload: 60 hours total</p>
<b>Literature</b>	<p>Literatur:</p> <p>Script: High Pressure Chemical Engineering.</p> <p>G. Brunner: Gas Extraction. An Introduction to Fundamentals of Supercritical Fluids and the Application to Separation Processes. Steinkopff, Darmstadt, Springer, New York, 1994.</p>

Course L0094: Advanced Separation Processes	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Monika Johannsen
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Introduction/Overview on Properties of Supercritical Fluids (SCF) and their Application in Gas Extraction Processes</li> <li>• Solubility of Compounds in Supercritical Fluids and Phase Equilibrium with SCF</li> <li>• Extraction from Solid Substrates: Fundamentals, Hydrodynamics and Mass Transfer</li> <li>• Extraction from Solid Substrates: Applications and Processes (including Supercritical Water)</li> <li>• Countercurrent Multistage Extraction: Fundamentals and Methods, Hydrodynamics and Mass Transfer</li> <li>• Countercurrent Multistage Extraction: Applications and Processes</li> <li>• Solvent Cycle, Methods for Precipitation</li> <li>• Supercritical Fluid Chromatography (SFC): Fundamentals and Application</li> <li>• Simulated Moving Bed Chromatography (SMB)</li> <li>• Membrane Separation of Gases at High Pressures</li> <li>• Separation by Reactions in Supercritical Fluids (Enzymes)</li> </ul>
<b>Literature</b>	G. Brunner: Gas Extraction. An Introduction to Fundamentals of Supercritical Fluids and the Application to Separation Processes. Steinkopff, Darmstadt, Springer, New York, 1994.

Module M1702: Process Imaging				
<b>Courses</b>				
<b>Title</b>		<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
Process Imaging (L2723)		Lecture	2	3
Process Imaging (L2724)		Project-/problem-based Learning	2	3
<b>Module Responsible</b>	Prof. Alexander Penn			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>				
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b> <i>Knowledge</i> <i>Skills</i>				
<b>Personal Competence</b> <i>Social Competence</i> <i>Autonomy</i>				
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56			
<b>Credit points</b>	6			
<b>Course achievement</b>	None			
<b>Examination</b>	Written exam			
<b>Examination duration and scale</b>	120 min			
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory			

Course L2723: Process Imaging	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Alexander Penn
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	
<b>Literature</b>	

<b>Course L2724: Process Imaging</b>	
<b>Typ</b>	Project-/problem-based Learning
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Alexander Penn
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	
<b>Literature</b>	



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
<b>Module Responsible</b>	Prof. Daniel Ruprecht		
<b>Admission Requirements</b>	None		
<b>Recommended Previous Knowledge</b>	<ul style="list-style-type: none"> <li>Mathematik I, II, III für Ingenieurstudierende (deutsch oder englisch) oder Analysis &amp; Lineare Algebra I + II sowie Analysis III für Technomathematiker</li> <li>Basic MATLAB knowledge</li> </ul>		
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results		
<b>Professional Competence</b>	<p><i>Knowledge</i> Students are able to</p> <ul style="list-style-type: none"> <li>list numerical methods for the solution of ordinary differential equations and explain their core ideas,</li> <li>repeat convergence statements for the treated numerical methods (including the prerequisites tied to the underlying problem),</li> <li>explain aspects regarding the practical execution of a method.</li> <li>select the appropriate numerical method for concrete problems, implement the numerical algorithms efficiently and interpret the numerical results</li> </ul> <p><i>Skills</i> Students are able to</p> <ul style="list-style-type: none"> <li>implement (MATLAB), apply and compare numerical methods for the solution of ordinary differential equations,</li> <li>to justify the convergence behaviour of numerical methods with respect to the posed problem and selected algorithm,</li> <li>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.</li> </ul> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> Students are able to</p> <ul style="list-style-type: none"> <li>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.</li> </ul> <p><i>Autonomy</i> Students are capable</p> <ul style="list-style-type: none"> <li>to assess whether the supporting theoretical and practical exercises are better solved individually or in a team,</li> <li>to assess their individual progress and, if necessary, to ask questions and seek help.</li> </ul>		
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56		
<b>Credit points</b>	6		
<b>Course achievement</b>	None		
<b>Examination</b>	Written exam		
<b>Examination duration and scale</b>	90 min		
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Computer Science: Specialisation III. Mathematics: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Core qualification: Elective Compulsory Interdisciplinary Mathematics: Specialisation II. Numerical - Modelling Training: Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory		

