Module Manual

Master of Science (M.Sc.)

Chemical and Bioprocess Engineering
Dual study program

Cohort: Winter Term 2025

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Program description

Content

The Master of Science degree programme in Chemical and Bioengineering at the TUHH prepares its graduates for innovative work in leading positions in the chemical, energy, environmental, food and pharmaceutical industries, at specialist authorities and administrations in this field and for independent scientific work in research. Accordingly, the Master's programme is characterised by a scientific orientation, a focus on content and the teaching of effective, structured, interdisciplinary working methods. The content focuses are closely linked to the research topics of the institutes of the School of Studies and reflect the unity of research and teaching. This ensures that the content of lectures is always up-to-date and that students have the opportunity to participate in research at the TUHH, e.g. in the context of student research projects and final theses. In many courses, a direct link to industrial practice is established through problem-orientated learning. The former separation into the degree programmes ‘Process Engineering’ and ‘Bioprocess Engineering’ has been deliberately overcome in order to take account of the ever-increasing differentiation and at the same time networking of the discipline and to enable a holistic approach. Instead, the degree programme offers a high degree of freedom in the choice of modules, which enables a strong profile to be formed.

In addition to the basic technical canon at the TUHH, seminars on personal skills development are integrated into the dual study programme as part of the theory-practice transfer, which meet the modern professional requirements of an engineer and support the linking of the two learning locations.

The practice-integrated intensive dual study programmes at the TUHH consist of a science-oriented and a practice-oriented part, which are carried out at two learning locations. The science-orientated part involves studying at the TUHH. The practice-oriented part is coordinated with the degree programme in terms of content and time and takes place during the lecture-free period in a cooperating company in the form of practical modules and phases.

Career prospects

With a Master's degree in Chemical and Bioengineering from the TUHH, you can work in the following professional fields:

- Chemical and pharmaceutical industry
- Food and biotechnology
- Energy and environmental technology
- Management positions at the interface between engineering/chemistry/biology
- Diverse fields of activity: Research and development, production, quality management, management consultancy

Learning target

- Graduates will be able to support and assess the design of a process engineering system with regard to momentum, heat and mass transfer.
- Graduates are able to assess economic, ecological and social aspects of process engineering processes and are able to design a sustainable process.
- Graduates are able to provide a broad overview of chemical and bioengineering topics and explain sub-areas of the discipline in depth.
- Graduates are able to comprehensively reflect the current state of science in the field of chemical and bioengineering. They are able to explain the phenomena occurring in this field and in related disciplines in a well-founded manner.
- Graduates are able to explain the essential principles of chemical and bioengineering for the design, modelling and simulation of process engineering and bioprocess engineering processes and chemical and biochemical reactions, of energy, material and momentum transport processes, of separation processes on the micro, meso and macro scale and for the operation of corresponding plants comprehensively and in detail in sub-areas.
- Graduates are able to consider legal aspects in connection with process engineering and bioprocess engineering processes and production facilities. Graduates are able to use digital tools sensibly in the field of chemical and bioengineering.

The topics ‘Ethics’, “Sustainability” and ‘Entrepreneurship’ taught in the degree programme give students the opportunity to combine forward-looking entrepreneurial approaches with a deep awareness of ethical responsibility and sustainable practices in order to develop innovative solutions to the challenges of the modern world.

Program structure

The curriculum of the Master's degree programme in Chemical and Bioengineering follows an approach characterised by a high degree of freedom of choice.

Core qualification: choice of 5 out of 10 specialist modules, 30 CP, 1st and 2nd semesters,
supplemented by the compulsory module Responsible Management: Entrepreneurship, Ethics, Sustainability, 6 CP + additional 30 CP for additional theory-practice transfer.

Specialisation: compulsory elective modules totalling 54 CP from a catalogue of 42 modules (258 CP), 2nd and 3rd semesters
Master's thesis: 30 CP, 4th semester

This results in a total workload of 150 CP.

In the core qualification, 5 modules are selected from the 10 most important areas of the degree programme. The only compulsory module is the Responsible Management: Entrepreneurship, Ethics, Sustainability module. This reflects the overarching importance of the subject for future engineers.

In addition to the subject-specific basic canon at the TUHH, seminars on personal skills development are integrated into the dual study programme as part of the theory-practice transfer. These are three practical modules, each worth 10 CP.

In the specialisation students can choose their own modules to focus on. This is supported by the offer of sample study programmes. The modules have a high proportion of work placements to consolidate practical skills. The specialisation includes a supplementary technical course. This opens up the choice of a technically related module. Of course, it is also possible to train interdisciplinary and non-technical skills in addition to the specialised modules.

The third semester is well suited for a stay abroad, as according to the curriculum only compulsory elective modules have to be completed.

Core Qualification

Module M1759: Linking theory and practice (dual study program, Master's degree)

Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	• Successful completion of practical modules as part of the dual Bachelor’s course • Module "interlinking theory and practice as part of the dual Master’s course"
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... ... can describe and classify selected classic and current theories, concepts and methods • related to project management and • change and transformation management ... and apply them to specific situations, processes and plans in a personal, professional context.
Skills	Dual students ... • ... anticipate typical difficulties, positive and negative effects, as well as success and failure factors in the engineering sector, evaluate them and consider promising strategies and courses of action. • ... develop specialised technical and conceptual skills to solve complex tasks and problems in their professional field of activity/work.
Personal Competence	
Social Competence	Dual students ... • ... can responsibly lead interdisciplinary teams within the framework of complex tasks and problems. • ... engage in sector-specific and cross-sectoral discussions with experts, stakeholders and staff, representing their approaches, points of view and work results.
Autonomy	Dual students ... • ... define, reflect and evaluate goals and measures for complex application-oriented projects and change processes. • ... shape their professional area of responsibility independently and sustainably. • ... take responsibility for their actions and for the results of their work.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Studienbegleitende und semesterübergreifende Dokumentation: Die Leistungspunkte für das Modul werden durch die Anfertigung eines digitalen Lern- und Entwicklungsberichtes (E-Portfolio) erworben. Dabei handelt es sich um eine fortlaufende Dokumentation und Reflexion der Lernerfahrungen und der Kompetenzentwicklung im Bereich der Personalen Kompetenz.

