



Module Manual

Master of Science

Bioprocess Engineering

Cohort: Winter Term 2018

Updated: 28th September 2018

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Master

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Program description

Content

Knowledge

Graduates are able to recount extensive, in-depth engineering, mathematical, and scientific knowledge and critically assess recent findings in their discipline.

Skills

On successful completion of the program, graduates are able to:

- Work scientifically in process engineering with a focus on biotechnologies and related disciplines.

- Analyze and solve problems scientifically even if they are unusual or are defined incompletely and involve competing specifications.
- Abstract and formulate complex problems from a new or emerging area of their discipline.
- Apply innovative methods to fundamental problem solving and develop new scientific methods.
- Plan and implement theoretical and experimental investigations, evaluate critically the data received, and reach conclusions accordingly.
- Investigate and evaluate the application of new and upcoming technologies.
- Create and develop new products, processes, and methods.

Social Competence

Graduates are qualified to:

- Collaborate with professionals or specialists in other disciplines and to present the findings of their work orally and in writing in a way that is appropriate to the addressees.
- Communicate in German and English with professionals or specialists and non-specialists on contents and problems of bioprocess engineering. They can respond appropriately to inquiries, additions, and comments.
- Work in groups. They can define, distribute, and integrate subtasks. They are able to make time arrangements and interact socially.

Self-reliance

Graduates have acquired the skills required to:

- Recognize a need for information and find and procure relevant information.
- Familiarize themselves with new tasks systematically and in a short time.

Reflect systematically on non-technical repercussions of engineering activity and incorporate their findings responsibly into what they do.

Core qualification

Module M0523: Business & Management	
Module Responsible	Prof. Matthias Meyer
Admission Requirements	None
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	<ul style="list-style-type: none"> • Students are able to find their way around selected special areas of management within the scope of business management. • Students are able to explain basic theories, categories, and models in selected special areas of business management. • Students are able to interrelate technical and management knowledge. • Students are able to apply basic methods in selected areas of business management. • Students are able to explain and give reasons for decision proposals on practical issues in areas of business management. • Students are able to communicate in small interdisciplinary groups and to jointly develop solutions for complex problems • Students are capable of acquiring necessary knowledge independently by means of research and preparation of material.
<i>Knowledge</i>	
<i>Skills</i>	
Personal Competence	
<i>Social Competence</i>	
<i>Autonomy</i>	
Workload in Hours	Depends on choice of courses
Credit points	6

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

Module M0524: Nontechnical Elective Complementary Courses for Master	
Module Responsible	Dagmar Richter
Admission Requirements	None
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	<p>The Nontechnical Academic Programms (NTA)</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 teaching architecture, in its teaching and learning arrangements, in teaching areas and by means of teaching offerings in which students can qualify by opting for specific competences and a competence level at the Bachelor's or Master's level. The teaching offerings are pooled in two different catalogues for nontechnical complementary courses.</p> <p>The Learning Architecture</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>Teaching and Learning Arrangements</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>Fields of Teaching</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>The Competence Level</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>Specialized Competence (Knowledge)</p> <p>Students can</p> <ul style="list-style-type: none"> • explain specialized areas in context of the relevant non-technical disciplines, • outline basic theories, categories, terminology, models, concepts or artistic techniques in the disciplines represented in the learning area, • different specialist disciplines relate to their own discipline and differentiate it as well as make connections, • 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, • Can communicate in a foreign language in a manner appropriate to the subject.

	<p>Professional Competence (Skills)</p> <p>In selected sub-areas students can</p> <ul style="list-style-type: none"> • apply basic and specific methods of the said scientific disciplines, • question a specific technical phenomena, models, theories from the viewpoint of another, aforementioned specialist discipline, • to handle simple and advanced questions in aforementioned scientific disciplines in a successful manner, • justify their decisions on forms of organization and application in practical questions in contexts that go beyond the technical relationship to the subject.
<p>Personal Competence</p>	<p>Personal Competences (Social Skills)</p> <p>Students will be able</p> <ul style="list-style-type: none"> • to learn to collaborate in different manner, • to present and analyze problems in the abovementioned fields in a partner or group situation in a manner appropriate to the addressees, • 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), • to explain nontechnical items to auditorium with technical background knowledge.
<p><i>Social Competence</i></p>	<p>Personal Competences (Self-reliance)</p> <p>Students are able in selected areas</p> <ul style="list-style-type: none"> • to reflect on their own profession and professionalism in the context of real-life fields of application • to organize themselves and their own learning processes • to reflect and decide questions in front of a broad education background • to communicate a nontechnical item in a competent way in written form or verbally • to organize themselves as an entrepreneurial subject country (as far as this study-focus would be chosen)
<p>Workload in Hours</p>	<p>Depends on choice of courses</p>
<p>Credit points</p>	<p>6</p>

Courses

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

Course L0104: Multiphase Flows	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Interfaces in MPF (boundary layers, surfactants) • Hydrodynamics & pressure drop in Film Flows • Hydrodynamics & pressure drop in Gas-Liquid Pipe Flows • Hydrodynamics & pressure drop in Bubbly Flows • Mass Transfer in Film Flows • Mass Transfer in Gas-Liquid Pipe Flows • Mass Transfer in Bubbly Flows • Reactive mass Transfer in Multiphase Flows • Film Flow: Application Trickle Bed Reactors • Pipe Flow: Application Tubular Reactors • Bubbly Flow: Application Bubble Column Reactors
Literature	<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.; Delhaye, 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 & Sons, Inc, 1999.</p> <p>Crowe, C.T.: Multiphase Flows with Droplets and Particles. CRC Press, Boca Raton, Fla, 1998.</p>

Course L0105: Reactor Design Using Local Transport Processes	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	WiSe
Content	<p>In this Problem-Based Learning unit the students have to design a multiphase reactor for a fast chemical reaction concerning optimal hydrodynamic conditions of the multiphase flow.</p> <p>The four students in each team have to:</p> <ul style="list-style-type: none"> • collect and discuss material properties and equations for design from the literature, • calculate the optimal hydrodynamic design, • check the plausibility of the results critically, • write an exposé with the results. <p>This exposé will be used as basis for the discussion within the oral group examen of each team.</p>
Literature	see actual literature list in StudIP with recent published papers

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

Module M0541: Process and Plant Engineering II	
Courses	
Title	Typ Hrs/wk CP
Process and Plant Engineering II (L0097)	Lecture 2 2
Process and Plant Engineering II (L0098)	Recitation Section (large) 1 2
Process and Plant Engineering II (L1215)	Recitation Section (small) 1 2
Module Responsible	Prof. Georg Fieg
Admission Requirements	None
Recommended Previous Knowledge	unit operation of thermal and mechanical separation chemical reactor engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
<i>Knowledge</i>	students can: -present process control concepts of apparatus and complex process plants - classify process models and model equations - explain numerical methods and their use in simulation tasks - explain the solving strategy of flowsheet simulation - explain, present and discuss projects phases within the planning of processes - present and explain the critical path method
<i>Skills</i>	students are capable of: - formulation of targets of process control concepts and the translation into industrial practice - design and evaluation of process control concepts and structures - analyse the model structure and parameters from the process simulation - optimization of calculation sequence with respect to flowsheet simulation
Personal Competence	
<i>Social Competence</i>	students are capable of: • develop solutions in heterogeneous small groups
<i>Autonomy</i>	students are capable of: • tapping new knowledge on a special subject by literature research
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Studienleistung	None
Examination	Written exam
Examination duration and scale	120 Min.
Assignment for the Following Curricula	Bioprocess Engineering: Core qualification: Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Process Engineering: Core qualification: Compulsory

Course L0097: Process and Plant Engineering II	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Georg Fieg, Dr. Thomas Waluga
Language	DE
Cycle	WiSe
Content	<ol style="list-style-type: none"> 1. Process optimization Application areas Formulation of constrained optimization Solving strategy Classes of optimization tasks 2. Process control Typical control functions of equipment and apparatus in process engineering Structures of control systems Plantwide control 3. Process Modeling Process models (steady state and dynamic behaviour) Degrees of freedom Examples from industrial practice 4. Process simulation Structured approach Numerical methods Flowsheeting Solution methods Examples for experimental validation in industrial practice Application of flowsheet simulation 5. Plant design and construction Introduction Industrial project implementation Project execution: Applied aspects in industrial use critical path method
Literature	Literatur (Planung und Bau von Produktionsanlagen): G. Barnecker, Planung und Bau verfahrenstechnischer Anlagen, Springer Verlag, 2001 F.P. Helmus, Anlagenplanung, Wiley-VCH Verlag, Weinheim, 2003 E. Klapp, Apparate- und Anlagentechnik, Springer -Verlag, Berlin, 1980 P. Rinza, Projektmanagement: Planung, Überwachung und Steuerung von technischen und nichttechnischen Vorhaben, Düsseldorf, VDI-Verlag, 1994 K. Sattler, W. Kasper, Verfahrantechnische Anlagen, Wiley-VCH Verlag, Weinheim, 2000 G.H. Vogel, Verfahrensentwicklung, Wiley-VCH, Weinheim, 2002 K.H. Weber, Inbetriebnahme verfahrenstechnischer Anlagen, VDI Verlag, Düsseldorf, 1996 E. Wegener, Montagegerechte Anlagenplanung, Wiley-VCH Verlag, Weinheim, 2003

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

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

Module M0545: Separation Technologies for Life Sciences			
Courses			
Title	Typ	Hrs/wk	CP
Chromatographic Separation Processes (L0093)	Lecture	2	2
Unit Operations for Bio-Related Systems (L0112)	Lecture	2	2
Unit Operations for Bio-Related Systems (L0113)	Project-/problem-based Learning	2	2
Module Responsible	Prof. Irina Smirnova		
Admission Requirements	None		
Recommended Previous Knowledge	Fundamentals of Chemistry, Fluid Process Engineering, Thermal Separation Processes, Chemical Engineering, Chemical Engineering, Bioprocess Engineering Basic knowledge in thermodynamics and in unit operations related to thermal separation processes		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p><i>Knowledge</i></p> <p>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.</p> <p><i>Skills</i></p> <p>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.</p> <p>Personal Competence</p> <p>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.</p> <p><i>Social Competence</i></p> <p>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).</p> <p><i>Autonomy</i></p>		
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84		
Credit points	6		
Studienleistung	Compulsory Bonus	Form	Description
	Yes None	Presentation	

Examination	Written exam
Examination duration and scale	120 minutes; theoretical questions and calculations
Assignment for the Following Curricula	Bioprocess Engineering: Core qualification: Compulsory Chemical and Bioprocess Engineering: Core qualification: Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

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

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

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

Course L1158: Biocatalysis and Enzyme Technology	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Andreas Liese
Language	EN
Cycle	WiSe
Content	<ol style="list-style-type: none"> 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.
Literature	<ul style="list-style-type: none"> • K. Faber: Biotransformations in Organic Chemistry, Springer, 5th Ed., 2004 • A. Liese, K. Seelbach, C. Wandrey: Industrial Biotransformations, Wiley-VCH, 2006 • R. B. Silverman: The Organic Chemistry of Enzyme-Catalysed Reactions, Academic Press, 2000 • K. Buchholz, V. Kasche, U. Bornscheuer: Biocatalysts and Enzyme Technology. VCH, 2005. • R. D. Schmidt: Pocket Guide to Biotechnology and Genetic Engineering, Wiley-VCH, 2003

Course L1157: Technical Biocatalysis	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Andreas Liese
Language	EN
Cycle	WiSe
Content	1. Introduction 2. Production and Down Stream Processing of Biocatalysts 3. Analytics (offline/online) 4. Reaction Engineering & Process Control <ul style="list-style-type: none"> • Definitions • Reactors • Membrane Processes • Immobilization 5. Process Optimization <ul style="list-style-type: none"> • Simplex / DOE / GA 6. Examples of Industrial Processes <ul style="list-style-type: none"> • food / feed • fine chemicals 7. Non-Aqueous Solvents as Reaction Media <ul style="list-style-type: none"> • ionic liquids • scCO₂ • solvent free
Literature	<ul style="list-style-type: none"> • A. Liese, K. Seelbach, C. Wandrey: Industrial Biotransformations, Wiley-VCH, 2006 • H. Chmiel: Bioprozeßtechnik, Elsevier, 2005 • K. Buchholz, V. Kasche, U. Bornscheuer: Biocatalysts and Enzyme Technology, VCH, 2005 • R. D. Schmidt: Pocket Guide to Biotechnology and Genetic Engineering, Wiley-VCH, 2003

Module M0895: Advanced Chemical Reaction Engineering				
Courses				
Title		Typ	Hrs/wk	CP
Chemical Reaction Engineering (Advanced Topics) (L0222)		Lecture	2	2
Chemical Reaction Engineering (Advanced Topics) (L0245)		Recitation Section (large)	2	2
Experimental Course Chemical Engineering (Advanced Topics) (L0287)		Practical Course	2	2
Module Responsible	Prof. Raimund Horn			
Admission Requirements	None			
Recommended Previous Knowledge	Content of the bachelor-lecture "basics of chemical reaction engineering".			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<p>After completion of the module, students are able to:</p> <p><i>Knowledge</i></p> <ul style="list-style-type: none"> - identify differences between ideal and non-ideal reactors, - infer fundamental differences in kinetic models for catalyzed reactions, - name modelling algorithms for non-ideal reactors. <p>After successful completion of the module the students are able to</p> <p><i>Skills</i></p> <ul style="list-style-type: none"> -evaluate properties of non-ideal reactors -compare kinetic models of heterogeneous-catalyzed reactions and develop measuring techniques thereof -choose instruments for temperature, pressure- concentration and mass-flow measurements regarding process conditions -develop a concept for design of experiments <p>Personal Competence</p> <p><i>Social Competence</i></p> <p>The students are able to analyze scientific challenges and elaborate suitable solutions in small groups. Moreover they are able to document these approaches according to scientific guidelines.</p> <p>After successful completion of the lab-course the students have a strong ability to organize themselves in small groups to solve issues in chemical reaction engineering. The students can discuss their subject related knowledge among each other and with their teachers.</p> <p><i>Autonomy</i></p> <p>The students are able to obtain further information for experimental planning and assess their relevance autonomously.</p>			
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84			
Credit points	6			
Studienleistung	Compulsory Bonus	Form	Description	
	Yes None	Subject theoretical and practical work		
Examination	Written exam			
Examination duration and scale	120 min			
Assignment for the Following Curricula	Bioprocess Engineering: Core qualification: Compulsory Process Engineering: Core qualification: Compulsory			