Course L0576: Numerical Treatment of Ordinary Differential Equations	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Daniel Ruprecht
<b>Language</b>	DE/EN
<b>Cycle</b>	SoSe
<b>Content</b>	<p>Numerical methods for Initial Value Problems</p> <ul style="list-style-type: none"> <li>• single step methods</li> <li>• multistep methods</li> <li>• stiff problems</li> <li>• differential algebraic equations (DAE) of index 1</li> </ul> <p>Numerical methods for Boundary Value Problems</p> <ul style="list-style-type: none"> <li>• multiple shooting method</li> <li>• difference methods</li> <li>• variational methods</li> </ul>
<b>Literature</b>	<ul style="list-style-type: none"> <li>• E. Hairer, S. Noersett, G. Wanner: Solving Ordinary Differential Equations I: Nonstiff Problems</li> <li>• E. Hairer, G. Wanner: Solving Ordinary Differential Equations II: Stiff and Differential-Algebraic Problems</li> </ul>

Course L0582: Numerical Treatment of Ordinary Differential Equations	
<b>Typ</b>	Recitation Section (small)
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Daniel Ruprecht
<b>Language</b>	DE/EN
<b>Cycle</b>	SoSe
<b>Content</b>	See interlocking course
<b>Literature</b>	See interlocking course

Module M0906: Numerical Simulation and Lagrangian Transport			
<b>Courses</b>			
<b>Title</b>	<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
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
<b>Module Responsible</b>	Prof. Michael Schlüter		
<b>Admission Requirements</b>	None		
<b>Recommended Previous Knowledge</b>	<ul style="list-style-type: none"> <li>• Mathematics I-IV</li> <li>• Basic knowledge in Fluid Mechanics</li> <li>• Basic knowledge in chemical thermodynamics</li> </ul>		
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results		
<b>Professional Competence</b> <i>Knowledge</i>	After successful completion of the module the students are able to <ul style="list-style-type: none"> <li>• explain the the basic principles of statistical thermodynamics (ensembles, simple systems)</li> <li>• describe the main approaches in classical Molecular Modeling (Monte Carlo, Molecular Dynamics) in various ensembles</li> <li>• discuss examples of computer programs in detail,</li> <li>• evaluate the application of numerical simulations,</li> <li>• list the possible start and boundary conditions for a numerical simulation.</li> </ul>		
<i>Skills</i>	The students are able to: <ul style="list-style-type: none"> <li>• set up computer programs for solving simple problems by Monte Carlo or molecular dynamics,</li> <li>• solve problems by molecular modeling,</li> <li>• set up a numerical grid,</li> <li>• perform a simple numerical simulation with OpenFoam,</li> <li>• evaluate the result of a numerical simulation.</li> </ul>		
<b>Personal Competence</b> <i>Social Competence</i>	The students are able to <ul style="list-style-type: none"> <li>• develop joint solutions in mixed teams and present them in front of the other students,</li> <li>• to collaborate in a team and to reflect their own contribution toward it.</li> </ul>		
<i>Autonomy</i>	The students are able to: <ul style="list-style-type: none"> <li>• evaluate their learning progress and to define the following steps of learning on that basis,</li> <li>• evaluate possible consequences for their profession.</li> </ul>		
<b>Workload in Hours</b>	Independent Study Time 110, Study Time in Lecture 70		
<b>Credit points</b>	6		
<b>Course achievement</b>	None		
<b>Examination</b>	Oral exam		
<b>Examination duration and scale</b>	30 min		
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory		

Course L2301: Lagrangian transport in turbulent flows	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Alexandra von Kameke
<b>Language</b>	EN