Course L2890: Responsible Project Management in Engineering (for Dual Study Program)

Typ	Seminar
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Dr. Henning Haschke, Heiko Sieben
Language	DE
Cycle	WiSe/SoSe
Content	• Theories and methods of project management • Innovation management • Agile project management • Fundamentals of classic and agile methods • Hybrid use of classic and agile methods • Roles, perspectives and stakeholders throughout the project • Initiating and coordinating complex engineering projects • Principles of moderation, team management, team leadership, conflict management • Communication structures: in-house, cross-company • Public information policy • Promoting commitment and empowerment • Sharing experience with specialists and managers from the engineering sector • Documenting and reflecting on learning experiences
Literature	Seminarapparat

Course L2891: Responsible Change and Transformation Management in Engineering (for Dual Study Program)	
Typ	Seminar
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Dr. Henning Haschke, Heiko Sieben
Language	DE
Cycle	WiSe/SoSe
Content	• Basic concepts, opportunities and limits of organisational change • Models and methods of organisational design and development • Strategic orientation and change, and their short-, medium- and long-term consequences for individuals, organisations and society as a whole • Roles, perspectives and stakeholders in change processes • Initiating and coordinating change measures in engineering • Phase models of organisational change (Lewin, Kotter, etc.) • Change-oriented information policy and dealing with resistance and uncertainty • Promoting commitment and empowerment • Successfully handling change and transformation: personally, as an employee, as a manager (personal, professional, organisational) • Company-level and globally (systemic) • Sharing experience with specialists and managers from the engineering sector • Documenting and reflecting on learning experiences
Literature	Seminarapparat

Module M1756: Practical module 1 (dual study program, Master's degree)

Courses

Title	Typ	Hrs/wk	CP
Practical term 1 (dual study program, Master's degree) (L2887)		0	10

Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	• Successful completion of a compatible dual B.Sc. at TU Hamburg or comparable practical work experience and competences in the area of interlinking theory and practice • Course D from the module on interlinking theory and practice as part of the dual Master’s course
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... • ... combine their knowledge of facts, principles, theories and methods gained from previous study content with acquired practical knowledge - in particular their knowledge of practical professional procedures and approaches, in the current field of activity in engineering. • ... have a critical understanding of the practical applications of their engineering subject.
Skills	Dual students ... • ... apply technical theoretical knowledge to complex, interdisciplinary problems within the company, and evaluate the associated work processes and results, taking into account different possible courses of action. • ... implement the university’s application recommendations with regard to their current tasks. • ... develop solutions as well as procedures and approaches in their field of activity and area of responsibility.
Personal Competence	
Social Competence	Dual students ... • ... work responsibly in project teams within their working area and proactively deal with problems within their team. • ... represent complex engineering viewpoints, facts, problems and solution approaches in discussions with internal and external stakeholders.
Autonomy	Dual students ... • ... define goals for their own learning and working processes as engineers. • ... reflect on learning and work processes in their area of responsibility. • ... reflect on the relevance of subject modules specialisations and specialisation for work as an engineer, and also implement the university’s application recommendations and the associated challenges to positively transfer knowledge between theory and practice.
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Credit points	10
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Documentation accompanying studies and across semesters: Module credit points are earned by completing a digital learning and development report (e-portfolio). This documents and reflects individual learning experiences and skills development relating to interlinking theory and practice, as well as professional practice. In addition, the partner company provides proof to the dual@TUHH Coordination Office that the dual student has completed the practical phase.
Assignment for the Following Curricula	Civil Engineering: Core Qualification: Compulsory Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Computational Methods and Machine Learning in Engineering: Core Qualification: Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Electrical Engineering and Information Technology: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Energy Systems: Core Qualification: Compulsory Environmental Engineering: Core Qualification: Compulsory Aircraft Systems Engineering: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Information and Communication Systems: Core Qualification: Compulsory International Management and Engineering: Core Qualification: Compulsory Logistics, Infrastructure and Mobility: Core Qualification: Compulsory Aeronautics: Core Qualification: Compulsory Mechanical Engineering - Product Development and Production: Core Qualification: Compulsory Materials Science and Engineering: Core Qualification: Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Core Qualification: Compulsory Microelectronics and Microsystems: Core Qualification: Compulsory Product Development, Materials and Production: Core Qualification: Compulsory Renewable Energies: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Compulsory

	Naval Architecture and Ocean Engineering: Core Qualification: Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory Process Engineering: Core Qualification: Compulsory Water and Environmental Engineering: Core Qualification: Compulsory

Course L2887: Practical term 1 (dual study program, Master's degree)	
Typ	
Hrs/wk	0
CP	10
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Lecturer	Dr. Henning Haschke
Language	DE
Cycle	WiSe/SoSe
Content	**Company onboarding process** • Assigning a professional field of activity as an engineer (B.Sc.) and associated fields of work • Establishing responsibilities and authorisation of the dual student within the company as an engineer (B.Sc.) • Working independently in a team and on selected projects - across departments and, if applicable, across companies • Scheduling the current practical module with a clear correlation to work structures • Scheduling the examination phase/subsequent study semester **Operational knowledge and skills** • Company-specific: Responsibility as an engineer (B.Sc.) in their own area of work, coordinating team and project work, dealing with complex contexts and unsolved problems, developing and implementing innovative solutions • Subject specialisation (corresponding to the chosen course [M.Sc.]) in the field of activity • Systemic skills • Implementing the university’s application recommendations (theory-practice transfer) in corresponding work and task areas across the company **Sharing/reflecting on learning** • Creating an e-portfolio • Importance of course contents (M.Sc.) when working as an engineer • Importance of development and innovation when working as an engineer
Literature	• Studierendenhandbuch • Betriebliche Dokumente • Hochschulseitige Handlungsempfehlungen zum Theorie-Praxis-Transfer

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. Simon Müller
Admission Requirements	None
Recommended Previous Knowledge	Thermodynamics III
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are capable to formulate thermodynamic problems and to specify possible solutions. Furthermore, they can describe the current state of research in thermodynamic property predictions.
Skills	The students are capable to apply modern thermodynamic calculation methods to multi-component mixtures and relevant biological systems. They can calculate phase equilibria and partition coefficients by applying equations of state, gE models, and COSMO-RS methods. They can provide a comparison and a critical assessment of these methods with regard to their industrial relevance. The students are capable to use the software COSMOtherm and relevant property tools of ASPEN and to write short programs for the specific calculation of different thermodynamic properties. They can judge and evaluate the results from thermodynamic calculations/predictions for industrial processes.
Personal Competence	
Social Competence	Students are capable to develop and discuss solutions in small groups; further they can translate these solutions into calculation algorithms.
Autonomy	Students can rank the field of “Applied Thermodynamics” within the scientific and social context. They are capable to define research projects within the field of thermodynamic data calculation.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	Compulsory: Yes; Bonus: None; Form: Written elaboration; Description:
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective 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	Prof. Ralf Dohrn
Language	EN
Cycle	WiSe
Content	• Phase equilibria in multicomponent systems • Partioning 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 Potenitials • 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. Simon Müller
Language	EN
Cycle	WiSe
Content	exercises in computer pool, see lecture description for more details
Literature	-