Course L0222: Chemical Reaction Engineering (Advanced Topics)	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Raimund Horn
Language	DE
Cycle	SoSe
Content	<p>1. Real reactors (residence time distribution $E(t)$, $F(t)$-curve, measurement of $E(t)$ or $F(t)$, residence time distribution of ideal reactors, modeling of real reactors, segregated flow model, tanks in series model, dispersion model, compartment models)</p> <p>2. Heterogeneous catalysis (what is a catalyst, operation principle of a catalyst, volcano plot, homogeneous catalysis, heterogeneous catalysis, biocatalysis, physisorption and chemisorption, turn-over frequency (TOF), Sabatier's principle, Bronstedt-Evans-Polyani-relationship, Adsorption isotherms of single and multi-component systems, kinetic models of heterogeneous catalytic reactions, Langmuir-Hinshelwood kinetics, Eley-Rideal kinetics, power law rate equations, kinetic measurements on heterogeneously catalyzed reactions in the laboratory, microkinetic modeling, catalyst characterization)</p> <p>3. Diffusion in heterogeneous catalysis (diffusion regimes, Knudsen-diffusion, molecular diffusion, surface diffusion, single-file diffusion, reference systems, Stefan-Maxwell-Equations, Fick's law, pore effectiveness factor, impact of diffusion limitations in heterogeneous catalysis, Damköhler-relation, mass- and energy balance of heterogeneous catalytic reactors)</p> <p>4. Laboratory measurements in heterogeneous catalysis (temperature, pressure, concentration, mass flow controllers, laboratory reactors, experimental design)</p>
Literature	<ol style="list-style-type: none"> 1. Vorlesungsfolien R. Horn 2. Skript zur Vorlesung F. Keil 3. M. Baerns, A. Behr, A. Brehm, J. Gmehling, H. Hofmann, U. Onken, A. Renken, Technische Chemie, Wiley-VCH 4. G. Emig, E. Klemm, Technische Chemie, Springer 5. A. Behr, D. W. Agar, J. Jörissen, Einführung in die Technische Chemie 6. E. Müller-Erlwein, Chemische Reaktionstechnik 2012, 2. Auflage, Teubner Verlag 7. J. Hagen, Chemiereaktoren: Auslegung und Simulation, 2004, Wiley-VCH 8. H. S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall B 9. H. S. Fogler, Essentials of Chemical Reaction Engineering, Prentice Hall 10. O. Levenspiel, Chemical Reaction Engineering, John Wiley & Sons, 1998 11. L. D. Schmidt, The Engineering of Chemical Reactions, Oxford Univ. Press, 2009 12. J. B. Butt, Reaction Kinetics and Reactor Design, 2000, Marcel Dekker 13. R. Aris, Elementary Chemical Reactor Analysis, Dover Publ. Inc., 2000 14. M. E. Davis, R. J. Davis, Fundamentals of Chemical Reaction Engineering, McGraw Hill 15. G. F. Froment, K. B. Bischoff, J. De Wilde, Chemical Reactor Analysis and Design, John Wiley & Sons, 2010 16. A. Jess, P. Wasserscheid, Chemical Technology An Integrated Textbook, WILEY-VCH 17. C. G. Hill, An Introduction to Chemical Engineering Kinetics & Reactor Design, John Wiley & Sons

Course L0245: Chemical Reaction Engineering (Advanced Topics)	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Raimund Horn, Dr. Oliver Korup
Language	DE
Cycle	SoSe
Content	<p>1. Real reactors (residence time distribution $E(t)$, $F(t)$-curve, measurement of $E(t)$ or $F(t)$, residence time distribution of ideal reactors, modeling of real reactors, segregated flow model, tanks in series model, dispersion model, compartment models)</p> <p>2. Heterogeneous catalysis (what is a catalyst, operation principle of a catalyst, volcano plot, homogeneous catalysis, heterogeneous catalysis, biocatalysis, physisorption and chemisorption, turn-over frequency (TOF), Sabatier's principle, Bronstedt-Evans-Polyani-relationship, Adsorption isotherms of single and multi-component systems, kinetic models of heterogeneous catalytic reactions, Langmuir-Hinshelwood kinetics, Eley-Rideal kinetics, power law rate equations, kinetic measurements on heterogeneously catalyzed reactions in the laboratory, microkinetic modeling, catalyst characterization)</p> <p>3. Diffusion in heterogeneous catalysis (diffusion regimes, Knudsen-diffusion, molecular diffusion, surface diffusion, single-file diffusion, reference systems, Stefan-Maxwell-Equations, Fick's law, pore effectiveness factor, impact of diffusion limitations in heterogeneous catalysis, Damköhler-relation, mass- and energy balance of heterogeneous catalytic reactors)</p> <p>4. Laboratory measurements in heterogeneous catalysis (temperature, pressure, concentration, mass flow controllers, laboratory reactors, experimental design)</p>
Literature	<ol style="list-style-type: none"> 1. Vorlesungsfolien R. Horn 2. Skript zur Vorlesung F. Keil 3. M. Baerns, A. Behr, A. Brehm, J. Gmehling, H. Hofmann, U. Onken, A. Renken, Technische Chemie, Wiley-VCH 4. G. Emig, E. Klemm, Technische Chemie, Springer 5. A. Behr, D. W. Agar, J. Jörissen, Einführung in die Technische Chemie 6. E. Müller-Erlwein, Chemische Reaktionstechnik 2012, 2. Auflage, Teubner Verlag 7. J. Hagen, Chemiereaktoren: Auslegung und Simulation, 2004, Wiley-VCH 8. H. S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall B 9. H. S. Fogler, Essentials of Chemical Reaction Engineering, Prentice Hall 10. O. Levenspiel, Chemical Reaction Engineering, John Wiley & Sons, 1998 11. L. D. Schmidt, The Engineering of Chemical Reactions, Oxford Univ. Press, 2009 12. J. B. Butt, Reaction Kinetics and Reactor Design, 2000, Marcel Dekker 13. R. Aris, Elementary Chemical Reactor Analysis, Dover Publ. Inc., 2000 14. M. E. Davis, R. J. Davis, Fundamentals of Chemical Reaction Engineering, McGraw Hill 15. G. F. Froment, K. B. Bischoff, J. De Wilde, Chemical Reactor Analysis and Design, John Wiley & Sons, 2010 16. A. Jess, P. Wasserscheid, Chemical Technology An Integrated Textbook, WILEY-VCH 17. C. G. Hill, An Introduction to Chemical Engineering Kinetics & Reactor Design, John Wiley & Sons

Course L0287: Experimental Course Chemical Engineering (Advanced Topics)	
Typ	Practical Course
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Raimund Horn, Dr. Achim Bartsch
Language	DE/EN
Cycle	SoSe
Content	<p>Execution and evaluation of several experiments in chemical reaction engineering.</p> <ul style="list-style-type: none"> * Calculation of error propagation and error analysis * Steady state Wicke-Kallenbach measurements of diffusivities in a catalyst pellet * Interaction of reaction and diffusion in a catalyst particle, dissociation of methanol on zinc oxide * Mass transfer in gas/liquid system * Stability of a CSTR (hydrolysis of acetic anhydride)
Literature	<p>Skript zur Vorlesung, als Buch in der TU-Bibliothek</p> <p>Praktikumsskript</p> <p>Levenspiel, O.: Chemical reaction engineering; John Wiley & Sons, New York, 3. Ed., 1999 VTM 309(LB)</p> <p>Smith, J. M.: Chemical Engineering Kinetics, McGraw Hill, New York, 1981.</p> <p>Hill, C.: Chemical Engineering Kinetics & Reactor Design, John Wiley, New York, 1977.</p> <p>Fogler, H. S. : Elements of Chemical Reaction Engineering , Prentice Hall, 2006</p> <p>M. Baerns, A. Behr, A. Brehm, J. Gmehling, H. Hofmann, U. Onken, A. Renken: Technische Chemie, VCH , 2006</p> <p>G. F. Froment, K. B. Bischoff: Chemical Reactor Analysis and Design, Wiley, 1990</p>

Module M0896: Bioprocess and Biosystems Engineering			
Courses			
Title	Typ	Hrs/wk	CP
Bioreactor Design and Operation (L1034)	Lecture	2	2
Bioreactors and Biosystems Engineering (L1037)	Project-/problem-based Learning	1	2
Biosystems Engineering (L1036)	Lecture	2	2
Module Responsible	Prof. An-Ping Zeng		
Admission Requirements	None		
Recommended Previous Knowledge	Knowledge of bioprocess engineering and process engineering at bachelor level		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p>After completion of this module, participants will be able to:</p> <ul style="list-style-type: none"> differentiate between different kinds of bioreactors and describe their key features identify and characterize the peripheral and control systems of bioreactors depict integrated biosystems (bioprocesses including up- and downstream processing) name different sterilization methods and evaluate those in terms of different applications recall and define the advanced methods of modern systems-biological approaches connect the multiple "omics"-methods and evaluate their application for biological questions recall the fundamentals of modeling and simulation of biological networks and biotechnological processes and to discuss their methods 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. <p>After completion of this module, participants will be able to:</p> <ul style="list-style-type: none"> describe different process control strategies for bioreactors and chose them after analysis of characteristics of a given bioprocess plan and construct a bioreactor system including peripherals from lab to pilot plant scale adapt a present bioreactor system to a new process and optimize it develop concepts for integration of bioreactors into bioproduction processes combine the different modeling methods into an overall modeling approach, to apply these methods to specific problems and to evaluate the achieved results critically connect all process components of biotechnological processes for a holistic system view. 		
<i>Knowledge</i>			
<i>Skills</i>			
Personal Competence	<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>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"> 		
<i>Social Competence</i>			
<i>Autonomy</i>			
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70		
Credit points	6		
Studienleistung	Compulsory Bonus	Form	Description
	Yes 20 %	Presentation	
Examination	Written exam		
Examination duration and scale	120 min		
	Bioprocess Engineering: Core qualification: Compulsory Chemical and Bioprocess Engineering: Core qualification: Compulsory Environmental Engineering: Specialisation Biotechnology: Elective Compulsory		

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

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

Course L1036: Biosystems Engineering	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. An-Ping Zeng
Language	EN
Cycle	SoSe
Content	<p>Introduction to Biosystems Engineering</p> <p>Experimental basis and methods for biosystems analysis</p> <ul style="list-style-type: none"> • Introduction to genomics, transcriptomics and proteomics • More detailed treatment of metabolomics • Determination of in-vivo kinetics • Techniques for rapid sampling • Quenching and extraction • Analytical methods for determination of metabolite concentrations <p>Analysis, modelling and simulation of biological networks</p> <ul style="list-style-type: none"> • Metabolic flux analysis • Introduction • Isotope labelling • Elementary flux modes • Mechanistic and structural network models • Regulatory networks • Systems analysis • Structural network analysis • Linear and non-linear dynamic systems • Sensitivity analysis (metabolic control analysis) <p>Modelling and simulation for bioprocess engineering</p> <ul style="list-style-type: none"> • Modelling of bioreactors • Dynamic behaviour of bioprocesses <p>Selected projects for biosystems engineering</p> <ul style="list-style-type: none"> • Miniaturisation of bioreaction systems • Miniplant technology for the integration of biosynthesis and downstream processing • Technical and economic overall assessment of bioproduction processes
Literature	<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 M0914: Technical Microbiology	
Courses	
Title	Typ Hrs/wk CP
Applied Molecular Biology (L0877)	Lecture 2 3
Technical Microbiology (L0999)	Lecture 2 2
Technical Microbiology (L1000)	Recitation Section (large) 1 1
Module Responsible	Dr. Anna Krüger
Admission Requirements	None
Recommended Previous Knowledge	Bachelor with basic knowledge in microbiology and genetics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	After successfully finishing this module, students are able
<i>Knowledge</i>	<ul style="list-style-type: none"> • to give an overview of genetic processes in the cell • to explain the application of industrial relevant biocatalysts • to explain and prove genetic differences between pro- and eukaryotes
<i>Skills</i>	After successfully finishing this module, students are able <ul style="list-style-type: none"> • to explain and use advanced molecularbiological methods • to recognize problems in interdisciplinary fields
Personal Competence	Students are able to
<i>Social Competence</i>	<ul style="list-style-type: none"> • write protocols and PBL-summaries in teams • to lead and advise members within a PBL-unit in a group • develop and distribute work assignments for given problems
<i>Autonomy</i>	Students are able to <ul style="list-style-type: none"> • search information for a given problem by themselves • prepare summaries of their search results for the team • make themselves familiar with new topics
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Studienleistung	None
Examination	Written exam
Examination duration and scale	60 min exam (and PBL-part and short tests during the semester)
Assignment for the Following Curricula	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	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Carola Schröder
Language	EN
Cycle	SoSe
Content	Lecture and PBL - Methods in genetics / molecular cloning - Industrial relevance of microbes and their biocatalysts - Biotransformation at extreme conditions - Genomics - Protein engineering techniques - Synthetic biology
Literature	Relevante Literatur wird im Kurs zur Verfügung gestellt. Grundwissen in Molekularbiologie, Genetik, Mikrobiologie und Biotechnologie erforderlich. Lehrbuch: Brock - Mikrobiologie / Microbiology (Madigan et al.)