Cycle	SoSe
<p><b>Content</b></p>	<p>Contents</p> <ul style="list-style-type: none"> <li>- Common variables and terms for characterizing turbulence (energy spectra, energy cascade, etc.)</li> <li>- An overview of Lagrange analysis methods and experiments in fluid mechanics</li> <li>- Critical examination of the concept of turbulence and turbulent structures.</li> <li>- Calculation of the transport of ideal fluid elements and associated analysis methods (absolute and relative diffusion, Lagrangian Coherent Structures, etc.)</li> <li>- Implementation of a Runge-Kutta 4th-order in Matlab</li> <li>- Introduction to particle integration using ODE solver from Matlab</li> <li>- Problems from turbulence research</li> <li>- Application analytical methods with Matlab.</li> </ul> <p>Structure:</p> <ul style="list-style-type: none"> <li>- 14 units a 2x45 min.</li> <li>- 10 units lecture</li> <li>- 4 Units Matlab Exercise- Go through the exercises Matlab, Peer2Peer? Explain solutions to your colleague</li> </ul> <p>Learning goals:</p> <p>Students receive very specific, in-depth knowledge from modern turbulence research and transport analysis. → Knowledge</p> <p>The students learn to classify the acquired knowledge, they study approaches to further develop the knowledge themselves and to relate different data sources to each other. → Knowledge, skills</p> <p>The students are trained in the personal competence to independently delve into and research a scientific topic. → Independence</p> <p>Matlab exercises in small groups during the lecture and guided Peer2Peer discussion rounds train communication skills in complex situations. The mixture of precise language and intuitive understanding is learnt. → Knowledge, social competence</p> <p>Required knowledge:</p> <p>Fluid mechanics 1 and 2 advantageous</p> <p>Programming knowledge advantageous</p>
<p><b>Literature</b></p>	<p>Bakunin, Oleg G. (2008): Turbulence and Diffusion. Scaling Versus Equations. Berlin [u. a.]: Springer Verlag.</p> <p>Bourgoin, Mickaël; Ouellette, Nicholas T.; Xu, Haitao; Berg, Jacob; Bodenschatz, Eberhard (2006): The role of pair dispersion in turbulent flow. In: Science (New York, N.Y.) 311 (5762), S. 835-838. DOI: 10.1126/science.1121726.</p> <p>Davidson, P. A. (2015): Turbulence. An introduction for scientists and engineers. Second edition. Oxford: Oxford Univ. Press.</p> <p>Graff, L. S.; Guttu, S.; LaCasce, J. H. (2015): Relative Dispersion in the Atmosphere from Reanalysis Winds. In: J. Atmos. Sci. 72 (7), S. 2769-2785. DOI: 10.1175/JAS-D-14-0225.1.</p> <p>Grigoriev, Roman (2011): Transport and Mixing in Laminar Flows. Weinheim, Germany: Wiley-VCH Verlag GmbH &amp; Co. KGaA.</p> <p>Haller, George (2015): Lagrangian Coherent Structures. In: Annu. Rev. Fluid Mech. 47 (1), S. 137-162. DOI: 10.1146/annurev-fluid-010313-141322.</p> <p>Kameke, A. von; Huhn, F.; Fernández-García, G.; Muñozuri, A. P.; Pérez-Muñozuri, V. (2010): Propagation of a chemical wave front in a quasi-two-dimensional superdiffusive flow. In: Physical review. E, Statistical, nonlinear, and soft matter physics 81 (6 Pt 2), S. 66211. DOI: 10.1103/PhysRevE.81.066211.</p> <p>Kameke, A. von; Huhn, F.; Fernández-García, G.; Muñozuri, A. P.; Pérez-Muñozuri, V. (2011): Double cascade turbulence and Richardson dispersion in a horizontal fluid flow induced by Faraday waves. In: Physical review letters 107 (7), S. 74502. DOI: 10.1103/PhysRevLett.107.074502.</p> <p>Kameke, A.v.; Kastens, S.; Rüttinger, S.; Herres-Pawlis, S.; Schlüter, M. (2019): How coherent structures dominate the residence time in a bubble wake: An experimental example. In: Chemical Engineering Science 207, S. 317-326. DOI: 10.1016/j.ces.2019.06.033.</p> <p>Klages, Rainer; Radons, Günter; Sokolov, Igor M. (2008): Anomalous Transport: Wiley.</p> <p>LaCasce, J. H. (2008): Statistics from Lagrangian observations. In: Progress in Oceanography 77 (1), S. 1-29. DOI:</p>

	<p>10.1016/j.pocean.2008.02.002.</p> <p>Neufeld, Zoltán; Hernández-García, Emilio (2009): Chemical and Biological Processes in Fluid Flows: PUBLISHED BY IMPERIAL COLLEGE PRESS AND DISTRIBUTED BY WORLD SCIENTIFIC PUBLISHING CO.</p> <p>Onu, K.; Huhn, F.; Haller, G. (2015): LCS Tool: A computational platform for Lagrangian coherent structures. In: Journal of Computational Science 7, S. 26-36. DOI: 10.1016/j.jocs.2014.12.002.</p> <p>Ouellette, Nicholas T.; Xu, Haitao; Bourgoin, Mickaël; Bodenschatz, Eberhard (2006): An experimental study of turbulent relative dispersion models. In: New J. Phys. 8 (6), S. 109. DOI: 10.1088/1367-2630/8/6/109.</p> <p>Pope, Stephen B. (2000): Turbulent Flows. Cambridge: Cambridge University Press.</p> <p>Rivera, M. K.; Ecke, R. E. (2005): Pair dispersion and doubling time statistics in two-dimensional turbulence. In: Physical review letters 95 (19), S. 194503. DOI: 10.1103/PhysRevLett.95.194503.</p> <p>Vallis, Geoffrey K. (2010): Atmospheric and oceanic fluid dynamics. Fundamentals and large-scale circulation. 5. printing. Cambridge: Cambridge Univ. Press.</p>
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Course L1375: Computational Fluid Dynamics - Exercises in OpenFoam	
<b>Typ</b>	Recitation Section (small)
<b>Hrs/wk</b>	1
<b>CP</b>	1
<b>Workload in Hours</b>	Independent Study Time 16, Study Time in Lecture 14
<b>Lecturer</b>	Prof. Michael Schlüter
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• generation of numerical grids with a common grid generator</li> <li>• selection of models and boundary conditions</li> <li>• basic numerical simulation with OpenFoam within the TUHH CIP-Pool</li> </ul>
<b>Literature</b>	OpenFoam Tutorials (StudIP)