Module M0519: Particle Technology and Solid Matter Process Technology

Courses

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

Module Responsible	Prof. Stefan Heinrich
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of solids processes and particle technology
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After completion of the module the students will be able to describe and explain processes for solids processing in detail based on microprocesses on the particle level.
Skills	Students are able to choose process steps and apparatuses for the focused treatment of solids depending on the specific characteristics. They furthermore are able to adapt these processes and to simulate them.
Personal Competence	
Social Competence	Students are able to present results from small teamwork projects in an oral presentation and to discuss their knowledge with scientific researchers.
Autonomy	Students are able to analyze and solve problems regarding solid particles independently or in small groups.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** None; **Form** Written elaboration; **Description** 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 B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Materials Science and Engineering: Specialisation Nano and Hybrid Materials: 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/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0050: Advanced Particle Technology II

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Stefan Heinrich
Language	DE/EN
Cycle	WiSe
Content	• Exercise in form of "Project based Learning" • 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 methids, Descrete Particle Modeling • Treatment of simulation problems with distributed properties, solution of population balances
Literature	Schubert, H.; Heidenreich, E.; Liepe, F.; Neeße, T.: Mechanische Verfahrenstechnik. Deutscher Verlag für die Grundstoffindustrie, Leipzig, 1990. Stieß, M.: Mechanische Verfahrenstechnik I und II. Springer Verlag, Berlin, 1992.

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

Module M1970: Process Modelling and Control

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Process modeling and control (L3220)	Lecture	2	3
Process modeling and control (L3221)	Recitation Section (small)	3	3

Module Responsible	Prof. Mirko Skiborowski
Admission Requirements	None
Recommended Previous Knowledge	Engineering fundamentals Unit operations of mechanical and thermal process engineering as well as chemical reaction engineering Conceptual Process Design
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to - classify types of process models and model equations - explain numerical methods for simulation - explain the solution system for flow diagram simulation - classify control structures and present process control concepts for different apparatus and complex process engineering systems
Skills	Students are able to - formulate and implement process control objectives - design and evaluate control strategies and structures - analyze model structure and model parameters from the simulation of processes
Personal Competence	
Social Competence	Students are enabled to develop solutions together in groups
Autonomy	Students are enabled to acquire knowledge on the basis of further literature
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** No; **Bonus** 10 %; **Form** Midterm; **Description**
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Process Engineering: Core Qualification: Compulsory

Course L3220: Process modeling and control

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Mirko Skiborowski
Language	EN
Cycle	WiSe
Content	Process modeling: introduction, mathematical modeling, model building blocks, structured model development, analysis of model equations Process simulation: numeric, validation, flow sheet simulation, solution strategies Process control: process variables, control loops, model-based methods, plant-wide control
Literature	C. Eck, et al., Mathematische Modellierung, Springer, 2017 W. Luyben, Process Modeling, Simulation and Control for Chemical Engineers, 1990 H. Schuler, Prozesssimulation, VCH, 1995 H. Schuler, Prozessführung, Oldenburg, 1999

Course L3221: Process modeling and control	
Typ	Recitation Section (small)
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Mirko Skiborowski
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0973: Biocatalysis

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

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

Course L1158: Biocatalysis and Enzyme Technology

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Andreas Liese
Language	EN
Cycle	WiSe
Content	1. Introduction: Impact and potential of enzyme-catalysed processes in biotechnology. 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	• 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, Woley-VCH, 2003

Course L1157: Technical Biocatalysis	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Andreas Liese
Language	EN
Cycle	WiSe
Content	1. Introduction 2. Production and Down Stream Processing of Biocatalysts 3. Analytics (offline/online) 4. Reaction Engineering & Process Control • Definitions • Reactors • Membrane Processes • Immobilization 5. Process Optimization • Simplex / DOE / GA 6. Examples of Industrial Processes • food / feed • fine chemicals 7. Non-Aqueous Solvents as Reaction Media • ionic liquids • $scCO_2$ • solvent free
Literature	• 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, Woley-VCH, 2003

Module M2050: Cellular and Molecular Biotechnology

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Applications of whole cell biocatalysts in biotechnology (L3301)	Seminar	1	1
Advanced microbial genetics (L3302)	Lecture	1	1
Challenges for genetic engineering in biotechnology (L3303)	Seminar	1	1
Microbial Diversity in Applications (L3300)	Lecture	1	1
Parctical course: Cellular and molecular biotechnology (L3304)	Practical Course	2	2

Module Responsible	Prof. Johannes Gescher
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	
Skills	
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** None; **Form** Presentation; **Description** Vortrag
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess 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 L3301: Applications of whole cell biocatalysts in biotechnology

Typ	Seminar
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Johannes Gescher
Language	EN
Cycle	WiSe
Content	
Literature	

Course L3302: Advanced microbial genetics

Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Johannes Gescher
Language	EN
Cycle	WiSe
Content	
Literature	

Course L3303: Challenges for genetic engineering in biotechnology

Typ	Seminar
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Johannes Gescher
Language	EN
Cycle	WiSe
Content	
Literature	

Course L3300: Microbial Diversity in Applications	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Johannes Gescher
Language	EN
Cycle	WiSe
Content	
Literature	

Course L3304: Parctical course: Cellular and molecular biotechnology	
Typ	Practical Course
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Johannes Gescher
Language	EN
Cycle	WiSe
Content	
Literature	

Module M2175: Transport Processes

Courses

Title	Typ	Hrs/wk	CP
Multiphase Flows (L0104)	Lecture	2	2
Reactor design under consideration of local transport processes (L0105)	Project-/problem-based Learning	2	2
Heat & Mass Transfer in Process Engineering (L0103)	Lecture	2	2