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

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

Module M0904: Process Design Project	
Courses	
Title	Typ
Process Design Project (L1050)	Projection Course
Hrs/wk	CP
6	6
Module Responsible	Dozenten des SD V
Admission Requirements	None
Recommended Previous Knowledge	<ul style="list-style-type: none"> • Particle Technology and Solid Process Engineering • Transport Processes • Process- and Plant Design II • Fluid Mechanics for Process Engineering • Chemical Reaction Engineering • Bioprocess- and Biosystems-Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	After the students passed the project course successfully they know:
<i>Knowledge</i>	<ul style="list-style-type: none"> • how a team is working together so solve a complex task in process engineering • what kind of tools are necessary to design a process • what kind of drawbacks and difficulties are coming up by designing a process
<i>Skills</i>	After passing the Module successfully the students are able to: <ul style="list-style-type: none"> • utilize tools for process design for a specific given process engineering task, • choose and connect apparatuses for a complete process, • collecting all relevant data for an economical and ecological evaluation, • optimization of calculation sequence with respect to flowsheet simulation.
Personal Competence	
<i>Social Competence</i>	The students are able to discuss in international teams in english and develop an approach under pressure of time.
<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.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Studienleistung	None
Examination	Subject theoretical and practical work
Examination duration and scale	.
Assignment for the Following Curricula	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	
Typ	Projection Course
Hrs/wk	6
CP	6
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Lecturer	NN
Language	DE
Cycle	WiSe
Content	In the Process Design Project the students have to design in teams an energy or process engineering plant by calculating and designing single plant components. The calculation of costs as well as the process safety is another important aspect of this course. Furthermore the approval procedures have to be taken into account.
Literature	

Module M0951: Bioprocess Engineering Advanced Practical Course			
Courses			
Title	Typ	Hrs/wk	CP
Bioprocess Engineering Advanced Practical Course (L1112)	Practical Course	3	3
Advanced Practical Course in Microbiology (L0878)	Practical Course	3	3
Module Responsible	Prof. An-Ping Zeng		
Admission Requirements	None		
Recommended Previous Knowledge	Bioprocess Engineering - Fundamental Practical Course		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p><i>Knowledge</i></p> <p>After completing this module, students are able to perform and explain the essential steps of a process for the production of the semi-synthetic beta-lactam antibiotic amoxicillin using microorganisms as well as cell-free enzymes.</p> <p><i>Skills</i></p> <p>The students can perform practical tasks in a chemical / biotechnological laboratory. This especially includes the fermentation of filamentous fungi in submerged culture, the recovery of intermediates from the fermentation broth and the processing of those intermediates using cell-free enzymes. They can record and interpret the results of guided experiments and create an error analysis and present the results.</p> <p>Personal Competence</p> <p><i>Social Competence</i></p> <p>Students can reflect their specific knowledge orally and discuss this with other students and teachers.</p> <p>After completing the module the students are able to independently protocol experiments and to discuss, analyze and record the results. They can present those results as a team.</p> <p><i>Autonomy</i></p>		
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84		
Credit points	6		
Studienleistung	None		
Examination	Written elaboration		
Examination duration and scale	Written report		
Assignment for the Following Curricula	Bioprocess Engineering: Core qualification: Compulsory		

Course L1112: Bioprocess Engineering Advanced Practical Course	
Typ	Practical Course
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. An-Ping Zeng, Prof. Andreas Liese, Prof. Ralf Pörtner
Language	DE
Cycle	WiSe
Content	<p>This experimental course focuses on a complete process from starting material like glucose over several production steps to a valuable final product.</p> <p>Production of the semi-synthetic beta-lactam antibiotic amoxicillin is investigated and conducted as an example for industrial processes on a laboratory scale involving microorganisms as well as cell free enzymes. The first step - fermentation of <i>Penicillium chrysogenum</i> to produce penicillin G - is carried out in the Institute of Bioprocess and Biosystems Engineering of Prof. Zeng. After recovery of penicillin G it is hydrolysed by penicillin acylase (<i>Escherichia coli</i>) to produce 6-aminopenicillanic acid which is further acylated by the same enzyme to produce amoxicillin. The enzymatic steps are done in the Institute of Technical Biocatalysis of Prof. Liese.</p> <p>A colloquium is part of the course.</p>
Literature	<p>Liese A, Seelbach K, Wandrey C, Industrial Biotransformations, Wiley-VCH, 2006</p> <p>Chmiel H, Einführung in die Bioverfahrenstechnik, Elsevier Spektrum Akademischer Verlag, 2006</p> <p>Schügerl K, Bioreaktionstechnik: Bioprozesse mit Mikroorganismen und Zellen. Prozeßüberwachung, Birkhäuser, 1997</p>

Course L0878: Advanced Practical Course in Microbiology	
Typ	Practical Course
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Dr. Carola Schröder
Language	EN
Cycle	WiSe
Content	<p>Participation in actual projects:</p> <ul style="list-style-type: none"> - From gene to product in heterologous hosts - Molecular biology - Enzyme assays - Taxonomy
Literature	Aktuelle themenbezogene Literatur wird im Kurs zur Verfügung gestellt

Specialization A - General Bioprocess Engineering

Module M0513: System Aspects of Renewable Energies			
Courses			
Title	Typ	Hrs/wk	CP
Fuel Cells, Batteries, and Gas Storage: New Materials for Energy Production and Storage (L0021)	Lecture	2	2
Energy Trading (L0019)	Lecture	1	1
Energy Trading (L0020)	Recitation Section (small)	1	1
Deep Geothermal Energy (L0025)	Lecture	2	2
Module Responsible	Prof. Martin Kaltschmitt		
Admission Requirements	None		
Recommended Previous Knowledge	Module: Technical Thermodynamics I Module: Technical Thermodynamics II		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p><i>Knowledge</i></p> <p>Students are able to describe the processes in energy trading and the design of energy markets and can critically evaluate them in relation to current subject specific problems. Furthermore, they are able to explain the basics of thermodynamics of electrochemical energy conversion in fuel cells and can establish and explain the relationship to different types of fuel cells and their respective structure. Students can compare this technology with other energy storage options. In addition, students can give an overview of the procedure and the energetic involvement of deep geothermal energy.</p> <p><i>Skills</i></p> <p>Students can apply the learned knowledge of storage systems for excessive energy to explain for various energy systems different approaches to ensure a secure energy supply. In particular, they can plan and calculate domestic, commercial and industrial heating equipment using energy storage systems in an energy-efficient way and can assess them in relation to complex power systems. In this context, students can assess the potential and limits of geothermal power plants and explain their operating mode.</p> <p>Furthermore, the students are able to explain the procedures and strategies for marketing of energy and apply it in the context of other modules on renewable energy projects. In this context they can unassistedly carry out analysis and evaluations of energie markets and energy trades.</p> <p>Personal Competence</p> <p><i>Social Competence</i></p> <p>Students are able to discuss issues in the thematic fields in the renewable energy sector addressed within the module.</p> <p><i>Autonomy</i></p> <p>Students can independently exploit sources , acquire the particular knowledge about the subject area and transform it to new questions.</p>		
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84		
Credit points	6		
Studienleistung	None		
Examination	Written exam		
Examination duration and scale	3 hours written exam		
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Renewable Energies: 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		

Course L0021: Fuel Cells, Batteries, and Gas Storage: New Materials for Energy Production and Storage	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Fröba
Language	DE
Cycle	SoSe
Content	<ol style="list-style-type: none"> 1. Introduction to electrochemical energy conversion 2. Function and structure of electrolyte 3. Low-temperature fuel cell <ul style="list-style-type: none"> ◦ Types ◦ Thermodynamics of the PEM fuel cell ◦ Cooling and humidification strategy 4. High-temperature fuel cell <ul style="list-style-type: none"> ◦ The MCFC ◦ The SOFC ◦ Integration Strategies and partial reforming 5. Fuels <ul style="list-style-type: none"> ◦ Supply of fuel ◦ Reforming of natural gas and biogas ◦ Reforming of liquid hydrocarbons 6. Energetic Integration and control of fuel cell systems
Literature	<ul style="list-style-type: none"> • Hamann, C.; Vielstich, W.: Elektrochemie 3. Aufl.; Weinheim: Wiley - VCH, 2003

Course L0019: Energy Trading	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Michael Sagorje
Language	DE
Cycle	SoSe
Content	<ul style="list-style-type: none"> • Basic concepts and tradable products in energy markets • Primary energy markets • Electricity Markets • European Emissions Trading Scheme • Influence of renewable energy • Real options • Risk management <p>Within the exercise the various tasks are actively discussed and applied to various cases of application.</p>
Literature	

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

Course L0025: Deep Geothermal Energy	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Ben Norden
Language	DE
Cycle	SoSe
Content	<ol style="list-style-type: none"> 1. Introduction to the deep geothermal use 2. Geological Basics I 3. Geological Basics II 4. Geology and thermal aspects 5. Rock Physical Aspects 6. Geochemical aspects 7. Exploration of deep geothermal reservoirs 8. Drilling technologies, piping and expansion 9. Borehole Geophysics 10. Underground system characterization and reservoir engineering 11. Microbiology and Upper-day system components 12. Adapted investment concepts, cost and environmental aspect
Literature	<ul style="list-style-type: none"> • Dippippo, R.: Geothermal Power Plants: Principles, Applications, Case Studies and Environmental Impact. Butterworth Heinemann; 3rd revised edition. (29. Mai 2012) • www.geo-energy.org • Edenhofer et al. (eds): Renewable Energy Sources and Climate Change Mitigation; Special Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 2012. • Kaltschmitt et al. (eds): Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte. Springer, 5. Aufl. 2013. • Kaltschmitt et al. (eds): Energie aus Erdwärme. Spektrum Akademischer Verlag; Auflage: 1999 (3. September 2001) • Huenges, E. (ed.): Geothermal Energy Systems: Exploration, Development, and Utilization. Wiley-VCH Verlag GmbH & Co. KGaA; Auflage: 1. Auflage (19. April 2010)

Module M0874: Wastewater Systems	
Courses	
Title	Typ Hrs/wk CP
Wastewater Systems - Collection, Treatment and Reuse (L0934)	Lecture 2 2
Wastewater Systems - Collection, Treatment and Reuse (L0943)	Recitation Section (large) 1 1
Advanced Wastewater Treatment (L0357)	Lecture 2 2
Advanced Wastewater Treatment (L0358)	Recitation Section (large) 1 1
Module Responsible	Prof. Ralf Otterpohl
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of wastewater management and the key processes involved in wastewater treatment.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
<i>Knowledge</i>	Students are able to outline key areas of the full range of treatment systems in waste water management, as well as their mutual dependence for sustainable water protection. They can describe relevant economic, environmental and social factors.
<i>Skills</i>	Students are able to pre-design and explain the available wastewater treatment processes and the scope of their application in municipal and for some industrial treatment plants.
Personal Competence	
<i>Social Competence</i>	Social skills are not targeted in this module.
<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.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Studienleistung	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Energy and Environmental Engineering: Specialisation Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Compulsory

Course L0934: Wastewater Systems - Collection, Treatment and Reuse	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Ralf Otterpohl
Language	EN
Cycle	SoSe
Content	<ul style="list-style-type: none"> •Understanding the global situation with water and wastewater •Regional planning and decentralised systems •Overview on innovative approaches •In depth knowledge on advanced wastewater treatment options for different situations, for end-of-pipe and reuse •Mathematical Modelling of Nitrogen Removal •Exercises with calculations and design
Literature	<p>Henze, Mogens: Wastewater Treatment: Biological and Chemical Processes, Springer 2002, 430 pages</p> <p>George Tchobanoglous, Franklin L. Burton, H. David Stensel: Wastewater Engineering: Treatment and Reuse, Metcalf & Eddy McGraw-Hill, 2004 - 1819 pages</p>

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

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

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

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

Course L1278: High Pressure Technique for Apparatus Engineering	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Robert Surma
Language	DE/EN
Cycle	SoSe
Content	<ol style="list-style-type: none"> 1. Basic laws and certification standards 2. Basics for calculations of pressurized vessels 3. Stress hypothesis 4. Selection of materials and fabrication processes 5. vessels with thin walls 6. vessels with thick walls 7. Safety installations 8. Safety analysis <p>Applications:</p> <ul style="list-style-type: none"> - subsea technology (manned and unmanned vessels) - steam vessels - heat exchangers - LPG, LEG transport vessels
Literature	<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; Stadtmuller: Experimental Techniques in High-Pressure Research, Wiley & Sons Verlag</p> <p>Klapp: Apparate- und Anlagentechnik, Springer Verlag</p>

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

Module M0875: Nexus Engineering - Water, Soil, Food and Energy			
Courses			
Title	Typ	Hrs/wk	CP
Ecological Town Design - Water, Energy, Soil and Food Nexus (L1229)	Seminar	2	2
Water & Wastewater Systems in a Global Context (L0939)	Lecture	2	4
Module Responsible	Prof. Ralf Otterpohl		
Admission Requirements	None		
Recommended Previous Knowledge	Basic knowledge of the global situation with rising poverty, soil degradation, migration to cities, lack of water resources and sanitation		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence			
<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.		
Personal Competence			
<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.		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Credit points	6		
Studienleistung	None		
Examination	Subject theoretical and practical work		
Examination duration and scale	During the course of the semester, the students work towards mile stones. The work includes presentations and papers. Detailed information can be found at the beginning of the semester in the StudIP course module handbook.		
Assignment for the Following Curricula	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		

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

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

Course L0355: Fundamentals of Cell and Tissue Engineering	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Ralf Pörtner, Prof. An-Ping Zeng
Language	EN
Cycle	SoSe
Content	Overview of cell culture technology and tissue engineering (cell culture product manufacturing, complexity of protein therapeutics, examples of tissue engineering) (Pörtner, Zeng) Fundamentals of cell biology for process engineering (cells: source, composition and structure, interactions with environment, growth and death - cell cycle, protein glycolysation) (Pörtner) Cell physiology for process engineering (Overview of central metabolism, genomics etc.) (Zeng) Medium design (impact of media on the overall cell culture process, basic components of culture medium, serum and protein-free media) (Pörtner) Stoichiometry and kinetics of cell growth and product formation (growth of mammalian cells, quantitative description of cell growth & product formation, kinetics of growth)
Literature	Butler, M (2004) Animal Cell Culture Technology - The basics, 2 nd 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	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Ralf Pörtner
Language	EN
Cycle	SoSe
Content	Requirements for cell culture 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
Literature	Butler, M (2004) Animal Cell Culture Technology - The basics, 2 nd 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
Module Responsible	Prof. Sabine Le Borne		
Admission Requirements	None		
Recommended Previous Knowledge	<ul style="list-style-type: none"> Mathematik I, II, III für Ingenieurstudierende (deutsch oder englisch) oder Analysis & Lineare Algebra I + II sowie Analysis III für Technomathematiker Basic MATLAB knowledge 		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p>Students are able to</p> <ul style="list-style-type: none"> list numerical methods for the solution of ordinary differential equations and explain their core ideas, repeat convergence statements for the treated numerical methods (including the prerequisites tied to the underlying problem), explain aspects regarding the practical execution of a method. select the appropriate numerical method for concrete problems, implement the numerical algorithms efficiently and interpret the numerical results <p>Students are able to</p> <ul style="list-style-type: none"> implement (MATLAB), apply and compare numerical methods for the solution of ordinary differential equations, to justify the convergence behaviour of numerical methods with respect to the posed problem and selected algorithm, for a given problem, develop a suitable solution approach, if necessary by the composition of several algorithms, to execute this approach and to critically evaluate the results. 		
Personal Competence	<p>Students are able to</p> <ul style="list-style-type: none"> 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. <p>Students are capable</p> <ul style="list-style-type: none"> to assess whether the supporting theoretical and practical exercises are better solved individually or in a team, to assess their individual progress and, if necessary, to ask questions and seek help. 		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Credit points	6		
Studienleistung	None		
Examination	Written exam		
Examination duration and scale	90 min		
Assignment for the Following Curricula	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 Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory Mathematical Modelling in Engineering: Theory, Numerics, Applications: Specialisation I. Numerics (TUHH): 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	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sabine Le Borne, Dr. Patricio Farrell
Language	DE/EN
Cycle	SoSe
Content	Numerical methods for Initial Value Problems <ul style="list-style-type: none"> • single step methods • multistep methods • stiff problems • differential algebraic equations (DAE) of index 1 Numerical methods for Boundary Value Problems <ul style="list-style-type: none"> • multiple shooting method • difference methods • variational methods
Literature	<ul style="list-style-type: none"> • E. Hairer, S. Noersett, G. Wanner: Solving Ordinary Differential Equations I: Nonstiff Problems • E. Hairer, G. Wanner: Solving Ordinary Differential Equations II: Stiff and Differential-Algebraic Problems