Course L1052: Computational Fluid Dynamics in Process Engineering	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Michael Schlüter
<b>Language</b>	EN
<b>Cycle</b>	SoSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Introduction into partial differential equations</li> <li>• Basic equations</li> <li>• Boundary conditions and grids</li> <li>• Numerical methods</li> <li>• Finite difference method</li> <li>• Finite volume method</li> <li>• Time discretisation and stability</li> <li>• Population balance</li> <li>• Multiphase Systems</li> <li>• Modeling of Turbulent Flows</li> <li>• Exercises: Stability Analysis</li> <li>• Exercises: Example on CFD - analytically/numerically</li> </ul>
<b>Literature</b>	<p>Paschedag A.R.: CFD in der Verfahrenstechnik: Allgemeine Grundlagen und mehrphasige Anwendungen, Wiley-VCH, 2004 ISBN 3-527-30994-2.</p> <p>Ferziger, J.H.; Peric, M.: Numerische Strömungsmechanik. Springer-Verlag, Berlin, 2008, ISBN: 3540675868.</p> <p>Ferziger, J.H.; Peric, M.: Computational Methods for Fluid Dynamics. Springer, 2002, ISBN 3-540-42074-6</p>

Module M1709: Applied optimization in energy and process engineering				
<b>Courses</b>				
<b>Title</b>		<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
Applied optimization in energy and process engineering (L2693)		Integrated Lecture	2	3
Applied optimization in energy and process engineering (L2695)		Recitation Section (small)	2	3
<b>Module Responsible</b>	Prof. Mirko Skiborowski			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	Fundamentals in the field of mathematical modeling and numerical mathematics, as well as a basic understanding of process engineering processes.  In particular the contents of the module Process and Plant Engineering II			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>	<p><i>Knowledge</i> The module provides a general introduction to the basics of applied mathematical optimization and deals with application areas on different scales from the identification of kinetic models, to the optimal design of unit operations and the optimization of entire (sub)processes, as well as production planning. In addition to the basic classification and formulation of optimization problems, different solution approaches are discussed and tested during the exercises. Besides deterministic gradient-based methods, metaheuristics such as evolutionary and genetic algorithms and their application are discussed as well.</p> <ul style="list-style-type: none"> <li>• Introduction to Applied Optimization</li> <li>• Formulation of optimization problems</li> <li>• Linear Optimization</li> <li>• Nonlinear Optimization</li> <li>• Mixed-integer (non)linear optimization</li> <li>• Multi-objective optimization</li> <li>• Global optimization</li> </ul> <p><i>Skills</i> After successful participation in the module "Applied Optimization in Energy and Process Engineering", students are able to formulate the different types of optimization problems and to select appropriate solution methods in suitable software such as Matlab and GAMS and to develop improved solution strategies. Furthermore, students will be able to interpret and critically examine the results accordingly.</p> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> Students are capable of:</p> <ul style="list-style-type: none"> <li>•develop solutions in heterogeneous small groups</li> </ul> <p><i>Autonomy</i> Students are capable of:</p> <ul style="list-style-type: none"> <li>•taping new knowledge on a special subject by literature research</li> </ul>			
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56			
<b>Credit points</b>	6			
<b>Course achievement</b>	None			
<b>Examination</b>	Oral exam			
<b>Examination duration and scale</b>	35 min			
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory			