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

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

Course L0105: Reactor design under consideration of local transport processes	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	WiSe
Content	In this Problem-Based Learning unit the students have to design a multiphase reactor for a fast chemical reaction concerning optimal hydrodynamic conditions of the multiphase flow. The four students in each team have to: • 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. This exposé will be used as basis for the discussion within the oral group examen of each team.
Literature	Bird, R.B.; Stewart, W.R.; Lightfoot, E.N.: Transport Phenomena, John Wiley & Sons Inc (2007), ISBN 978-0-470-11539-8. Brauer, H.; Mewes, D.: Stoffaustausch einschließlich chemischer Reaktion; Verlag Sauerländer, Aarau und Frankfurt am Main (1971), ISBN: 3794100085. Brauer, H.: Grundlagen der Einphasen- und Mehrphasenströmungen, Sauerländer, 1971, Clift, R.; Grace, J.R.; Weber, M.E.: Bubbles, Drops, and Particles, Verlag Academic Press, 1978, ISBN 012176950X, 9780121769505 Deckwer, W.-D.: Reaktionstechnik in Blasensäulen, Salle Verlag und Verlag Sauerländer, Aarau, Frankfurt am Main, Berlin, München, Salzburg (1985), DOI 10.1002/CITE.330590530 Deckwer, W.-D.: Bubble Column Reactors. Wiley, New York (1992), DOI 10.1002/AIC.690380821. Fan, L.; Tsuchiya, K.: Bubble wake dynamics in liquids and liquid-solid suspension. Butterworth-Heinemann, (1990), DOI 10.1016/c2009-0-24002-5. Kraume, M., Transportvorgänge in der Verfahrenstechnik, Springer Berlin, 2020, ISBN 978-3-662-60392-5. Lienhard, J. H. (2019). A Heat Transfer Textbook, Dover Publications. ISBN:9780486837352, 0486837351.

Course L0103: Heat & Mass Transfer in Process Engineering	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	WiSe
Content	• Introduction - Transport Processes in Chemical Engineering • 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	1. Baehr, Stephan: Heat and Mass Transfer, Wiley 2002. 2. Bird, Stewart, Lightfood: 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 M1757: Practical module 2 (dual study program, Master's degree)

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Practical term 2 (dual study program, Master's degree) (L2888)		0	10

Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	• Successful completion of practical module 1 as part of the dual Master's course • course D from the module on interlinking theory and practice as part of the dual Master's course
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... • ... combine their knowledge of facts, principles, theories and methods gained from previous study content with acquired practical knowledge - in particular their knowledge of practical professional procedures and approaches, in the current field of activity in engineering. • ... have a critical understanding of the practical applications of their engineering subject.
Skills	Dual students ... • ... apply technical theoretical knowledge to complex, interdisciplinary problems within the company, and evaluate the associated work processes and results, taking into account different possible courses of action. • ... implement the university's application recommendations with regard to their current tasks. • ... develop (new) solutions as well as procedures and approaches in their field of activity and area of responsibility - including in the case of frequently changing requirements (systemic skills).
Personal Competence	
Social Competence	Dual students ... • ... work responsibly in cross-departmental and interdisciplinary project teams and proactively deal with problems within their team. • ... represent complex engineering viewpoints, facts, problems and solution approaches in discussions with internal and external stakeholders and develop these further together.
Autonomy	Dual students ... • ... define goals for their own learning and working processes as engineers. • ... reflect on learning and work processes in their area of responsibility. • ... reflect on the relevance of subject modules specialisations and specialisation for work as an engineer, and also implement the university's application recommendations and the associated challenges to positively transfer knowledge between theory and practice.
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Credit points	10
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Documentation accompanying studies and across semesters: Module credit points are earned by completing a digital learning and development report (e-portfolio). This documents and reflects individual learning experiences and skills development relating to interlinking theory and practice, as well as professional practice. In addition, the partner company provides proof to the dual@TUHH Coordination Office that the dual student has completed the practical phase.
Assignment for the Following Curricula	Civil Engineering: Core Qualification: Compulsory Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Computational Methods and Machine Learning in Engineering: Core Qualification: Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Electrical Engineering and Information Technology: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Energy Systems: Core Qualification: Compulsory Environmental Engineering: Core Qualification: Compulsory Aircraft Systems Engineering: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Information and Communication Systems: Core Qualification: Compulsory International Management and Engineering: Core Qualification: Compulsory Logistics, Infrastructure and Mobility: Core Qualification: Compulsory Aeronautics: Core Qualification: Compulsory Mechanical Engineering - Product Development and Production: Core Qualification: Compulsory Materials Science and Engineering: Core Qualification: Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Core Qualification: Compulsory Microelectronics and Microsystems: Core Qualification: Compulsory Product Development, Materials and Production: Core Qualification: Compulsory Renewable Energies: Core Qualification: Compulsory

	Naval Architecture and Ocean Engineering: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory Process Engineering: Core Qualification: Compulsory Water and Environmental Engineering: Core Qualification: Compulsory

Course L2888: Practical term 2 (dual study program, Master's degree)	
Typ	
Hrs/wk	0
CP	10
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Lecturer	Dr. Henning Haschke
Language	DE
Cycle	WiSe/SoSe
Content	**Company onboarding process** • Assigning a professional field of activity as an engineer (B.Sc.) and associated fields of work • Establishing responsibilities and authorisation of the dual student within the company as an engineer (B.Sc.) • Taking personal responsibility within a team and on selected projects - across departments and, if applicable, across companies • Scheduling the current practical module with a clear correlation to work structures • Scheduling the examination phase/subsequent study semester **Operational knowledge and skills** • Company-specific: Responsibility as an engineer (B.Sc.) in their own area of work, coordinating team and project work, dealing with complex contexts and unsolved problems, developing and implementing innovative solutions • Subject specialisation (corresponding to the chosen course [M.Sc.]) in the field of activity • Systemic skills • Implementing the university’s application recommendations (theory-practice transfer) in corresponding work and task areas across the company **Sharing/reflecting on learning** • Updating their e-portfolio • Importance of course contents (M.Sc.) when working as an engineer • Importance of development and innovation when working as an engineer
Literature	• Studierendenhandbuch • Betriebliche Dokumente • Hochschulseitige Anwendungsempfehlungen zum Theorie-Praxis-Transfer