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

Module M0749: Waste Treatment and Solid Matter Process Technology	
Courses	
Title	Typ Hrs/wk CP
Solid Matter Process Technology for Biomass (L0052)	Lecture 2 2
Thermal Waste Treatment (L0320)	Lecture 2 2
Thermal Waste Treatment (L1177)	Recitation Section (large) 1 2
Module Responsible	Prof. Kerstin Kuchta
Admission Requirements	None
Recommended Previous Knowledge	Basics of <ul style="list-style-type: none"> • thermo dynamics • fluid dynamics • chemistry
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	<p>The students can name, describe current issue and problems in the field of thermal waste treatment and particle process engineering and contemplate them in the context of their field.</p> <p><i>Knowledge</i> The industrial application of unit operations as part of process engineering is explained by actual examples of waste incineration technologies and solid biomass processes. Compostion, particle sizes, transportation and dosing, drying and agglomeration of renewable resources and wastes are described as important unit operations when producing solid fuels and bioethanol, producing and refining edible oils, electricity , heat and mineral recyclables.</p> <p><i>Skills</i> The students are able to select suitable processes for the treatment of wastes or raw material with respect to their characteristics and the process aims. They can evaluate the efforts and costs for processes and select economically feasible treatment concepts.</p>
Personal Competence	Students can
<i>Social Competence</i>	<ul style="list-style-type: none"> • respectfully work together as a team and discuss technical tasks • participate in subject-specific and interdisciplinary discussions, • develop cooperated solutions • promote the scientific development and accept professional constructive criticism.
<i>Autonomy</i>	Students can independently tap knowledge of the subject area and transform it to new questions. They are capable, in consultation with supervisors, to assess their learning level and define further steps on this basis. Furthermore, they can define targets for new application-or research-oriented duties in accordance with the potential social, economic and cultural impact.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Studienleistung	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory

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

Course L0320: Thermal Waste Treatment	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Kerstin Kuchta, Dr. Joachim Gerth, Dr. Ernst-Ulrich Hartge
Language	EN
Cycle	SoSe
Content	<ul style="list-style-type: none"> • Introduction, actual state-of-the-art of waste incineration, aims. legal background, reaction principals • basics of incineration processes: waste composition, calorific value, calculation of air demand and flue gas composition • Incineration techniques: grate firing, ash transfer, boiler • Flue gas cleaning: Volume, composition, legal frame work and emission limits, dry treatment, scrubber, de-nox techniques, dioxin elimination, Mercury elimination • Ash treatment: Mass, quality, treatment concepts, recycling, disposal
Literature	Thomé-Kozmiensky, K. J. (Hrsg.): Thermische Abfallbehandlung Bande 1-7. EF-Verlag für Energie- und Umwelttechnik, Berlin, 196 - 2013.

Course L1177: Thermal Waste Treatment	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Dr. Ernst-Ulrich Hartge, Dr. Joachim Gerth
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0898: Heterogeneous Catalysis			
Courses			
Title	Typ	Hrs/wk	CP
Analysis and Design of Heterogeneous Catalytic Reactors (L0223)	Lecture	2	2
Modern Methods in Heterogeneous Catalysis (L0533)	Lecture	2	2
Modern Methods in Heterogeneous Catalysis (L0534)	Practical Course	2	2
Module Responsible	Prof. Raimund Horn		
Admission Requirements	None		
Recommended Previous Knowledge	Content of the bachelor-modules "process technology", as well as particle technology, fluidmechanics in process-technology and transport processes.		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p><i>Knowledge</i></p> <p>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></p> <p>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>Personal Competence</p> <p><i>Social Competence</i></p> <p>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></p> <p>The students are able to obtain further information for experimental planning and assess their relevance autonomously.</p>		
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84		
Credit points	6		
Studienleistung	Compulsory Bonus	Form	Description
	Yes None	Presentation	
Examination	Written exam		
Examination duration and scale	120 min		
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core qualification: Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory		

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

Course L0533: Modern Methods in Heterogeneous Catalysis	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Raimund Horn
Language	EN
Cycle	SoSe
Content	<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"> • Materials Science (synthesis and characterization of solid catalysts) • Physics (structure and electronic properties of solids, defects) • Physical Chemistry (thermodynamics, reaction mechanisms, chemical kinetics, adsorption, desorption, spectroscopy, surface chemistry, theory) • Reaction Engineering (catalytic reactors, mass- and heat transport in catalytic reactors, multi-scale modeling, application of heterogeneous catalysis) <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 aquired theoretical knowledge by synthesizing a solid catalyst, characterizing it with a variety of modern instrumental methods (e.g. BET, chemisorption, pore analysis, XRD, Raman-Spectroscopy, Electron Microscopy) and measuring its kinetics. Class and laboratory „Modern Methods in Heterogeneous Catalysis“ in combination with the lecture „Analysis and Design of Heterogeneous Catalytic Reactors“ will give interested students the opportunity to specialize in this vibrant, multifaceted and application oriented field of research.</p>
Literature	<ul style="list-style-type: none"> • J.M. Thomas, W.J. Thomas: Principles and Practice of Heterogeneous Catalysis, VCH • I. Chorkendorff, J. W. Niemantsverdriet, Concepts of Modern Catalysis and Kinetics, WILEY-VCH • B.C. Gates: Catalytic Chemistry, John Wiley • R.A. van Santen, P.W.N.M. van Leeuwen, J.A. Moulijn, B.A. Averill (Eds.): Catalysis: an integrated approach, Elsevier • D.P. Woodruff, T.A. Delchar: Modern Techniques of Surface Science, Cambridge Univ. Press • J.W. Niemantsverdriet: Spectroscopy in Catalysis, VCH • F. Delannay (Ed.): Characterization of heterogeneous catalysts, Marcel Dekker • C.H. Bartholomew, R.J. Farrauto: Fundamentals of Industrial Catalytic Processes (2nd Ed.), Wiley

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

Course L1375: Computational Fluid Dynamics - Exercises in OpenFoam	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	SoSe
Content	<ul style="list-style-type: none"> • generation of numerical grids with a common grid generator • selection of models and boundary conditions • basic numerical simulation with OpenFoam within the TUHH CIP-Pool
Literature	OpenFoam Tutorials (StudIP)

Course L1052: Computational Fluid Dynamics in Process Engineering	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	SoSe
Content	<ul style="list-style-type: none"> • Introduction into partial differential equations • Basic equations • Boundary conditions and grids • Numerical methods • Finite difference method • Finite volume method • Time discretisation and stability • Population balance • Multiphase Systems • Modeling of Turbulent Flows • Exercises: Stability Analysis • Exercises: Example on CFD - analytically/numerically
Literature	<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>

Course L0099: Statistical Thermodynamics and Molecular Modelling	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Sven Jakobtorweihen
Language	EN
Cycle	SoSe
Content	<ul style="list-style-type: none"> • Some lectures will be carried out as computer exercises • Introduction to Statistical Mechanics • The ensemble concept • The classical limit • Intermolecular potentials, force fields • Monte Carlo simulations (acceptance rules) (Übungen im Rechnerpool) (exercises in computer pool) • Molecular Dynamics Simulations (integration of equations of motion, calculating transport properties) (exercises in computer pool) • Molecular simulation of Phase equilibria (Gibbs Ensemble) • Methods for the calculation of free energies
Literature	<p>Daan Frenkel, Berend Smit: Understanding Molecular Simulation, Academic Press</p> <p>M. P. Allen, D. J. Tildesley: Computer Simulations of Liquids, Oxford Univ. Press</p> <p>A.R. Leach: Molecular Modelling - Principles and Applications, Prentice Hall, N.Y.</p> <p>D. A. McQuarrie: Statistical Mechanics, University Science Books</p> <p>T. L. Hill: Statistical Mechanics , Dover Publications</p>

Module M1033: Special Areas of Process Engineering	
Courses	
Title	Typ Hrs/wk CP
Chemical Kinetics (L0508)	Lecture 2 2
Solid Matter Process in chemical Industry (L2021)	Lecture 2 2
Interfaces and Colloids (L0194)	Lecture 2 2
Industrial Inorganic and Organic Processes (L0531)	Lecture 2 2
Polymer Reaction Engineering (L1244)	Lecture 2 2
Safety of Chemical Reactions (L1321)	Lecture 2 2
Ceramics Technology (L0379)	Lecture 2 3
Environmental Analysis (L0354)	Lecture 2 3
Module Responsible	Prof. Michael Schlüter
Admission Requirements	None
Recommended Previous Knowledge	The students should have passed the Bachelor modules "Process Engineering" successfully.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
<i>Knowledge</i>	Students are able to find their way around selected special areas of Process Engineering within the scope of Process Engineering. Students are able to explain technical dependencies and models in selected special areas of Process Engineering.
<i>Skills</i>	Students are able to apply basic methods in selected areas of process engineering.
Personal Competence	
<i>Social Competence</i>	
<i>Autonomy</i>	Students can chose independently, in which field the want to deepen their knowledge and skills through the election of courses.
Workload in Hours	Depends on choice of courses
Credit points	6
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0508: Chemical Kinetics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	120 Minuten
Lecturer	Prof. Raimund Horn
Language	EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> - Micro kinetics, formal kinetics, molecularity, reaction order, integrated rate laws - Complex reactions, reversible reactions, consecutive reactions, parallel reactions, approximation methods: steady-state, pseudo-first order, numerical solution of rate equations , example : Belousov-Zhabotinskii reaction - Experimental methods of kinetics, integral approach, differential approach, initial rate method, method of half-life, relaxation methods - Collision theory, Maxwell velocity distribution, collision numbers, line of centers model - Transition state theory, partition functions of atoms and molecules, examples, calculating reaction equilibria on the basis of molecular data only, heats of reaction, calculating rates of reaction by means of statistical thermodynamics - Kinetics of heterogeneous reactions, peculiarities of heterogeneous reactions, mean-field approximation, Langmuir adsorption isotherm, reaction mechanisms, Langmuir-Hinshelwood Mechanism, Eley-Rideal Mechanism, steady-state approximation, quasi-equilibrium approximation, most abundant reaction intermediate (MARI), reaction order, apparent activation energy, example: CO oxidation, transition state theory of surface reactions, Sabatier's principle, sticking coefficient, parameter fitting - Explosions, cold flames
Literature	<p>J. I. Steinfeld, J. S. Francisco, W. L. Hase: Chemical Kinetics & Dynamics, Prentice Hall</p> <p>K. J. Laidler: Chemical Kinetics, Harper & Row Publishers</p> <p>R. K. Masel. Chemical Kinetics & Catalysis , Wiley</p> <p>I. Chorkendorff,, J. W. Niemantsverdriet: Concepts of modern Catalysis and Kinetics, Wiley</p>

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

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

Course L0531: Industrial Inorganic and Organic Processes	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	45 Minuten
Lecturer	Dr. Achim Bartsch
Language	DE
Cycle	WiSe
Content	<p>The occupational area of chemical engineers is principally the chemical industry.</p> <p>This survey course will focus on history, economic significance, technical applications, and main production processes in detail of major primary bulk inorganic and organic chemicals. Disposition of raw materials as well as ecological problems are discussed.</p> <p>Inorganic Products</p> <ul style="list-style-type: none"> * inorganic raw materials (hydrogen and compounds, nitrogen and compounds...) * inorganic fertilizers * metals and their compounds * semiconductors * inorganic solids (building materials, ceramics, fibers, pigments ...) ... <p>Organic Products</p> <ul style="list-style-type: none"> * bulk products for organic synthesis (synthesis gas, C1-compounds) * Production and processing of olefines, alcohols, hydrocarbons, aromatics * Petroleum and Petrochemicals * Surfactants and Detergents * Production and processing of oleochemicals * Synthetic Polymers ...
Literature	<p>Ullmann's Encyclopedia of Industrial Chemistry, Wiley online library 2014</p> <p>M. Bertau, A. Müller, P. Fröhlich und M. Katzberg: Industrielle Anorganische Chemie, Wiley-VCH 2013</p> <p>Hans-Jürgen Arpe: Industrielle Organische Chemie, Wiley-VCH 2007</p>

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

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

Course L0379: Ceramics Technology	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 Minuten
Lecturer	Dr. Rolf Janßen
Language	DE/EN
Cycle	WiSe
Content	<p>Introduction to ceramic processing with emphasis on advanced structural ceramics. The course focus predominately on powder-based processing, e.g. "powder-metallurgical techniques and sintering (solid state and liquid phase). Also, some aspects of glass and cement science as well as new developments in powderless forming techniques of ceramics and ceramic composites will be addressed. Examples will be discussed in order to give engineering students an understanding of technology development and specific applications of ceramic components.</p> <p>Content:</p> <ol style="list-style-type: none"> 1. Introduction Inhalt: 2. Raw materials 3. Powder fabrication 4. Powder processing 5. Shape-forming processes 6. Densification, sintering 7. Glass and Cement technology 8. Ceramic-metal joining techniques
Literature	<p>W.D. Kingery, „Introduction to Ceramics“, John Wiley & Sons, New York, 1975</p> <p>ASM Engineering Materials Handbook Vol.4 „Ceramics and Glasses“, 1991</p> <p>D.W. Richerson, „Modern Ceramic Engineering“, Marcel Decker, New York, 1992</p> <p>Skript zur Vorlesung</p>