<b>Course L2693: Applied optimization in energy and process engineering</b>	
<b>Typ</b>	Integrated Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Mirko Skiborowski
<b>Language</b>	DE/EN
<b>Cycle</b>	SoSe
<b>Content</b>	<p>The lecture offers a general introduction to the basics and possibilities of applied mathematical optimization and deals with application areas on different scales from kinetics identification, optimal design of unit operations to the optimization of entire (sub)processes, and production planning. In addition to the basic classification and formulation of optimization problems, different solution approaches are discussed. Besides deterministic gradient-based methods, metaheuristics such as evolutionary and genetic algorithms and their application are discussed as well.</p> <ul style="list-style-type: none"> <li>- Introduction to Applied Optimization</li> <li>- Formulation of optimization problems</li> <li>- Linear Optimization</li> <li>- Nonlinear Optimization</li> <li>- Mixed-integer (non)linear optimization</li> <li>- Multi-objective optimization</li> <li>- Global optimization</li> </ul>
<b>Literature</b>	<p>Weicker, K., Evolutionäre Algorithmen, Springer, 2015</p> <p>Edgar, T. F., Himmelblau D. M., Lasdon, L. S., Optimization of Chemical Processes, McGraw Hill, 2001</p> <p>Biegler, L. Nonlinear Programming - Concepts, Algorithms, and Applications to Chemical Processes, 2010</p> <p>Kallrath, J. Gemischt-ganzzahlige Optimierung: Modellierung in der Praxis, Vieweg, 2002</p>

<b>Course L2695: Applied optimization in energy and process engineering</b>	
<b>Typ</b>	Recitation Section (small)
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Mirko Skiborowski
<b>Language</b>	DE/EN
<b>Cycle</b>	SoSe
<b>Content</b>	See interlocking course
<b>Literature</b>	See interlocking course

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	
<b>Module Responsible</b>	Prof. Alexander Schlaefer			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	mathematics and optimization methods principles of automata principles of algorithms and data structures programming skills			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>	<p><i>Knowledge</i> 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'.</p> <p><i>Skills</i> 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.</p> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> The students work in teams to solve problems.</p> <p><i>Autonomy</i> The students can reflect their knowledge and document the results of their work.</p>			
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56			
<b>Credit points</b>	6			
<b>Course achievement</b>	<b>Compulsory</b>	<b>Bonus</b>	<b>Form</b>	<b>Description</b>
	No	10 %	Exercises	
<b>Examination</b>	Written exam			
<b>Examination duration and scale</b>	90 minutes			
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory			



Course L0344: Industrial Process Automation	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Alexander Schlaefer
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>- foundations of problem solving and system modeling, discrete event systems</li> <li>- properties of processes, modeling using automata and Petri-nets</li> <li>- design considerations for processes (mutex, deadlock avoidance, liveness)</li> <li>- optimal scheduling for processes</li> <li>- optimal decisions when planning manufacturing systems, decisions under uncertainty</li> <li>- software design and software architectures for automation, PLCs</li> </ul>
<b>Literature</b>	<p>J. Lunze: „Automatisierungstechnik“, Oldenbourg Verlag, 2012</p> <p>Reisig: Petrinetze: Modellierungstechnik, Analysemethoden, Fallstudien; Vieweg+Teubner 2010</p> <p>Hrúz, Zhou: Modeling and Control of Discrete-event Dynamic Systems; Springer 2007</p> <p>Li, Zhou: Deadlock Resolution in Automated Manufacturing Systems, Springer 2009</p> <p>Pinedo: Planning and Scheduling in Manufacturing and Services, Springer 2009</p>

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

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	
<b>Module Responsible</b>	Prof. Mathias Ernst			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	Basic knowledge of water chemistry. Knowledge of the core processes involved in water, gas and steam treatment			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>				
<i>Knowledge</i>	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.			
<i>Skills</i>	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.			
<b>Personal Competence</b>				
<i>Social Competence</i>	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.			
<i>Autonomy</i>	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.			
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56			
<b>Credit points</b>	6			
<b>Course achievement</b>	None			
<b>Examination</b>	Written exam			
<b>Examination duration and scale</b>	90 min			
<b>Assignment for the Following Curricula</b>	Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory Environmental Engineering: Specialisation Water: Elective Compulsory Joint European Master in Environmental Studies - Cities and Sustainability: Specialisation Water: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory			

Course L0399: Membrane Technology	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	3
<b>Workload in Hours</b>	Independent Study Time 62, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Mathias Ernst
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<p>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 electrodialysis, 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.</p> <p>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.</p> <p>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.</p>
<b>Literature</b>	<ul style="list-style-type: none"> <li>• T. Melin, R. Rautenbach: Membranverfahren: Grundlagen der Modul- und Anlagenauslegung (2., erweiterte Auflage), Springer-Verlag, Berlin 2004.</li> <li>• Marcel Mulder, Basic Principles of Membrane Technology, Kluwer Academic Publishers, Dordrecht, The Netherlands</li> <li>• Richard W. Baker, Membrane Technology and Applications, Second Edition, John Wiley &amp; Sons, Ltd., 2004</li> </ul>