Module M0895: Advanced Chemical Reaction Engineering

Courses

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

Module Responsible	Prof. Raimund Horn
Admission Requirements	None
Recommended Previous Knowledge	Content of the bachelor-lecture "basics of chemical reaction engineering".
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After completition of the module, students are able to: - identify differences between ideal and non-ideal rectors, - infer fundamental differences in kinetic models for catalyzed reactions, - name modelling algorithms for non-ideal reactors.
Skills	After successfull completition of the module the students are able to -evaluate properties of non-ideal reactors -compare kinetic modells 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
Personal Competence	
Social Competence	The students are able to analyze scientific challenges and elaborate suitable solutions in small groups. Moreover they are able to document these approaches according to scientific guidelines. After successful completition of the lab-course the students have a strong ability to organize themselfes in small groups to solve issues in chemical reaction engineering. The students can discuss their subject related knowledge among each other and with their teachers.
Autonomy	The students are able to obtain further information for experimental planning and assess their relevance autonomously.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory**: Yes; **Bonus**: None; **Form**: Subject theoretical and practical work; **Description**:
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective 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	EN
Cycle	SoSe
Content	1. Real reactors (residence time distribution E(t), F(t)-curve, measurement of E(t) or F(t), residence time distribution of ideal reactors, modeling of real reactors, segregated flow model, tanks in series model, dispersion model, compartment models) 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) 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) 4. Laboratory measurements in heterogeneous catalysis (temperature, pressure, concentration, mass flow controllers, laboratory reactors, experimental design)
Literature	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 Pubn. 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	EN
Cycle	SoSe
Content	1. Real reactors (residence time distribution E(t), F(t)-curve, measurement of E(t) or F(t), residence time distribution of ideal reactors, modeling of real reactors, segregated flow model, tanks in series model, dispersion model, compartment models) 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) 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) 4. Laboratory measurements in heterogeneous catalysis (temperature, pressure, concentration, mass flow controllers, laboratory reactors, experimental design)
Literature	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 Pubn. 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
Language	EN
Cycle	SoSe
Content	Execution and evaluation of several experiments in chemical reaction engineering. * 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	Skript zur Vorlesung, als Buch in der TU-Bibliothek Praktikumsskript Levenspiel, O.: Chemical reaction engineering; John Wiley & Sons, New York, 3. Ed., 1999 VTM 309(LB) Smith, J. M.: Chemical Engineering Kinetics, McGraw Hill, New York, 1981. Hill, C.: Chemical Engineering Kinetics & Reactor Design, John Wiley, New York, 1977. Fogler, H. S. : Elements of Chemical Reaction Engineering , Prentice Hall, 2006 M. Baerns, A. Behr, A. Brehm, J. Gmehling, H. Hofmann, U. Onken, A. Renken: Technische Chemie, VCH , 2006 G. F. Froment, K. B. Bischoff: Chemical Reactor Analysis and Design, Wiley, 1990

Module M2002: Waste and Resource Management

Courses

Title	Typ	Hrs/wk	CP
Waste management (L3261)	Project-/problem-based Learning	3	3
International waste concepts (L3259)	Lecture	2	2
International waste concepts (L3260)	Recitation Section (small)	1	1

Module Responsible	Prof. Kerstin Kuchta
Admission Requirements	None
Recommended Previous Knowledge	Basics in process engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to describe waste as a resource as well as advanced technologies for recycling and recovery of resources from waste in detail. This covers collection, transport, treatment and disposal in national and international contexts.
Skills	Students are able to select suitable processes for the treatment with respect to the national or cultural and developmental context. They can evaluate the ecological impact and the technical effort of different technologies and management systems.
Personal Competence	
Social Competence	Students can work together as a team of 2-5 persons, participate in subject-specific and interdisciplinary discussions, develop cooperated solutions and defend their own work results in front of others and promote the scientific development of colleagues. Furthermore, they can give and accept professional constructive criticisms.
Autonomy	Students can independently gain additional knowledge of the subject area and apply it in solving the given course tasks and projects.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** 20 %; **Form** Written elaboration; **Description**
Examination	Presentation
Examination duration and scale	PowerPoint presentation (10-15 minutes)
Assignment for the Following Curricula	Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Environmental Engineering: Specialisation Energy and Resources: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory

Course L3261: Waste management

Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Rüdiger Siechau
Language	EN
Cycle	SoSe

Content

- Introduction into the "Waste Management" consisting of:
  - Thermal Process (incinerator, RDF combustion)
  - Biological processes (Wet-/Dryfermentation)
  - technology, energy, emissions, approval , etc.
- Group work
  - design of systems/plants for energy recovery from waste
  - The following points are to be processed:
    - Input: waste (fraction collection and transportation, current quantity, material flows , possible amount of development)
    - Plant (design, process diagram, technology, energy production)
    - Output (energy quantity / type, by-products)
    - Costs and revenues
    - Climate and resource protection (CO2 balance , substitution of primary raw materials / fossil fuels)
    - Location and approval (infrastructure , expiration authorization procedure)
    - Focus at the whole concept (advantages, disadvantages , risks and opportunities , discussion)

Literature

Einführung in die Abfallwirtschaft; Martin Kranert, Klaus Cord-Landwehr (Hrsg.); Vieweg + Teubner Verlag; 2010

Powerpoint-Folien in Stud IP

Course L3259: International waste concepts	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	SoSe
Content	Waste avoidance and recycling are the focus of this lecture. Additionally, waste logistics (Collection, transport, export, fees and taxes) as well as international waste shipment solutions are presented. Other specific wastes, e.g. industrial waste, treatment concepts will be presented and developed by students themselves Waste composition and production on international level, wast eulogistic, collection and treatment in emerging and developing countries. Single national projects and studies will be prepared and presented by students
Literature	Basel convention

Course L3260: International waste concepts	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

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. Anna-Lena Heins
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of bioprocess engineering and process engineering at bachelor level
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After completion of this module, participants will be able to: • 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.
Skills	After completion of this module, participants will be able to: • 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.
Personal Competence	
Social Competence	After completion of this module, participants will be able to debate technical questions in small teams to enhance the ability to take position to their own opinions and increase their capacity for teamwork. The students can reflect their specific knowledge orally and discuss it with other students and teachers.
Autonomy	After completion of this module, participants will be able to solve a technical problem in teams of approx. 8-12 persons independently including a presentation of the results. •
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Core Qualification: Compulsory