Course L0354: Environmental Analysis	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	45 Minuten
Lecturer	Dr. Dorothea Rechtenbach, Dr. Henning Mangels
Language	EN
Cycle	WiSe
Content	<p>Introduction</p> <p>Sampling in different environmental compartments, sample transportation, sample storage</p> <p>Sample preparation</p> <p>Photometry</p> <p>Wastewater analysis</p> <p>Introduction into chromatography</p>

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

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

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

Module M0519: Particle Technology and Solid Matter Process Technology			
Courses			
Title	Typ	Hrs/wk	CP
Advanced Particle Technology II (L0051)	Project-/problem-based Learning	1	1
Advanced Particle Technology II (L0050)	Lecture	2	2
Experimental Course Particle Technology (L0430)	Practical Course	3	3
Module Responsible	Prof. Stefan Heinrich		
Admission Requirements	None		
Recommended Previous Knowledge	Basic knowledge of solids processes and particle technology		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p><i>Knowledge</i> After completion of the module the students will be able to describe and explain processes for solids processing in detail based on microprocesses on the particle level.</p> <p><i>Skills</i> Students are able to choose process steps and apparatuses for the focused treatment of solids depending on the specific characteristics. They furthermore are able to adapt these processes and to simulate them.</p>		
Personal Competence	<p><i>Social Competence</i> Students are able to present results from small teamwork projects in an oral presentation and to discuss their knowledge with scientific researchers.</p> <p><i>Autonomy</i> Students are able to analyze and solve problems regarding solid particles independently or in small groups.</p>		
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84		
Credit points	6		
Studienleistung	Compulsory Bonus	Form	Description
	Yes None	Written elaboration	fünf Berichte (pro Versuch ein Bericht) à 5-10 Seiten
Examination	Written exam		
Examination duration and scale	120 minutes		
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Energy and Environmental Engineering: Specialisation Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Process Engineering: Core qualification: Compulsory		

Course L0051: Advanced Particle Technology II	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Stefan Heinrich
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0050: Advanced Particle Technology II	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Stefan Heinrich
Language	DE
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Exercise in form of "Project based Learning" • Agglomeration, particle size enlargement • advanced particle size reduction • Advanced theorie of fluid/particle flows • CFD-methods for the simulation of disperse fluid/solid flows, Euler/Euler methods, Descrete Particle Modeling • Treatment of simulation problems with distributed properties, solution of population balances
Literature	<p>Schubert, H.; Heidenreich, E.; Liepe, F.; Neeße, T.: Mechanische Verfahrenstechnik. Deutscher Verlag für die Grundstoffindustrie, Leipzig, 1990.</p> <p>Stieß, M.: Mechanische Verfahrenstechnik I und II. Springer Verlag, Berlin, 1992.</p>

Course L0430: Experimental Course Particle Technology	
Typ	Practical Course
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Stefan Heinrich
Language	DE
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Fluidization • Agglomeration • Granulation • Drying • Determination of mechanical properties of agglomerats
Literature	<p>Schubert, H.; Heidenreich, E.; Liepe, F.; Neeße, T.: Mechanische Verfahrenstechnik. Deutscher Verlag für die Grundstoffindustrie, Leipzig, 1990.</p> <p>Stieß, M.: Mechanische Verfahrenstechnik I und II. Springer Verlag, Berlin, 1992.</p>

Module M0537: Applied Thermodynamics: Thermodynamic Properties for Industrial Applications			
Courses			
Title	Typ	Hrs/wk	CP
Applied Thermodynamics: Thermodynamic Properties for Industrial Applications (L0100)	Lecture	4	3
Applied Thermodynamics: Thermodynamic Properties for Industrial Applications (L0230)	Recitation Section (small)	2	3
Module Responsible	Dr. Sven Jakobtorweihen		
Admission Requirements	None		
Recommended Previous Knowledge	Thermodynamics III		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p>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.</p> <p>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.</p>		
<i>Knowledge</i>			
<i>Skills</i>			
Personal Competence	<p>Students are capable to develop and discuss solutions in small groups; further they can translate these solutions into calculation algorithms.</p> <p>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.</p>		
<i>Social Competence</i>			
<i>Autonomy</i>			
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84		
Credit points	6		
Studienleistung	Compulsory Bonus	Form	Description
	Yes None	Written elaboration	
Examination	Oral exam		
Examination duration and scale	1 Stunde Gruppenprüfung		
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory 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	
Typ	Lecture
Hrs/wk	4
CP	3
Workload in Hours	Independent Study Time 34, Study Time in Lecture 56
Lecturer	Dr. Sven Jakobtorweihen, Prof. Ralf Dohrn
Language	EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Phase equilibria in multicomponent systems • Partitioning in biorelevant systems • Calculation of phase equilibria in colloidal systems: UNIFAC, COSMO-RS (exercises in computer pool) • Calculation of partitioning coefficients in biological membranes: COSMO-RS (exercises in computer pool) • Application of equations of state (vapour pressure, phase equilibria, etc.) (exercises in computer pool) • Intermolecular forces, interaction Potentials • Introduction in statistical thermodynamics
Literature	

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

Module M0633: Industrial Process Automation			
Courses			
Title	Typ	Hrs/wk	CP
Industrial Process Automation (L0344)	Lecture	2	3
Industrial Process Automation (L0345)	Recitation Section (small)	2	3
Module Responsible	Prof. Alexander Schlaefer		
Admission Requirements	None		
Recommended Previous Knowledge	mathematics and optimization methods principles of automata principles of algorithms and data structures programming skills		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p><i>Knowledge</i></p> <p>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></p> <p>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>Personal Competence</p> <p><i>Social Competence</i></p> <p>The students work in teams to solve problems.</p> <p><i>Autonomy</i></p> <p>The students can reflect their knowledge and document the results of their work.</p>		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Credit points	6		
Studienleistung	Compulsory Bonus	Form	Description
	Yes	10 %	Excercises
Examination	Written exam		
Examination duration and scale	90 minutes		
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory International Production Management: Specialisation Production Technology: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory		

Course L0344: Industrial Process Automation	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> - foundations of problem solving and system modeling, discrete event systems - properties of processes, modeling using automata and Petri-nets - design considerations for processes (mutex, deadlock avoidance, liveness) - optimal scheduling for processes - optimal decisions when planning manufacturing systems, decisions under uncertainty - software design and software architectures for automation, PLCs
Literature	<p>J. Lunze: „Automatisierungstechnik“, Oldenbourg Verlag, 2012</p> <p>Reisig: Petrinetze: Modellierungstechnik, Analysemethoden, Fallstudien; Vieweg+Teubner 2010</p> <p>Hruz, 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	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0106: Applications of Fluid Mechanics in Process Engineering	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	DE
Cycle	WiSe
Content	The Exercise-Lecture will bridge the gap between the theoretical content from the lecture and practical calculations. For this aim a special exercise is calculated at the blackboard that shows how the theoretical knowledge from the lecture can be used to solve real problems in Process Engineering.
Literature	<ol style="list-style-type: none"> 1. Brauer, H.: Grundlagen der Einphasen- und Mehrphasenströmungen. Verlag Sauerländer, Aarau, Frankfurt (M), 1971. 2. Brauer, H.; Mewes, D.: Stoffaustausch einschließlich chemischer Reaktion. Frankfurt: Sauerländer 1972. 3. Crowe, C. T.: Engineering fluid mechanics. Wiley, New York, 2009. 4. Durst, F.: Strömungsmechanik: Einführung in die Theorie der Strömungen von Fluiden. Springer-Verlag, Berlin, Heidelberg, 2006. 5. Fox, R.W.; et al.: Introduction to Fluid Mechanics. J. Wiley & Sons, 1994. 6. Herwig, H.: Strömungsmechanik: Eine Einführung in die Physik und die mathematische Modellierung von Strömungen. Springer Verlag, Berlin, Heidelberg, New York, 2006. 7. Herwig, H.: Strömungsmechanik: Einführung in die Physik von technischen Strömungen: Vieweg+Teubner Verlag / GWV Fachverlage GmbH, Wiesbaden, 2008. 8. Kuhlmann, H.C.: Strömungsmechanik. München, Pearson Studium, 2007 9. Oertl, H.: Strömungsmechanik: Grundlagen, Grundgleichungen, Lösungsmethoden, Softwarebeispiele. Vieweg+ Teubner / GWV Fachverlage GmbH, Wiesbaden, 2009. 10. Schade, H.; Kunz, E.: Strömungslehre. Verlag de Gruyter, Berlin, New York, 2007. 11. Truckenbrodt, E.: Fluidmechanik 1: Grundlagen und elementare Strömungsvorgänge dichtebeständiger Fluide. Springer-Verlag, Berlin, Heidelberg, 2008. 12. Schlichting, H. : Grenzschicht-Theorie. Springer-Verlag, Berlin, 2006. 13. van Dyke, M.: An Album of Fluid Motion. The Parabolic Press, Stanford California, 1882. 14. White, F.: Fluid Mechanics, Mcgraw-Hill, ISBN-10: 0071311211, ISBN-13: 978-0071311212, 2011.

Course L0001: Fluid Mechanics II	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	DE
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Differential equations for momentum-, heat and mass transfer • Examples for simplifications of the Navier-Stokes Equations • Unsteady momentum transfer • Free shear layer, turbulence and free jets • Flow around particles - Solids Process Engineering • Coupling of momentum and heat transfer - Thermal Process Engineering • Rheology – Bioprocess Engineering • Coupling of momentum- and mass transfer – Reactive mixing, Chemical Process Engineering • Flow thre porous structures - heterogeneous catalysis • Pumps and turbines - Energy- and Environmental Process Engineering • Wind- and Wave-Turbines - Renewable Energy • Introduction into Computational Fluid Dynamics
Literature	<ol style="list-style-type: none"> 1. Brauer, H.: Grundlagen der Einphasen- und Mehrphasenströmungen. Verlag Sauerländer, Aarau, Frankfurt (M), 1971. 2. Brauer, H.; Mewes, D.: Stoffaustausch einschließlich chemischer Reaktion. Frankfurt: Sauerländer 1972. 3. Crowe, C. T.: Engineering fluid mechanics. Wiley, New York, 2009. 4. Durst, F.: Strömungsmechanik: Einführung in die Theorie der Strömungen von Fluiden. Springer-Verlag, Berlin, Heidelberg, 2006. 5. Fox, R.W.; et al.: Introduction to Fluid Mechanics. J. Wiley & Sons, 1994. 6. Herwig, H.: Strömungsmechanik: Eine Einführung in die Physik und die mathematische Modellierung von Strömungen. Springer Verlag, Berlin, Heidelberg, New York, 2006. 7. Herwig, H.: Strömungsmechanik: Einführung in die Physik von technischen Strömungen: Vieweg+Teubner Verlag / GWV Fachverlage GmbH, Wiesbaden, 2008. 8. Kuhlmann, H.C.: Strömungsmechanik. München, Pearson Studium, 2007 9. Oertl, H.: Strömungsmechanik: Grundlagen, Grundgleichungen, Lösungsmethoden, Softwarebeispiele. Vieweg+ Teubner / GWV Fachverlage GmbH, Wiesbaden, 2009. 10. Schade, H.; Kunz, E.: Strömungslehre. Verlag de Gruyter, Berlin, New York, 2007. 11. Truckenbrodt, E.: Fluidmechanik 1: Grundlagen und elementare Strömungsvorgänge dichtebeständiger Fluide. Springer-Verlag, Berlin, Heidelberg, 2008. 12. Schlichting, H. : Grenzschicht-Theorie. Springer-Verlag, Berlin, 2006. 13. van Dyke, M.: An Album of Fluid Motion. The Parabolic Press, Stanford California, 1882.

Module M0881: Mathematical Image Processing	
Courses	
Title	Typ Hrs/wk CP
Mathematical Image Processing (L0991)	Lecture 3 4
Mathematical Image Processing (L0992)	Recitation Section (small) 1 2
Module Responsible	Prof. Marko Lindner
Admission Requirements	None
Recommended Previous Knowledge	<ul style="list-style-type: none"> • Analysis: partial derivatives, gradient, directional derivative • Linear Algebra: eigenvalues, least squares solution of a linear system
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	<p>Students are able to</p> <p><i>Knowledge</i></p> <ul style="list-style-type: none"> • characterize and compare diffusion equations • explain elementary methods of image processing • explain methods of image segmentation and registration • sketch and interrelate basic concepts of functional analysis <p>Students are able to</p> <p><i>Skills</i></p> <ul style="list-style-type: none"> • implement and apply elementary methods of image processing • explain and apply modern methods of image processing <p>Personal Competence</p> <p><i>Social Competence</i></p> <p>Students are able to work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge) and to explain theoretical foundations.</p> <p><i>Autonomy</i></p> <ul style="list-style-type: none"> • Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them. • Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Studienleistung	None
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Computational Science and Engineering: Specialisation Kernfächer Mathematik (2 Kurse): Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0991: Mathematical Image Processing	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Marko Lindner
Language	DE/EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> • basic methods of image processing • smoothing filters • the diffusion / heat equation • variational formulations in image processing • edge detection • image segmentation • image registration
Literature	Bredies/Lorenz: Mathematische Bildverarbeitung