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

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

Module M1327: Modeling of Granular Materials				
Courses				
Title		Typ	Hrs/wk	CP
Multiscale simulation of granular materials (L1858)		Lecture	2	2
Multiscale simulation of granular materials (L1860)		Recitation Section (small)	2	2
Thermodynamic and kinetic modeling of the solid state (L1859)		Lecture	2	2
<b>Module Responsible</b>	Prof. Maksym Dosta			
<b>Admission Requirements</b>	None			
<b>Recommended Previous Knowledge</b>	Fundamentals in Mathematics, Physics and Mechanics			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results			
<b>Professional Competence</b>	<p><i>Knowledge</i></p> <p>After successful completion of the module the students are able to:</p> <ul style="list-style-type: none"> <li>describe modern modeling approaches which can be applied for simulation of granular materials</li> <li>analyze and evaluate possibility to apply numerical simulations on different time and length scales: from description of single particle properties on micro scale up to process simulation on macro scale</li> <li>list modern simulation system and discuss possibility of their application</li> <li>explain fundamentals of main numerical methods which are used for modeling of particulate materials</li> <li>list experimental methods to characterize granular materials</li> <li>explain fundamental thermodynamic and kinetic relations for the processes with solids</li> <li>explain theoretical background and limitations of the discrete models for the processes with solids</li> </ul> <p><i>Skills</i></p> <p>After successful completion of the module the students are able to,</p> <ul style="list-style-type: none"> <li>perform flowsheet simulation of solids processes and analyze steady-state or dynamic process behavior</li> <li>simulate behavior of granular materials on the micro scale with Discrete Element Method (DEM)</li> <li>optimize processes of mechanical process engineering (mixing, separation, crushing, ...) with DEM</li> <li>apply multiscale simulations for modeling of particulate materials</li> <li>evaluate results of numerical simulations</li> <li>select and apply appropriate thermodynamic and kinetic models for processes with solids</li> <li>select and apply appropriate discrete models for the processes with solids.</li> </ul>			
<i>Knowledge</i>				
<i>Skills</i>				
<b>Personal Competence</b>	<p><i>Social Competence</i></p> <p>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.</p> <p><i>Autonomy</i></p> <p>After completion of this module, participants will be able to solve a technical problem independently including a presentation of the results. 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.</p>			
<b>Workload in Hours</b>	Independent Study Time 96, Study Time in Lecture 84			
<b>Credit points</b>	6			
<b>Course achievement</b>	None			
<b>Examination</b>	Written exam			
<b>Examination duration and scale</b>	90 min			
<b>Assignment for the Following Curricula</b>	Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory			

<b>Course L1858: Multiscale simulation of granular materials</b>	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Maksym Dosta
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Steady-state flowsheet simulation of solids processes</li> <li>• Dynamic flowsheet simulation of solids processes</li> <li>• Introduction to Discrete Element Method (DEM)</li> <li>• Contact and breakage mechanics of granular materials</li> <li>• Extension of DEM</li> <li>• Modeling of Gas/Solid streams with coupled DEM and CFD methods</li> <li>• Population balance modelling of solids processes</li> <li>• Multiscale simulation of particulate materials</li> </ul>
<b>Literature</b>	<p>B.V. Babu (2004). Process plant simulation, Oxford Univ. Press, New York.</p> <p>S.J. Antony, W. Hoyle, Y. Ding (Eds.) (2004). Granular materials: Fundamentals and Applications, RSC, Cambridge.</p> <p>T. Pöschel (2010). Computational Granular Dynamics: Models and Algorithms, Springer Verl. Berlin.</p> <p>Other lecture materials to be distributed</p>

<b>Course L1860: Multiscale simulation of granular materials</b>	
<b>Typ</b>	Recitation Section (small)
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Maksym Dosta
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Introduction into simulation frameworks: Aspen Plus (Solids), Dyssol, MUSEN</li> <li>• Steady-state flowsheet simulation of solids processes (Aspen Plus)</li> <li>• Dynamic flowsheet simulation of solids processes (Dyssol)</li> <li>• Implementation of new contact laws and calculation of particle interactions (Matlab)</li> <li>• Simulation of granular materials with population balance models (Matlab)</li> <li>• Simulation of granular materials with discrete element method (MUSEN)</li> <li>• Optimization of several processes with discrete element method (MUSEN)</li> </ul>
<b>Literature</b>	<p>M. Dosta: Lecture notes.</p> <p>S. Attaway (2013). Matlab: A Practical Introduction to Programming and Problem Solving, Third Ed.</p> <p>Other lecture materials to be distributed</p>