Course L1034: Bioreactor Design and Operation	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Anna-Lena Heins
Language	EN
Cycle	SoSe
Content	**Design of bioreactors and peripheries:** • 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 **Sterile operation:** • 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 **Instrumentation and control:** • 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 **Bioreactor selection and scale-up:** • selection criteria • scale-up and scale-down • reactors for mammalian cell culture **Integrated biosystem:** • interactions and integration of microorganisms, bioreactor and downstream processing • Miniplant technologies **Team work with presentation:** • Operation mode of selected bioprocesses (e.g. fundamentals of batch, fed-batch and continuous cultivation)
Literature	• Storhas, Winfried, Bioreaktoren und periphere Einrichtungen, Braunschweig: Vieweg, 1994 • 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. Anna-Lena Heins
Language	EN
Cycle	SoSe
Content	**Introduction to Biosystems Engineering (Exercise)** **Experimental basis and methods for biosystems analysis** • 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 **Analysis, modelling and simulation of biological networks** • 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) **Modelling and simulation for bioprocess engineering** • Modelling of bioreactors • Dynamic behaviour of bioprocesses **Selected projects for biosystems engineering** • Miniaturisation of bioreaction systems • Miniplant technology for the integration of biosynthesis and downstream processin • Technical and economic overall assessment of bioproduction processes
Literature	E. Klipp et al. Systems Biology in Practice, Wiley-VCH, 2006 R. Dohrn: Miniplant-Technik, Wiley-VCH, 2006 G.N. Stephanopoulos et. al.: Metabolic Engineering, Academic Press, 1998 I.J. Dunn et. al.: Biological Reaction Engineering, Wiley-VCH, 2003 Lecture materials to be distributed

Course L1036: Biosystems Engineering	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Johannes Gescher, Prof. Anna-Lena Heins
Language	EN
Cycle	SoSe
Content	**Introduction to Biosystems Engineering** **Experimental basis and methods for biosystems analysis** • 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 **Analysis, modelling and simulation of biological networks** • 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) **Modelling and simulation for bioprocess engineering** • Modelling of bioreactors • Dynamic behaviour of bioprocesses **Selected projects for biosystems engineering** • Miniaturisation of bioreaction systems • Miniplant technology for the integration of biosynthesis and downstream processin • Technical and economic overall assessment of bioproduction processes
Literature	E. Klipp et al. Systems Biology in Practice, Wiley-VCH, 2006 R. Dohrn: Miniplant-Technik, Wiley-VCH, 2006 G.N. Stephanopoulos et. al.: Metabolic Engineering, Academic Press, 1998 I.J. Dunn et. al.: Biological Reaction Engineering, Wiley-VCH, 2003 Lecture materials to be distributed

Module M2029: Process Imaging

Courses

Title	Typ	Hrs/wk	CP
Process Imaging (L2723)	Lecture	3	3
Applied Process Imaging (L2724)	Project-/problem-based Learning	3	3

Module Responsible	Prof. Alexander Penn
Admission Requirements	None
Recommended Previous Knowledge	No special prerequisites needed. An interest in imaging techniques and image processing is helpful but not mandatory.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The module focuses primarily on discussing established imaging techniques including (a) optical and infrared imaging, (b) magnetic resonance imaging, (c) X-ray imaging and tomography. Moreover, it presents and discusses a range of more recent imaging modalities. The students will learn: 1. what these imaging techniques can measure (such as sample density or concentration, material transport, chemical composition, temperature), 2. how the measurement techniques work (physical measurement principles, hardware requirements, image reconstruction), and 3. how to determine the most suited imaging methods for a given problem.
Skills	After the successful completion of the course, the students shall: 1. understand the physical principles and practical aspects of the most common imaging methods, 2. be able to assess the pros and cons of these methods with regard to cost, complexity, expected contrasts, spatial and temporal resolution, and based on this assessment 3. be able to identify the most suited imaging modality for any specific engineering challenge in the field of chemical and bioprocess engineering.
Personal Competence	
Social Competence	In the problem-based interactive course, students work in small teams and set up two process imaging systems and use these systems to measure relevant process parameters in different chemical and bioprocess engineering applications. The teamwork will foster interpersonal communication skills.
Autonomy	Students are guided to work in self-motivation due to the challenge-based character of this module. A final presentation improves presentation skills.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	70% written examination, 30% active participation and final presentation of the problem-based learning units with a 5-10 page report
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory

Course L2723: Process Imaging	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Alexander Penn
Language	EN
Cycle	SoSe
Content	The lecture focuses primarily on presenting and discussing established imaging techniques relevant to the field of engineering including (a) optical and infrared imaging, (b) magnetic resonance imaging, (c) X-ray imaging and tomography. Moreover, it presents and discusses a range of more recent imaging modalities. The students will learn: 1. what these imaging techniques can measure (such as sample density or concentration, material transport, chemical composition, temperature), 2. how the measurement techniques work (physical measurement principles, hardware requirements, image reconstruction), and 3. how to determine the most suited imaging methods for a given problem.
Literature	Wang, M. (2015). Industrial Tomography. Cambridge, UK: Woodhead Publishing. Available as e-book in the library of TUHH: https://katalog.tub.tuhh.de/Record/823579395

Course L2724: Applied Process Imaging	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Alexander Penn, Dr. Stefan Benders
Language	EN
Cycle	SoSe
Content	**Content:** The module focuses primarily on discussing established imaging techniques including (a) optical and infrared imaging, (b) magnetic resonance imaging, (c) X-ray imaging and tomography, and (d) ultrasound imaging and also covers a range of more recent imaging modalities. The students will learn: 1. what these imaging techniques can measure (such as sample density or concentration, material transport, chemical composition, temperature), 2. how the measurements work (physical measurement principles, hardware requirements, image reconstruction), and 3. how to determine the most suited imaging methods for a given problem. **Learning goals:** After the successful completion of the course, the students shall: 1. understand the physical principles and practical aspects of the most common imaging methods, 2. be able to assess the pros and cons of these methods with regard to cost, complexity, expected contrasts, spatial and temporal resolution, and based on this assessment 3. be able to identify the most suited imaging modality for any specific engineering challenge in the field of chemical and bioprocess engineering.
Literature	Wang, M. (2015). Industrial Tomography. Cambridge, UK: Woodhead Publishing. Available as e-book in the library of TUHH: https://katalog.tub.tuhh.de/Record/823579395

Module M1758: Practical Module 3 (Dual Study Program, Master's Degree)

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Practical term 3 (dual study program, Master's degree) (L2889)		0	10

Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	• Successful completion of practical module 2 as part of the dual Master's course • course E from the module on interlinking theory and practice as part of the dual Master's course
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... • ... combine their comprehensive and specialised engineering knowledge acquired from previous study contents with the strategy-oriented practical knowledge gained from their current field of work and area of responsibility. • ... have a critical understanding of the practical applications of their engineering subject, as well as related fields when implementing innovations.
Skills	Dual students ... • ... apply specialised and conceptual skills to solve complex, sometimes interdisciplinary problems within the company, and evaluate the associated work processes and results, taking into account different possible courses of action. • ... implement the university's application recommendations with regard to their current tasks. • ... develop new solutions as well as procedures and approaches to implement operational projects and assignments - even when facing frequently changing requirements and unpredictable changes (systemic skills). • ... can use academic methods to develop new ideas and procedures for operational problems and issues, and to assess these with regard to their usability.
Personal Competence	
Social Competence	Dual students ... • ... work responsibly in cross-departmental and interdisciplinary project teams and proactively deal with problems within their team. • ... can promote the professional development of others in a targeted manner. • ... represent complex and interdisciplinary engineering viewpoints, facts, problems and solution approaches in discussions with internal and external stakeholders and develop these further together.
Autonomy	Dual students ... • ... reflect on learning and work processes in their area of responsibility. • ... define goals for new application-oriented tasks, projects and innovation plans while reflecting on potential effects on the company and the public. • ... reflect on the relevance of areas of specialisation and research for work as an engineer, and also implement the university's application recommendations and the associated challenges to positively transfer knowledge between theory and practice.
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Credit points	10
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Documentation accompanying studies and across semesters: Module credit points are earned by completing a digital learning and development report (e-portfolio). This documents and reflects individual learning experiences and skills development relating to interlinking theory and practice, as well as professional practice. In addition, the partner company provides proof to the dual@TUHH Coordination Office that the dual student has completed the practical phase.
Assignment for the Following Curricula	Civil Engineering: Core Qualification: Compulsory Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Computational Methods and Machine Learning in Engineering: Core Qualification: Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Electrical Engineering and Information Technology: Core Qualification: Compulsory Energy Systems: Core Qualification: Compulsory Environmental Engineering: Core Qualification: Compulsory Aircraft Systems Engineering: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Information and Communication Systems: Core Qualification: Compulsory International Management and Engineering: Core Qualification: Compulsory Logistics, Infrastructure and Mobility: Core Qualification: Compulsory Aeronautics: Core Qualification: Compulsory Mechanical Engineering - Product Development and Production: Core Qualification: Compulsory Materials Science and Engineering: Core Qualification: Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory

	Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Core Qualification: Compulsory Microelectronics and Microsystems: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Compulsory Product Development, Materials and Production: Core Qualification: Compulsory Renewable Energies: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory Process Engineering: Core Qualification: Compulsory Water and Environmental Engineering: Core Qualification: Compulsory

Course L2889: Practical term 3 (dual study program, Master's degree)	
Typ	
Hrs/wk	0
CP	10
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Lecturer	Dr. Henning Haschke
Language	DE
Cycle	WiSe/SoSe
Content	**Company onboarding process** • Assigning a future professional field of activity as an engineer (M.Sc.) and associated fields of work • Extending responsibilities and authorisation of the dual student within the company up to the intended first assignment after completing their studies • Working responsibly in a team; project responsibility within own area - as well as across divisions and companies if necessary • Scheduling the final practical module with a clear correlation to work structures • Internal agreement on a potential topic or innovation project for the Master’s dissertation • Planning the Master’s dissertation within the company in cooperation with TU Hamburg • Scheduling the examination phase/subsequent study semester **Operational knowledge and skills** • Company-specific: dealing with change, project and team development, responsibility as an engineer in their future field of work (M.Sc.), dealing with complex contexts, frequent and unpredictable changes, developing and implementing innovative solutions • Specialising in one field of work (final dissertation) • Systemic skills • Implementing the university’s application recommendations (theory-practice transfer) in corresponding work and task areas across the company **Sharing/reflecting on learning** • E-portfolio • Relevance of study content and personal specialisation when working as an engineer • Relevance of research and innovation when working as an engineer
Literature	• Studierendenhandbuch • betriebliche Dokumente • Hochschulseitige Anwendungsempfehlungen zum Theorie-Praxis-Transfer

Specialization Chemical and Bioprocess Engineering

Module M0523: Business & Management

Module Responsible	Prof. Matthias Meyer
Admission Requirements	Successful completion of the modul "Foundations of Management"
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students are able to find their way around selected special areas of management within the scope of business management. • 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.
Skills	• 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.
Personal Competence	
Social Competence	• Students are able to communicate in small interdisciplinary groups and to jointly develop solutions for complex problems
Autonomy	• Students are capable of acquiring necessary knowledge independently by means of research and preparation of material.
Workload in Hours	Depends on choice of courses
Credit points	6

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

Module M0524: Non-technical 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	
Knowledge	**The Nontechnical Academic Programms (NTA)** 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. **The Learning Architecture** 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. 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". 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. **Teaching and Learning Arrangements** 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. **Fields of Teaching** 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. 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. **The Competence Level** 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. 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. **Specialized Competence (Knowledge)** Students can • 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.
Skills	**Professional Competence (Skills)** In selected sub-areas students can • apply basic and specific methods of the said scientific disciplines, • aquestion 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 sucsessful manner, • justify their decisions on forms of organization and application in practical questions in contexts that go beyond the technical relationship to the subject.
Personal Competence	
Social Competence	**Personal Competences (Social Skills)**

	Students will be able • 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.
Autonomy	**Personal Competences (Self-reliance)** Students are able in selected areas • 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 writen form or verbaly • to organize themselves as an entrepreneurial subject country (as far as this study-focus would be chosen)
Workload in Hours	Depends on choice of courses
Credit points	6

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

Module M0617: High Pressure Chemical Engineering

Courses

Title	Typ	Hrs/wk	CP
High pressure plant and vessel design (L1278)	Lecture	2	2
Industrial Processes Under High Pressure (L0116)	Lecture	2	2
Advanced Separation Processes (L0094)	Lecture	2	2