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

Module M0899: Synthesis and Design of Industrial Processes	
Courses	
Title	Typ
Synthesis and Design of Industrial Facilities (L1048)	Lecture
Industrial Plant Design and Economics (L1977)	Project-/problem-based Learning
	Hrs/wk
	1
	3
	CP
	2
	4
Module Responsible	Prof. Georg Fieg
Admission Requirements	None
Recommended Previous Knowledge	<p>process and plant engineering I and II</p> <p>thermal separation processes</p> <p>heat and mass transport processes</p> <p>CAPE (absolut necessarily!)</p>
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	<p>students can:</p> <ul style="list-style-type: none"> - reproduce the main elements of design of industrial processes - give an overview and explain the phases of design - describe and explain energy, mass balances, cost estimation methods and economic evaluation of invest projects - justify and discuss process control concepts and fundamentals of process optimization <p>students are capable of:</p> <ul style="list-style-type: none"> - conduction and evaluation of design of unit operations - combination of unit operation to a complex process plant - use of cost estimation methods for the prediction of production costs - carry out the pfd-diagram
Personal Competence	<p><i>Social Competence</i> students are able to discuss and develop in groups the design of an industrial process</p> <p><i>Autonomy</i> students are able to reflect the consequences of their professional activity</p>
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Studienleistung	None
Examination	Subject theoretical and practical work
Examination duration and scale	Engineering Handbook and oral exam (20 min)
Assignment for the Following Curricula	<p>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory</p> <p>Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory</p> <p>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory</p> <p>Process Engineering: Specialisation Process Engineering: Elective Compulsory</p>

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

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

Course L0023: Thermal Engineering	
Typ	Lecture
Hrs/wk	3
CP	5
Workload in Hours	Independent Study Time 108, Study Time in Lecture 42
Lecturer	Prof. Gerhard Schmitz
Language	DE
Cycle	WiSe
Content	<p>1. Introduction</p> <p>2. Fundamentals of Thermal Engineering 2.1 Heat Conduction 2.2 Convection 2.3 Radiation 2.4 Heat transition 2.5 Combustion parameters 2.6 Electrical heating 2.7 Water vapor transport</p> <p>3. Heating Systems 3.1 Warm water heating systems 3.2 Warm water supply 3.3 piping calculation 3.4 boilers, heat pumps, solar collectors 3.5 Air heating systems 3.6 radiative heating systems</p> <p>4. Thermal treatment systems 4.1 Industrial furnaces 4.2 Melting furnaces 4.3 Drying plants 4.4 Emission control 4.5 Chimney calculation 4.6 Energy measuring</p> <p>5. Laws and standards 5.1 Buildings 5.2 Industrial plants</p>
Literature	<ul style="list-style-type: none"> • Schmitz, G.: Klimaanlagen, Skript zur Vorlesung • VDI Wärmeatlas, 11. Auflage, Springer Verlag, Düsseldorf 2013 • Herwig, H.; Moschallski, A.: Wärmeübertragung, Vieweg+Teubner Verlag, Wiesbaden 2009 • Recknagel, H.; Sprenger, E.; Schrammek, E.-R.: Taschenbuch für Heizung- und Klimatechnik 2013/2014, 76. Auflage, Deutscher Industrieverlag, 2013

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

Module M0900: Examples in Solid Process Engineering			
Courses			
Title		Typ	Hrs/wk CP
Fluidization Technology (L0431)		Lecture	2 2
Practical Course Fluidization Technology (L1369)		Practical Course	1 1
Technical Applications of Particle Technology (L0955)		Lecture	2 2
Exercises in Fluidization Technology (L1372)		Recitation Section (small)	1 1
Module Responsible	Prof. Stefan Heinrich		
Admission Requirements	None		
Recommended Previous Knowledge	Knowledge from the module particle technology		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	After completion of the module the students will be able to describe based on examples the assembly of solids engineering processes consisting of multiple apparatuses and subprocesses. They are able to describe the coaction and interrelation of subprocesses.		
<i>Knowledge</i>			
<i>Skills</i>	Students are able to analyze tasks in the field of solids process engineering and to combine suitable subprocesses in a process chain.		
Personal Competence	Students are able to discuss technical problems in a scientific manner.		
<i>Social Competence</i>			
<i>Autonomy</i>	Students are able to acquire scientific knowledge independently and discuss technical problems in a scientific manner.		
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84		
Credit points	6		
Studienleistung	Compulsory Bonus	Form	Description
	Yes None	Written elaboration	drei Berichte (pro Versuch ein Bericht) à 5-10 Seiten
Examination	Written exam		
Examination duration and scale	120 minutes		
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory		

Course L0431: Fluidization Technology	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Stefan Heinrich
Language	EN
Cycle	WiSe
Content	Introduction: definition, fluidization regimes, comparison with other types of gas/solids reactors Typical fluidized bed applications Fluidmechanical principle Local fluid mechanics of gas/solid fluidization Fast fluidization (circulating fluidized bed) Entrainment Solids mixing in fluidized beds Application of fluidized beds to granulation and drying processes
Literature	Kunii, D.; Levenspiel, O.: Fluidization Engineering. Butterworth Heinemann, Boston, 1991.

Course L1369: Practical Course Fluidization Technology	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Stefan Heinrich
Language	EN
Cycle	WiSe
Content	Experiments: <ul style="list-style-type: none"> • Determination of the minimum fluidization velocity • heat transfer • granulation • drying
Literature	Kunii, D.; Levenspiel, O.: Fluidization Engineering. Butterworth Heinemann, Boston, 1991.

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

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

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

Course L0203: Air Pollution Abatement	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Ernst-Ulrich Hartge
Language	EN
Cycle	WiSe
Content	In the lecture methods for the reduction of emissions from industrial plants are treated. At the beginning a short survey of the different forms of air pollutants is given. In the second part physical principals for the removal of particulate and gaseous pollutants from flue gases are treated. Industrial applications of these principles are demonstrated with examples showing the removal of specific compounds, e.g. sulfur or mercury from flue gases of incinerators.
Literature	Handbook of air pollution prevention and control, Nicholas P. Cheremisinoff. - Amsterdam [u.a.] : Butterworth-Heinemann, 2002 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 M0802: Membrane Technology			
Courses			
Title	Typ	Hrs/wk	CP
Membrane Technology (L0399)	Lecture	2	3
Membrane Technology (L0400)	Recitation Section (small)	1	2
Membrane Technology (L0401)	Practical Course	1	1
Module Responsible	Prof. Mathias Ernst		
Admission Requirements	None		
Recommended Previous Knowledge	Basic knowledge of water chemistry. Knowledge of the core processes involved in water, gas and steam treatment		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p><i>Knowledge</i></p> <p>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></p> <p>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>Personal Competence</p> <p><i>Social Competence</i></p> <p>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></p> <p>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>		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Credit points	6		
Studienleistung	None		
Examination	Written exam		
Examination duration and scale	90 min		
Assignment for the Following Curricula	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 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		

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

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

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

Module M0949: Rural Development and Resources Oriented Sanitation for different Climate Zones			
Courses			
Title	Typ	Hrs/wk	CP
Rural Development and Resources Oriented Sanitation for different Climate Zones (L0942)	Seminar	2	3
Rural Development and Resources Oriented Sanitation for different Climate Zones (L0941)	Lecture	2	3
Module Responsible	Prof. Ralf Otterpohl		
Admission Requirements	None		
Recommended Previous Knowledge	Basic knowledge of the global situation with rising poverty, soil degradation, lack of water resources and sanitation		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p><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.</p> <p>Students are able to discuss a wide range of proven approaches in Rural Development from and for many regions of the world.</p> <p><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.</p>		
Personal Competence	<p><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.</p> <p><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.</p>		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Credit points	6		
Studienleistung	None		
Examination	Subject theoretical and practical work		
Examination duration and scale	During the course of the semester, the students work towards mile stones. The work includes presentations and papers. Detailed information will be provided at the beginning of the semester.		
Assignment for the Following Curricula	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		

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

Course L0941: Rural Development and Resources Oriented Sanitation for different Climate Zones	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Ralf Otterpohl
Language	EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Living Soil - THE key element of Rural Development • Participatory Approaches • Rainwater Harvesting • Ecological Sanitation Principles and practical examples • Permaculture Principles of Rural Development • Performance and Resilience of Organic Small Farms • Going Further: The TUHH Toolbox for Rural Development • EMAS Technologies, Low cost drinking water supply
Literature	<ul style="list-style-type: none"> • Miracle Water Village, India, Integrated Rainwater Harvesting, Water Efficiency, Reforestation and Sanitation: http://youtu.be/9hmkg0nBgk • Montgomery, David R. 2007: Dirt: The Erosion of Civilizations, University of California Press

Module M0990: Study work Bioprocess Engineering			
Courses			
Title		Typ	Hrs/wk
Study Work Bioprocess Engineering (L1192)		Practical Course	6
	CP		
	6		6
Module Responsible	Prof. An-Ping Zeng		
Admission Requirements	None		
Recommended Previous Knowledge	Knowledge of bioprocess engineering and process engineering at bachelor level		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p><i>Knowledge</i></p> <p>Students can explain the research project they have worked on and relate it to current issues of bioprocess engineering.</p> <p>They can explain the basic scientific methods they have worked with.</p> <p><i>Skills</i></p> <p>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.</p> <p>Personal Competence</p> <p><i>Social Competence</i></p> <p>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.</p> <p><i>Autonomy</i></p> <p>Based on their competences gained so far students are capable of defining meaningful tasks within ongoing research project for themselves. They are able to develop the necessary understanding and problem solving methods.</p> <p>They can schedule the execution of the necessary experiments and organize themselves.</p>		
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84		
Credit points	6		
Studienleistung	Compulsory Bonus	Form	Description
	Yes None	Group discussion	
	Yes None	Presentation	
Examination	Study work		
Examination duration and scale	according to specific regulations		
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory		

Course L1192: Study Work Bioprocess Engineering	
Typ	Practical Course
Hrs/wk	6
CP	6
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Lecturer	Dozenten des SD V
Language	DE
Cycle	WiSe/SoSe
Content	
Literature	

Module M1017: Food Technology			
Courses			
Title		Typ	Hrs/wk CP
Food Technology (L1216)		Lecture	2 3
Experimental Course: Brewing Technology (L1242)		Practical Course	2 3
Module Responsible	Prof. Stefan Heinrich		
Admission Requirements	None		
Recommended Previous Knowledge	<ul style="list-style-type: none"> • Basic knowledge of particulate technology • Separation Technique; Heat and Mass Transfer I 		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p>After successful completion of the module students are able to</p> <p><i>Knowledge</i></p> <ul style="list-style-type: none"> • discuss the material properties of food • explain basic of production processes in food engineering • describe some selected processes <p><i>Skills</i></p> <p>Students are able to</p> <ul style="list-style-type: none"> • choose and design process chains for the processing of food • assess the effect of the single process steps on the material properties of food <p>Personal Competence</p> <p><i>Social Competence</i></p> <p>Students are enabled to discuss knowledge in a scientific environment.</p> <p><i>Autonomy</i></p> <p>Students are able to acquire scientific knowledge independently and knowledge in a scientific manner.</p>		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Credit points	6		
Studienleistung	Compulsory Bonus	Form	Description
	Yes None	Written elaboration	10 - 15 Seiten
Examination	Written exam		
Examination duration and scale	120 minutes		
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory		

Course L1216: Food Technology	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Stefan Heinrich, Prof. Stefan Palzer
Language	DE
Cycle	WiSe
Content	<ol style="list-style-type: none"> 1. Material properties: Rheology, Transport coefficients, Measuring devices, Quality aspects 2. Processes at ambient condition, at elevated temperature and pressure 3. energy analysis 4. Selected processes: Seed oil production; Roasted Coffee
Literature	M. Bockisch: Handbuch der Lebensmitteltechnologie , Stuttgart, 1993 R. Eggers: Vorlesungsmanuskript

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

Course L0061: Biofuels Process Technology	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Oliver Lüdtke
Language	DE
Cycle	WiSe
Content	<ul style="list-style-type: none"> • General introduction • What are biofuels? • Markets & trends • Legal framework • Greenhouse gas savings • Generations of biofuels <ul style="list-style-type: none"> ◦ first-generation bioethanol <ul style="list-style-type: none"> ▪ raw materials ▪ fermentation distillation ◦ biobutanol / ETBE ◦ second-generation bioethanol <ul style="list-style-type: none"> ▪ bioethanol from straw ◦ first-generation biodiesel <ul style="list-style-type: none"> ▪ raw materials ▪ Production Process ▪ Biodiesel & Natural Resources ◦ HVO / HEFA ◦ second-generation biodiesel <ul style="list-style-type: none"> ▪ Biodiesel from Algae • Biogas as fuel <ul style="list-style-type: none"> ◦ the first biogas generation <ul style="list-style-type: none"> ▪ raw materials ▪ fermentation ▪ purification to biomethane ◦ Biogas second generation and gasification processes • Methanol / DME from wood and Tall oil ©
Literature	<ul style="list-style-type: none"> • Skriptum zur Vorlesung • Drapcho, Nhuan, Walker; Biofuels Engineering Process Technology • Harwardt; Systematic design of separations for processing of biorenewables • Kaltschmitt; Hartmann; Energie aus Biomasse: Grundlagen, Techniken und Verfahren • Mousdale; Biofuels - Biotechnology, Chemistry and Sustainable Development • VDI Wärmeatlas

Course L0062: Biofuels Process Technology	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Oliver Lüdtke
Language	DE
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Life Cycle Assessment <ul style="list-style-type: none"> ◦ Good example for the evaluation of CO₂ savings potential by alternative fuels - Choice of system boundaries and databases • Bioethanol production <ul style="list-style-type: none"> ◦ Application task in the basics of thermal separation processes (rectification, extraction) will be discussed. The focus is on a column design, including heat demand, number of stages, reflux ratio ... • Biodiesel production <ul style="list-style-type: none"> ◦ Procedural options for solid / liquid separation, including basic equations for estimating power, energy demand, selectivity and throughput • Biomethane production <ul style="list-style-type: none"> ◦ Chemical reactions that are relevant in the production of biofuels, including equilibria, activation energies, shift reactions
Literature	Skriptum zur Vorlesung