<b>Course L1859: Thermodynamic and kinetic modeling of the solid state</b>	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Dr. Pavel Gurikov
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Thermodynamics of pure solids: melting/crystallization; glassy and amorphous state.</li> <li>• Thermodynamics of solid-gas equilibria: adsorption and sublimation.</li> <li>• Thermodynamics of solid-liquid equilibria: solubility in aqueous and non-aqueous systems; solid solutions; supercritical fluids as solvents.</li> <li>• Kinetics of dissolution/precipitation processes: chemical vapor deposition; drug release; hydrothermal processes.</li> <li>• Characterization of solids: contact angle, adsorption techniques, IR spectroscopy, electron microscopy.</li> <li>• Discrete models of dissolution/precipitation processes: diffusion limited aggregation; random-like and ballistic-like deposition models</li> <li>• Advanced discrete models: surface wettability; adsorption and precipitation of (bio)polymers.</li> </ul>
<b>Literature</b>	<p>Prausnitz, J.M., Lichtenthaler, R.N., and Azevedo, E.G. de (1998). Molecular Thermodynamics of Fluid-Phase Equilibria, Pearson Education.</p> <p>Elliott, S., and Elliott, S.R. (1998). The Physics and Chemistry of Solids, Wiley.</p> <p>Chopard, B., and Droz, M. (2005). Cellular Automata Modeling of Physical Systems, Cambridge University Press.</p>

Module M1736: Industrial homogeneous catalysis			
Courses			
Title	Typ	Hrs/wk	CP
Homogeneous catalysis in application (L2804)	Practical Course	1	2
Industrial homogeneous catalysis (L2802)	Lecture	2	2
Industrial homogeneous catalysis (L2803)	Recitation Section (large)	1	2
<b>Module Responsible</b>	Prof. Jakob Albert		
<b>Admission Requirements</b>	None		
<b>Recommended Previous Knowledge</b>	<ul style="list-style-type: none"> <li>• Basic knowledge from the Bachelor's degree course in process engineering</li> <li>• Chemical reaction engineering</li> <li>• Process and plant engineering</li> </ul>		
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results		
<b>Professional Competence</b>	<p><i>Knowledge</i> Students can:</p> <ul style="list-style-type: none"> <li>• explain the principle of homogeneous catalysis,</li> <li>• give an overview of the versatile applications of homogeneous catalysis in industry</li> <li>• evaluate different homogeneously catalysed reactions with regard to their technical challenges and economic significance.</li> </ul> <p><i>Skills</i> The students are able to</p> <ul style="list-style-type: none"> <li>• develop concepts for the technical implementation of homogeneously catalysed reactions,</li> <li>• evaluate practical aspects of homogeneous catalysis using laboratory experiments,</li> <li>• apply the acquired knowledge to different homogeneously catalysed reactions.</li> </ul> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> The students:</p> <ul style="list-style-type: none"> <li>• are able to work out the practical aspects of homogeneous catalysis on the basis of laboratory experiments, to carry out and evaluate the analytics of the products and to precisely summarise the results of the experiments in a protocol.</li> <li>• are able to independently discuss approaches to solutions and problems in the field of homogeneous catalysis in an interdisciplinary small group,</li> <li>• are able to work together in small groups on subject-specific tasks, Translated with <a href="http://www.DeepL.com/Translator">www.DeepL.com/Translator</a> (free version)</li> </ul> <p><i>Autonomy</i> The students</p> <ul style="list-style-type: none"> <li>• are able to independently obtain extensive literature on the topic and to gain knowledge from it,</li> <li>• are able to independently solve tasks on the topic and assess their learning status based on the feedback given,</li> <li>• are able to independently conduct experimental studies on the topic.</li> </ul>		
<b>Workload in Hours</b>	Independent Study Time 124, Study Time in Lecture 56		
<b>Credit points</b>	6		
<b>Course achievement</b>	None		
<b>Examination</b>	Oral exam		
<b>Examination duration and scale</b>	30 min		
<b>Assignment for the Following Curricula</b>	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory		

Course L2804: Homogeneous catalysis in application	
<b>Typ</b>	Practical Course
<b>Hrs/wk</b>	1
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 46, Study Time in Lecture 14
<b>Lecturer</b>	Prof. Jakob Albert
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	In the laboratory practical course, practical experiments are carried out with reference to industrial application of homogeneous catalysis. The hurdles to the technical implementation of homogeneously catalysed reactions are made clear to the students. The associated analysis of the experimental samples is also part of the laboratory practical course and is carried out and evaluated by the students themselves. The results are precisely summarised and scientifically presented in an experimental protocol.
<b>Literature</b>	<ol style="list-style-type: none"> <li>1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013</li> <li>2. A. Behr, „Angewandte homogene Katalyse“, Wiley-VCH, 2008</li> </ol>