Course L1767: Thermal Utilization of Biomass	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Martin Kaltschmitt
Language	DE
Cycle	WiSe
Content	<p>Goal of this course is it to discuss the physical, chemical, and biological as well as the technical, economic, and environmental basics of all options to provide energy from biomass from a German and international point of view. Additionally different system approaches to use biomass for energy, aspects to integrate bioenergy within the energy system, technical and economic development potentials, and the current and expected future use within the energy system are presented.</p> <p>The course is structured as follows:</p> <ul style="list-style-type: none"> • Biomass as an energy carrier within the energy system; use of biomass in Germany and world-wide, overview on the content of the course • Photosynthesis, composition of organic matter, plant production, energy crops, residues, organic waste • Biomass provision chains for woody and herbaceous biomass, harvesting and provision, transport, storage, drying • Thermo-chemical conversion of solid biofuels <ul style="list-style-type: none"> ◦ Basics of thermo-chemical conversion ◦ Direct thermo-chemical conversion through combustion: combustion technologies for small and large scale units, electricity generation technologies, flue gas treatment technologies, ashes and their use ◦ Gasification: Gasification technologies, producer gas cleaning technologies, options to use the cleaned producer gas for the provision of heat, electricity and/or fuels ◦ Fast and slow pyrolysis: Technologies for the provision of bio-oil and/or for the provision of charcoal, oil cleaning technologies, options to use the pyrolysis oil and charcoal as an energy carrier as well as a raw material • Physical-chemical conversion of biomass containing oils and/or fats: Basics, oil seeds and oil fruits, vegetable oil production, production of a biofuel with standardized characteristics (trans-esterification, hydrogenation, co-processing in existing refineries), options to use this fuel, options to use the residues (i.e. meal, glycerine) • Bio-chemical conversion of biomass <ul style="list-style-type: none"> ◦ Basics of bio-chemical conversion ◦ Biogas: Process technologies for plants using agricultural feedstock, sewage sludge (sewage gas), organic waste fraction (landfill gas), technologies for the provision of bio methane, use of the digested slurry ◦ Ethanol production: Process technologies for feedstock containing sugar, starch or celluloses, use of ethanol as a fuel, use of the stillage
Literature	Kaltschmitt, M.; Hartmann, H. (Hrsg.): Energie aus Biomasse; Springer, Berlin, Heidelberg, 2009, 2. Auflage

Course L1768: Thermal Utilization of Biomass	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Martin Kaltschmitt
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

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

Course L0122: Verification Methods	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Siegfried Rump
Language	DE
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Fast and accurate interval arithmetic • Error-free transformations • Verification methods for linear and nonlinear systems • Verification methods for finite integrals • Treatment of multiple zeros • Automatic differentiation • Implementation in Matlab/INTLAB • Practical applications
Literature	<p>Neumaier: Interval Methods for Systems of Equations. In: Encyclopedia of Mathematics and its Applications. Cambridge University Press, 1990</p> <p>S.M. Rump. Verification methods: Rigorous results using floating-point arithmetic. Acta Numerica, 19:287-449, 2010.</p>

Course L1208: Verification Methods	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Siegfried Rump
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Following Curricula	General Engineering Science (English program): Specialisation Computer Science: Compulsory General Engineering Science (English program): Specialisation Biomedical Engineering: Compulsory General Engineering Science (English program): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory General Engineering Science (English program): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory General Engineering Science (English program, 7 semester): Specialisation Computer Science: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory Computational Science and Engineering: Core qualification: Compulsory Computational Science and Engineering: Core qualification: Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory
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Course L0417: Numerical Mathematics I	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sabine Le Borne, Dr. Patricio Farrell
Language	DE/EN
Cycle	WiSe
Content	<ol style="list-style-type: none"> 1. Error analysis: Number representation, error types, conditioning and stability 2. Interpolation: polynomial and spline interpolation 3. Numerical integration and differentiation: order, Newton-Cotes formula, error estimates, Gaussian quadrature, adaptive quadrature, difference formulas 4. Linear systems: LU and Cholesky factorization, matrix norms, conditioning 5. Linear least squares problems: normal equations, Gram-Schmidt and Householder orthogonalization, singular value decomposition, regularization 6. Eigenvalue problems: power iteration, inverse iteration, QR algorithm 7. Nonlinear systems of equations: Fixed point iteration, root-finding algorithms for real-valued functions, Newton and Quasi-Newton methods for systems
Literature	<ul style="list-style-type: none"> • Stoer/Bulirsch: Numerische Mathematik 1, Springer • Dahmen, Reusken: Numerik für Ingenieure und Naturwissenschaftler, Springer

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

Module M1336: Soft Computing	
Courses	
Title Soft Computing (L1869)	Typ Lecture
	Hrs/wk 4
	CP 6
Module Responsible	Prof. Karl-Heinz Zimmermann
Admission Requirements	None
Recommended Previous Knowledge	Bachelor in Computer Science. Basics in higher mathematics are inevitable, like calculus, linear algebra, graph theory, and optimization.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
<i>Knowledge</i>	Students are able to formalize, compute, and analyze belief networks, alignments of sequences, hidden Markov models, phylogenetic tree models, neural networks, and fuzzy controllers. In particular, inference and learning in belief networks are important topics that the students should be able to master.
<i>Skills</i>	Students can apply the relevant algorithms and determine their complexity, and they can make use of the statistics language R.
Personal Competence	
<i>Social Competence</i>	Students are able to solve specific problems alone or in a group and to present the results accordingly.
<i>Autonomy</i>	Students are able to acquire new knowledge from newer literature and to associate the acquired knowledge to other fields.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Studienleistung	None
Examination	Oral exam
Examination duration and scale	25 min
Assignment for the Following Curricula	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 Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory

Course L1869: Soft Computing	
Typ	Lecture
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Karl-Heinz Zimmermann
Language	DE/EN
Cycle	WiSe
Content	<p>Students are able to formalize, compute, and analyze belief networks, alignments of sequences, hidden Markov models, phylogenetic tree models, neural networks, and fuzzy controllers. In particular, inference and learning in belief networks are important topics that the students should be able to master.</p> <p>Students can apply the relevant algorithms and determine their complexity, and they can make use of the statistics language R.</p>
Literature	<ol style="list-style-type: none"> 1. David Barber, Bayes Reasoning and Machine Learning, Cambridge Univ. Press, Cambridge, 2012. 2. Volker Claus, Stochastische Automaten, Teubner, Stuttgart, 1971. 3. Ernst Klement, Radko Mesiar, Endre Pap, Triangular Norms, Kluwer, Dordrecht, 2000. 4. Timo Koski, John M. Noble, Bayesian Networks, Wiley, New York, 2009. 5. Dimitris Margaritis, Learning Bayesian Network Model Structure from Data, PhD thesis, Carnegie Mellon University, Pittsburgh, 2003. 6. Hidetoshi Nishimori, Statistical Physics of Spin Glasses and Information Processing, Oxford Univ. Press, London, 2001. 7. James R. Norris, Markov Chains, Cambridge Univ. Press, Cambridge, 1996. 8. Maria Rizzo, Statistical Computing with R, Chapman & Hall/CRC, Boca Raton, 2008. 9. Peter Sprites, Clark Glymour, Richard Scheines, Causation, Prediction, and Search, Springer, New York, 1993. 10. Raul Royas, Neural Networks, Springer, Berlin, 1996. 11. Lior Pachter, Bernd Sturmfels, Algebraic Statistics for Computational Biology, Cambridge Univ. Press, Cambridge, 2005. 12. David A. Sprecher, From Algebra to Computational Algorithms, Docent Press, Boston, 2017. 13. Karl-Heinz Zimmermann, Algebraic Statistics, TubDok, Hamburg, 2016.

Module M0952: Industrial Bioprocess Engineering	
Courses	
Title	Typ Hrs/wk CP
Biotechnical Processes (L1065)	Project-/problem-based Learning 2 3
Trends in Industrial Biocatalysis (L1172)	Seminar 2 3
Module Responsible	Prof. An-Ping Zeng
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of bioprocess engineering and process engineering at bachelor level
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	<p>After successful completion of the module</p> <p><i>Knowledge</i></p> <ul style="list-style-type: none"> the students can outline the current status of research on the specific topics discussed the students can explain the basic underlying principles of the respective biotechnological production processes <p>After successful completion of the module students are able to</p> <p><i>Skills</i></p> <ul style="list-style-type: none"> analyzing and evaluate current research approaches Lay-out biotechnological production processes basically <p>Personal Competence</p> <p><i>Social Competence</i></p> <p>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.</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>
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Studienleistung	None
Examination	Presentation
Examination duration and scale	oral presentation + discussion (45 min) + Written report (10 pages)
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation A - General 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 L1065: Biotechnical Processes	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Ralf Pörtner, Prof. An-Ping Zeng, Prof. Garabed Antranikian, Prof. Andreas Liese
Language	DE/EN
Cycle	WiSe
Content	<p>Biotechnical production process for</p> <ul style="list-style-type: none"> • Food, feed and food additives • Therapeutical proteins • Technical biopolymers • Pharmaceuticals, herbicides, insecticides • Organic acids and base chemicals • Compounds that may be recycled from wastes from biotechnical and other production processes <p>The students work in groups on a given biotechnological process and shall acquire knowledge on the main characteristics of this process (basics, design, economic importance). A critical analysis of the process is intended to identify possible improvements (in terms of raw materials, energy requirements, staffing requirements, waste disposal, etc.) and to draw up proposals for this purpose.</p>
Literature	<p>Rehm, Hans-Jürgen; G. Reed: Biotechnology : A comprehensive treatise in 8 Vol., Weinheim: Verlag Chemie, 1981-1988,</p> <p>Ullmann´s encyclopedia of industrial chemistry. Wiley-VCH (on-line)</p> <p>R.H. Baltz et al.: Manual of Industrial Microbiology and Biotechnology, 3. Edition, ASM Press, 2010.</p> <p>Recent articles on the selected process in the scientific-technical and patent literature (journals, handbooks, databases (Internet). Textbooks for previous courses in the programmes.</p>

Course L1172: Trends in Industrial Biocatalysis	
Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Andreas Liese
Language	EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Presentation and evaluation of 20-minute student lectures discussing a case study of an industrial biotransformation • The contents of this article shall be presented, evaluated and discussed with the fellow students.
Literature	<ul style="list-style-type: none"> • A. Liese, K. Seelbach, C. Wandrey: Industrial Biotransformations, Wiley-VCH, 2006 • selected scientific papers, that will be distributed during the course of the lecture

Module M1396: Hybrid Processes in Process Engineering			
Courses			
Title		Typ	Hrs/wk CP
Hybrid Processes in Process Engineering (L1715)		Project-/problem-based Learning	2 4
Hybrid Processes in Process Engineering (L1978)		Lecture	2 2
Module Responsible	Prof. Georg Fieg		
Admission Requirements	None		
Recommended Previous Knowledge	Process and Plant Engineering 1 Process and Plant Engineering 2 Basics in Process Engineering		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence			
<i>Knowledge</i>	Students are able to evaluate hybrid processes		
<i>Skills</i>	Students are able to evaluate processes with regard to their suitability as hybrid processes and to interpret them accordingly.		
Personal Competence			
<i>Social Competence</i>	Students are able to apply the principles of project management for small groups.		
<i>Autonomy</i>	Students are able to acquire and discuss specialized knowledge about hybrid processes.		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Credit points	6		
Studienleistung	Compulsory Bonus	Form	Description
	Yes 15 %	Midterm	
Examination	Written elaboration		
Examination duration and scale	Project report incl. PM-documents		
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory		

Course L1715: Hybrid Processes in Process Engineering	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Dr. Thomas Waluga
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1978: Hybrid Processes in Process Engineering	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Thomas Waluga
Language	DE
Cycle	WiSe
Content	
Literature	<ul style="list-style-type: none"> - H. Schmidt-Traub; Integrated Reaction and Separation Operations: Modelling and Experimental Validation; Springer 2006 - K. Sundmacher, A. Kienle, A. Seidel-Morgenstern; Integrated Chemical Processes: Synthesis, Operation, Analysis, and Control; Wiley-VCH 2005 - Mexandre C. Dimian (Ed); Integrated Design and Simulation of Chemical Processes; in Computer Aided Chemical Engineering, Volume 13, Pages 1-698 (2003)

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

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

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

Specialization B - Industrial Bioprocess Engineering

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

Course L1278: High Pressure Technique for Apparatus Engineering	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Robert Surma
Language	DE/EN
Cycle	SoSe
Content	<ol style="list-style-type: none"> 1. Basic laws and certification standards 2. Basics for calculations of pressurized vessels 3. Stress hypothesis 4. Selection of materials and fabrication processes 5. vessels with thin walls 6. vessels with thick walls 7. Safety installations 8. Safety analysis <p>Applications:</p> <ul style="list-style-type: none"> - subsea technology (manned and unmanned vessels) - steam vessels - heat exchangers - LPG, LEG transport vessels
Literature	<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; Stadtmuller: Experimental Techniques in High-Pressure Research, Wiley & Sons Verlag</p> <p>Klapp: Apparate- und Anlagentechnik, Springer Verlag</p>

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

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

Module M0897: Computer Aided Process Engineering (CAPE)			
Courses			
Title	Typ	Hrs/wk	CP
CAPE with Computer Exercises (L1039)	Lecture	2	3
Methods of Process Safety and Dangerous Substances (L1040)	Lecture	2	3
Module Responsible	Prof. Georg Fieg		
Admission Requirements	None		
Recommended Previous Knowledge	thermal separation processes heat and mass transport processes		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p><i>Knowledge</i></p> <p>students can:</p> <ul style="list-style-type: none"> - outline types of simulation tools - describe principles of flowsheet and equation oriented simulation tools - describe the setting of flowsheet simulation tools - explain the main differences between steady state and dynamic simulations - present the fundamentals of toxicology and hazardous materials - explain the main methods of safety engineering - present the importance of safety analysis with respect to plant design - describe the definitions within the legal accident insurance <p>accident insurance</p> <p><i>Skills</i></p> <p>students can:</p> <ul style="list-style-type: none"> - conduct steady state and dynamic simulations - evaluate simulation results and transform them in the practice - choose and combine suitable simulation models into a production plant - evaluate the achieved simulation results regarding practical importance - evaluate the results of many experimental methods regarding safety aspects - review, compare and use results of safety considerations for a plant design <p><i>Personal Competence</i></p> <p><i>Social Competence</i></p> <p>students are able to:</p> <ul style="list-style-type: none"> - work together in teams in order to simulate process elements and develop an integral process - develop in teams a safety concept for a process and present it to the audience <p><i>Autonomy</i></p> <p>students are able to</p> <ul style="list-style-type: none"> - act responsible with respect to environment and needs of the society 		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Credit points	6		
Studienleistung	None		
Examination	Written exam		
Examination duration and scale	180 min		
Assignment for the	Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory		

Following Curricula	Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory
	Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L1039: CAPE with Computer Exercises	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Georg Fieg
Language	DE
Cycle	SoSe
Content	<p>I. Introduction</p> <ol style="list-style-type: none"> 1. Fundamentals of steady state process simulation <ol style="list-style-type: none"> 1.1. Classes of simulation tools 1.2. Sequential-modularer approach 1.3. Operating mode of ASPEN PLUS 2. Introduction in ASPEN PLUS <ol style="list-style-type: none"> 2.1. GUI 2.2. Estimation methods of physical properties 2.3. Aspen tools (z.B. Designspecification) 2.4. Convergence methods <p>II. Exercises using ASPEN PLUS and ACM</p> <ul style="list-style-type: none"> Performance and constraints of ASPEN PLUS ASPEN datenbank using Estimation methods of physical properties Application of model databank, process synthesis Design specifications Sensitivity analysis Optimization tasks Industrial cases
Literature	<ul style="list-style-type: none"> - G. Fieg: Lecture notes - Seider, W.D.; Seader, J.D.; Lewin, D.R.: Product and Process Design Principles: Synthesis, Analysis, and Evaluation; Hoboken, J. Wiley & Sons, 2010

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

Course L1375: Computational Fluid Dynamics - Exercises in OpenFoam	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	SoSe
Content	<ul style="list-style-type: none"> • generation of numerical grids with a common grid generator • selection of models and boundary conditions • basic numerical simulation with OpenFoam within the TUHH CIP-Pool
Literature	OpenFoam Tutorials (StudIP)

Course L1052: Computational Fluid Dynamics in Process Engineering	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	SoSe
Content	<ul style="list-style-type: none"> • Introduction into partial differential equations • Basic equations • Boundary conditions and grids • Numerical methods • Finite difference method • Finite volume method • Time discretisation and stability • Population balance • Multiphase Systems • Modeling of Turbulent Flows • Exercises: Stability Analysis • Exercises: Example on CFD - analytically/numerically
Literature	<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>

Course L0099: Statistical Thermodynamics and Molecular Modelling	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Sven Jakobtorweihen
Language	EN
Cycle	SoSe
Content	<ul style="list-style-type: none"> • Some lectures will be carried out as computer exercises • Introduction to Statistical Mechanics • The ensemble concept • The classical limit • Intermolecular potentials, force fields • Monte Carlo simulations (acceptance rules) (Übungen im Rechnerpool) (exercises in computer pool) • Molecular Dynamics Simulations (integration of equations of motion, calculating transport properties) (exercises in computer pool) • Molecular simulation of Phase equilibria (Gibbs Ensemble) • Methods for the calculation of free energies
Literature	<p>Daan Frenkel, Berend Smit: Understanding Molecular Simulation, Academic Press</p> <p>M. P. Allen, D. J. Tildesley: Computer Simulations of Liquids, Oxford Univ. Press</p> <p>A.R. Leach: Molecular Modelling - Principles and Applications, Prentice Hall, N.Y.</p> <p>D. A. McQuarrie: Statistical Mechanics, University Science Books</p> <p>T. L. Hill: Statistical Mechanics , Dover Publications</p>

Course L0355: Fundamentals of Cell and Tissue Engineering	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Ralf Pörtner, Prof. An-Ping Zeng
Language	EN
Cycle	SoSe
Content	Overview of cell culture technology and tissue engineering (cell culture product manufacturing, complexity of protein therapeutics, examples of tissue engineering) (Pörtner, Zeng) Fundamentals of cell biology for process engineering (cells: source, composition and structure, interactions with environment, growth and death - cell cycle, protein glycolysation) (Pörtner) Cell physiology for process engineering (Overview of central metabolism, genomics etc.) (Zeng) Medium design (impact of media on the overall cell culture process, basic components of culture medium, serum and protein-free media) (Pörtner) Stoichiometry and kinetics of cell growth and product formation (growth of mammalian cells, quantitative description of cell growth & product formation, kinetics of growth)
Literature	Butler, M (2004) Animal Cell Culture Technology - The basics, 2 nd 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	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Ralf Pörtner
Language	EN
Cycle	SoSe
Content	Requirements for cell culture 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
Literature	Butler, M (2004) Animal Cell Culture Technology - The basics, 2 nd 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 M0519: Particle Technology and Solid Matter Process Technology			
Courses			
Title		Typ	Hrs/wk CP
Advanced Particle Technology II (L0051)		Project-/problem-based Learning	1 1
Advanced Particle Technology II (L0050)		Lecture	2 2
Experimental Course Particle Technology (L0430)		Practical Course	3 3
Module Responsible	Prof. Stefan Heinrich		
Admission Requirements	None		
Recommended Previous Knowledge	Basic knowledge of solids processes and particle technology		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence			
<i>Knowledge</i>	After completion of the module the students will be able to describe and explain processes for solids processing in detail based on microprocesses on the particle level.		
<i>Skills</i>	Students are able to choose process steps and apparatuses for the focused treatment of solids depending on the specific characteristics. They furthermore are able to adapt these processes and to simulate them.		
Personal Competence			
<i>Social Competence</i>	Students are able to present results from small teamwork projects in an oral presentation and to discuss their knowledge with scientific researchers.		
<i>Autonomy</i>	Students are able to analyze and solve problems regarding solid particles independently or in small groups.		
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84		
Credit points	6		
Studienleistung	Compulsory Bonus	Form	Description
	Yes None	Written elaboration	fünf Berichte (pro Versuch ein Bericht) à 5-10 Seiten
Examination	Written exam		
Examination duration and scale	120 minutes		
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Energy and Environmental Engineering: Specialisation Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Process Engineering: Core qualification: Compulsory		

Course L0051: Advanced Particle Technology II	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Stefan Heinrich
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0050: Advanced Particle Technology II	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Stefan Heinrich
Language	DE
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Exercise in form of "Project based Learning" • Agglomeration, particle size enlargement • advanced particle size reduction • Advanced theorie of fluid/particle flows • CFD-methods for the simulation of disperse fluid/solid flows, Euler/Euler methods, Descrete Particle Modeling • Treatment of simulation problems with distributed properties, solution of population balances
Literature	<p>Schubert, H.; Heidenreich, E.; Liepe, F.; Neeße, T.: Mechanische Verfahrenstechnik. Deutscher Verlag für die Grundstoffindustrie, Leipzig, 1990.</p> <p>Stieß, M.: Mechanische Verfahrenstechnik I und II. Springer Verlag, Berlin, 1992.</p>

Course L0430: Experimental Course Particle Technology	
Typ	Practical Course
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Stefan Heinrich
Language	DE
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Fluidization • Agglomeration • Granulation • Drying • Determination of mechanical properties of agglomerats
Literature	<p>Schubert, H.; Heidenreich, E.; Liepe, F.; Neeße, T.: Mechanische Verfahrenstechnik. Deutscher Verlag für die Grundstoffindustrie, Leipzig, 1990.</p> <p>Stieß, M.: Mechanische Verfahrenstechnik I und II. Springer Verlag, Berlin, 1992.</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
Module Responsible	Prof. Mathias Ernst		
Admission Requirements	None		
Recommended Previous Knowledge	Basic knowledge of water chemistry. Knowledge of the core processes involved in water, gas and steam treatment		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p><i>Knowledge</i></p> <p>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></p> <p>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>Personal Competence</p> <p><i>Social Competence</i></p> <p>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></p> <p>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>		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Credit points	6		
Studienleistung	None		
Examination	Written exam		
Examination duration and scale	90 min		
Assignment for the Following Curricula	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 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		

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

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

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

Course L1065: Biotechnical Processes	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Ralf Pörtner, Prof. An-Ping Zeng, Prof. Garabed Antranikian, Prof. Andreas Liese
Language	DE/EN
Cycle	WiSe
Content	<p>Biotechnical production process for</p> <ul style="list-style-type: none"> • Food, feed and food additives • Therapeutical proteins • Technical biopolymers • Pharmaceuticals, herbicides, insecticides • Organic acids and base chemicals • Compounds that may be recycled from wastes from biotechnical and other production processes <p>The students work in groups on a given biotechnological process and shall acquire knowledge on the main characteristics of this process (basics, design, economic importance). A critical analysis of the process is intended to identify possible improvements (in terms of raw materials, energy requirements, staffing requirements, waste disposal, etc.) and to draw up proposals for this purpose.</p>
Literature	<p>Rehm, Hans-Jürgen; G. Reed: Biotechnology : A comprehensive treatise in 8 Vol., Weinheim: Verlag Chemie, 1981-1988,</p> <p>Ullmann´s encyclopedia of industrial chemistry. Wiley-VCH (on-line)</p> <p>R.H. Baltz et al.: Manual of Industrial Microbiology and Biotechnology, 3. Edition, ASM Press, 2010.</p> <p>Recent articles on the selected process in the scientific-technical and patent literature (journals, handbooks, databases (Internet). Textbooks for previous courses in the programmes.</p>

Course L1172: Trends in Industrial Biocatalysis	
Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Andreas Liese
Language	EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Presentation and evaluation of 20-minute student lectures discussing a case study of an industrial biotransformation • The contents of this article shall be presented, evaluated and discussed with the fellow students.
Literature	<ul style="list-style-type: none"> • A. Liese, K. Seelbach, C. Wandrey: Industrial Biotransformations, Wiley-VCH, 2006 • selected scientific papers, that will be distributed during the course of the lecture

Module M0990: Study work Bioprocess Engineering			
Courses			
Title		Typ	Hrs/wk
Study Work Bioprocess Engineering (L1192)		Practical Course	6
	CP		
	6		6
Module Responsible	Prof. An-Ping Zeng		
Admission Requirements	None		
Recommended Previous Knowledge	Knowledge of bioprocess engineering and process engineering at bachelor level		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p><i>Knowledge</i></p> <p>Students can explain the research project they have worked on and relate it to current issues of bioprocess engineering.</p> <p>They can explain the basic scientific methods they have worked with.</p> <p><i>Skills</i></p> <p>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.</p> <p><i>Personal Competence</i></p> <p>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.</p> <p><i>Social Competence</i></p> <p>Based on their competences gained so far students are capable of defining meaningful tasks within ongoing research project for themselves. They are able to develop the necessary understanding and problem solving methods.</p> <p><i>Autonomy</i></p> <p>They can schedule the execution of the necessary experiments and organize themselves.</p>		
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84		
Credit points	6		
Studienleistung	Compulsory Bonus	Form	Description
	Yes None	Group discussion	
	Yes None	Presentation	
Examination	Study work		
Examination duration and scale	according to specific regulations		
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory		

Course L1192: Study Work Bioprocess Engineering	
Typ	Practical Course
Hrs/wk	6
CP	6
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Lecturer	Dozenten des SD V
Language	DE
Cycle	WiSe/SoSe
Content	
Literature	

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

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

Module M1396: Hybrid Processes in Process Engineering			
Courses			
Title		Typ	Hrs/wk CP
Hybrid Processes in Process Engineering (L1715)		Project-/problem-based Learning	2 4
Hybrid Processes in Process Engineering (L1978)		Lecture	2 2
Module Responsible	Prof. Georg Fieg		
Admission Requirements	None		
Recommended Previous Knowledge	Process and Plant Engineering 1 Process and Plant Engineering 2 Basics in Process Engineering		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence			
<i>Knowledge</i>	Students are able to evaluate hybrid processes		
<i>Skills</i>	Students are able to evaluate processes with regard to their suitability as hybrid processes and to interpret them accordingly.		
Personal Competence			
<i>Social Competence</i>	Students are able to apply the principles of project management for small groups.		
<i>Autonomy</i>	Students are able to acquire and discuss specialized knowledge about hybrid processes.		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Credit points	6		
Studienleistung	Compulsory Bonus	Form	Description
	Yes 15 %	Midterm	
Examination	Written elaboration		
Examination duration and scale	Project report incl. PM-documents		
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory		

Course L1715: Hybrid Processes in Process Engineering	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Dr. Thomas Waluga
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1978: Hybrid Processes in Process Engineering	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Thomas Waluga
Language	DE
Cycle	WiSe
Content	
Literature	<ul style="list-style-type: none"> - H. Schmidt-Traub; Integrated Reaction and Separation Operations: Modelling and Experimental Validation; Springer 2006 - K. Sundmacher, A. Kienle, A. Seidel-Morgenstern; Integrated Chemical Processes: Synthesis, Operation, Analysis, and Control; Wiley-VCH 2005 - Mexandre C. Dimian (Ed); Integrated Design and Simulation of Chemical Processes; in Computer Aided Chemical Engineering, Volume 13, Pages 1-698 (2003)

Thesis

Module M-002: Master Thesis	
Courses	
Title	Typ Hrs/wk CP
Module Responsible	Professoren der TUHH
Admission Requirements	<ul style="list-style-type: none"> According to General Regulations §21 (1): <p>At least 60 credit points have to be achieved in study programme. The examinations board decides on exceptions.</p>
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	<ul style="list-style-type: none"> The students can use specialized knowledge (facts, theories, and methods) of their subject competently on specialized issues. 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. The students can place a research task in their subject area in its context and describe and critically assess the state of research.
<i>Knowledge</i>	
<i>Skills</i>	<p>The students are able:</p> <ul style="list-style-type: none"> To select, apply and, if necessary, develop further methods that are suitable for solving the specialized problem in question. 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. To develop new scientific findings in their subject area and subject them to a critical assessment.
Personal Competence	Students can
<i>Social Competence</i>	<ul style="list-style-type: none"> Both in writing and orally outline a scientific issue for an expert audience accurately, understandably and in a structured way. 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.
<i>Autonomy</i>	<p>Students are able:</p> <ul style="list-style-type: none"> To structure a project of their own in work packages and to work them off accordingly. To work their way in depth into a largely unknown subject and to access the information required for them to do so. To apply the techniques of scientific work comprehensively in research of their own.
Workload in Hours	Independent Study Time 900, Study Time in Lecture 0
Credit points	30
Studienleistung	None
Examination	Thesis
Examination duration and scale	According to General Regulations
	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

**Assignment for the
Following Curricula**

Aircraft Systems Engineering: Thesis: Compulsory
Global Innovation Management: Thesis: Compulsory
Computational Science and Engineering: Thesis: Compulsory
Computational Science and Engineering: Thesis: Compulsory
Information and Communication Systems: Thesis: Compulsory
International Production Management: 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
Mathematical Modelling in Engineering: Theory, Numerics, Applications: Thesis: Compulsory
Mechanical Engineering and Management: Thesis: Compulsory
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
Theoretical Mechanical Engineering: Thesis: Compulsory
Process Engineering: Thesis: Compulsory
Water and Environmental Engineering: Thesis: Compulsory