Course L2802: Industrial homogeneous catalysis	
<b>Typ</b>	Lecture
<b>Hrs/wk</b>	2
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 32, Study Time in Lecture 28
<b>Lecturer</b>	Prof. Jakob Albert
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	<ul style="list-style-type: none"> <li>• Introduction to homogeneous catalysis</li> <li>• Elementary steps of catalysis</li> <li>• Homogeneous transition metal catalysis</li> <li>• Hydroformylation</li> <li>• Wacker process</li> <li>• Monsanto process</li> <li>• Shell higher olefin process (SHOP)</li> <li>• Extractive-oxidative desulphurisation (ECODS)</li> <li>• Phase transfer catalysis</li> <li>• Liquid-liquid two-phase catalysis</li> <li>• Catalyst recycling</li> <li>• Reactor concepts</li> </ul>
<b>Literature</b>	<ol style="list-style-type: none"> <li>1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013</li> <li>2. A. Behr, „Angewandte homogene Katalyse“, Wiley-VCH, 2008</li> </ol>

Course L2803: Industrial homogeneous catalysis	
<b>Typ</b>	Recitation Section (large)
<b>Hrs/wk</b>	1
<b>CP</b>	2
<b>Workload in Hours</b>	Independent Study Time 46, Study Time in Lecture 14
<b>Lecturer</b>	Prof. Jakob Albert
<b>Language</b>	EN
<b>Cycle</b>	WiSe
<b>Content</b>	In this exercise the contents of the lecture are further deepened and transferred into practical application. This is done using example tasks from practice, which are made available to the students. The students are to solve these tasks independently or in groups with the help of the lecture material. The solution is then discussed with students under scientific guidance, with parts of the task being presented on the blackboard.
<b>Literature</b>	<ol style="list-style-type: none"> <li>1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013</li> <li>2. A. Behr, „Angewandte homogene Katalyse“, Wiley-VCH, 2008</li> </ol>



**Thesis**

**Module M-002: Master Thesis**

**Courses**

<b>Title</b>	<b>Typ</b>	<b>Hrs/wk</b>	<b>CP</b>
<b>Module Responsible</b>	Professoren der TUHH		
<b>Admission Requirements</b>	<ul style="list-style-type: none"> <li>According to General Regulations §21 (1):</li> </ul> <p>At least 60 credit points have to be achieved in study programme. The examinations board decides on exceptions.</p>		
<b>Recommended Previous Knowledge</b>			
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results		
<b>Professional Competence</b> <i>Knowledge</i>	<ul style="list-style-type: none"> <li>The students can use specialized knowledge (facts, theories, and methods) of their subject competently on specialized issues.</li> <li>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.</li> <li>The students can place a research task in their subject area in its context and describe and critically assess the state of research.</li> </ul>		
<b>Skills</b>	<p>The students are able:</p> <ul style="list-style-type: none"> <li>To select, apply and, if necessary, develop further methods that are suitable for solving the specialized problem in question.</li> <li>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.</li> <li>To develop new scientific findings in their subject area and subject them to a critical assessment.</li> </ul>		
<b>Personal Competence</b> <i>Social Competence</i>	<p>Students can</p> <ul style="list-style-type: none"> <li>Both in writing and orally outline a scientific issue for an expert audience accurately, understandably and in a structured way.</li> <li>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.</li> </ul>		
<i>Autonomy</i>	<p>Students are able:</p> <ul style="list-style-type: none"> <li>To structure a project of their own in work packages and to work them off accordingly.</li> <li>To work their way in depth into a largely unknown subject and to access the information required for them to do so.</li> <li>To apply the techniques of scientific work comprehensively in research of their own.</li> </ul>		
<b>Workload in Hours</b>	Independent Study Time 900, Study Time in Lecture 0		
<b>Credit points</b>	30		
<b>Course achievement</b>	None		
<b>Examination</b>	Thesis		
<b>Examination duration and scale</b>	According to General Regulations		
<b>Assignment for the Following Curricula</b>	Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy and Environmental Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Global Innovation Management: Thesis: Compulsory Computational Science and Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory Interdisciplinary Mathematics: Thesis: Compulsory International Management and Engineering: Thesis: Compulsory Joint European Master in Environmental Studies - Cities and Sustainability: Thesis: Compulsory Logistics, Infrastructure and Mobility: Thesis: Compulsory Materials Science: Thesis: Compulsory Mechanical Engineering and Management: Thesis: Compulsory		

## Module Manual M.Sc. "Chemical and Bioprocess Engineering"

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