Module Responsible	Dr. Monika Johannsen
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of Chemistry, Chemical Engineering, Fluid Process Engineering, Thermal Separation Processes, Thermodynamics, Heterogeneous Equilibria
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After a successful completion of this module, students can: • 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.
Skills	After successful completion of this module, students are able to: • 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	
Social Competence	After successful completion of this module, students are able to: • present a scientific topic from an original publication in teams of 2 and defend the contents together.
Autonomy	• Students are able to carry out independent research and independently acquire the necessary subject-specific knowledge. • Students are able to independently develop a topic, present it and discuss it in a scientific manner.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	Compulsory: Yes; Bonus: 15 %; Form: Presentation; Description:
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 and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess 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 plant and vessel design	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Hans Häring
Language	DE/EN
Cycle	SoSe
Content	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 Applications: - subsea technology (manned and unmanned vessels) - steam vessels - heat exchangers - LPG, LEG transport vessels
Literature	Apparate und Armaturen in der chemischen Hochdrucktechnik, Springer Verlag Spain and Paauwe: High Pressure Technology, Vol. I und II, M. Dekker Verlag AD-Merkblätter, Heumanns Verlag Bertucco; Vetter: High Pressure Process Technology, Elsevier Verlag Sherman; Stadtmuller: Experimental Techniques in High-Pressure Research, Wiley & Sons Verlag Klapp: Apparate- und Anlagentechnik, Springer Verlag

Course L0116: Industrial Processes Under High Pressure	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Carsten Zetzl
Language	EN
Cycle	SoSe
Content	Part I : Physical Chemistry and Thermodynamics 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. Part II : High Pressure Processes 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 **Part III : Industrial production** 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 Learning Outcomes: After a successful completion of this module, the student should be able to - understand of the influences of pressure on properties of compounds, phase equilibria, and production processes. - Apply high pressure approches in the complex process design tasks - Estimate Efficiency of high pressure alternatives with respect to investment and operational costs Performance Record: 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) Workload: 60 hours total
Literature	Literatur: 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.

Course L0094: Advanced Separation Processes	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Monika Johannsen
Language	EN
Cycle	SoSe
Content	• Introduction/Overview on Properties of Supercritical Fluids (SCF)and their Application in Gas Extraction Processes • 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 M2002: Waste and Resource Management

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Waste management (L3261)	Project-/problem-based Learning	3	3
International waste concepts (L3259)	Lecture	2	2
International waste concepts (L3260)	Recitation Section (small)	1	1

Module Responsible	Prof. Kerstin Kuchta
Admission Requirements	None
Recommended Previous Knowledge	Basics in process engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to describe waste as a resource as well as advanced technologies for recycling and recovery of resources from waste in detail. This covers collection, transport, treatment and disposal in national and international contexts.
Skills	Students are able to select suitable processes for the treatment with respect to the national or cultural and developmental context. They can evaluate the ecological impact and the technical effort of different technologies and management systems.
Personal Competence	
Social Competence	Students can work together as a team of 2-5 persons, participate in subject-specific and interdisciplinary discussions, develop cooperated solutions and defend their own work results in front of others and promote the scientific development of colleagues. Furthermore, they can give and accept professional constructive criticisms.
Autonomy	Students can independently gain additional knowledge of the subject area and apply it in solving the given course tasks and projects.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** Yes / **Bonus** 20 % / **Form** Written elaboration / **Description**
Examination	Presentation
Examination duration and scale	PowerPoint presentation (10-15 minutes)
Assignment for the Following Curricula	Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Environmental Engineering: Specialisation Energy and Resources: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory

Course L3261: Waste management

Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Rüdiger Siechau
Language	EN
Cycle	SoSe

Content

- Introduction into the "Waste Management" consisting of:
  - Thermal Process (incinerator, RDF combustion)
  - Biological processes (Wet-/Dryfermentation)
  - technology, energy, emissions, approval , etc.
- Group work
  - design of systems/plants for energy recovery from waste
  - The following points are to be processed:
    - Input: waste (fraction collection and transportation, current quantity, material flows , possible amount of development)
    - Plant (design, process diagram, technology, energy production)
    - Output (energy quantity / type, by-products)
    - Costs and revenues
    - Climate and resource protection (CO2 balance , substitution of primary raw materials / fossil fuels)
    - Location and approval (infrastructure , expiration authorization procedure)
    - Focus at the whole concept (advantages, disadvantages , risks and opportunities , discussion)

Literature

Einführung in die Abfallwirtschaft; Martin Kranert, Klaus Cord-Landwehr (Hrsg.); Vieweg + Teubner Verlag; 2010

Powerpoint-Folien in Stud IP

Course L3259: International waste concepts	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	SoSe
Content	Waste avoidance and recycling are the focus of this lecture. Additionally, waste logistics (Collection, transport, export, fees and taxes) as well as international waste shipment solutions are presented. Other specific wastes, e.g. industrial waste, treatment concepts will be presented and developed by students themselves Waste composition and production on international level, wast eulogistic, collection and treatment in emerging and developing countries. Single national projects and studies will be prepared and presented by students
Literature	Basel convention

Course L3260: International waste concepts	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0895: Advanced Chemical Reaction Engineering

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

Module Responsible	Prof. Raimund Horn
Admission Requirements	None
Recommended Previous Knowledge	Content of the bachelor-lecture "basics of chemical reaction engineering".
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After completition of the module, students are able to: - identify differences between ideal and non-ideal rectors, - infer fundamental differences in kinetic models for catalyzed reactions, - name modelling algorithms for non-ideal reactors.
Skills	After successfull completition of the module the students are able to -evaluate properties of non-ideal reactors -compare kinetic modells 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
Personal Competence	
Social Competence	The students are able to analyze scientific challenges and elaborate suitable solutions in small groups. Moreover they are able to document these approaches according to scientific guidelines. After successful completition of the lab-course the students have a strong ability to organize themselfes in small groups to solve issues in chemical reaction engineering. The students can discuss their subject related knowledge among each other and with their teachers.
Autonomy	The students are able to obtain further information for experimental planning and assess their relevance autonomously.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** 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 Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective 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	EN
Cycle	SoSe
Content	1. Real reactors (residence time distribution E(t), F(t)-curve, measurement of E(t) or F(t), residence time distribution of ideal reactors, modeling of real reactors, segregated flow model, tanks in series model, dispersion model, compartment models) 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) 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) 4. Laboratory measurements in heterogeneous catalysis (temperature, pressure, concentration, mass flow controllers, laboratory reactors, experimental design)
Literature	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 Pubn. 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	EN
Cycle	SoSe
Content	1. Real reactors (residence time distribution E(t), F(t)-curve, measurement of E(t) or F(t), residence time distribution of ideal reactors, modeling of real reactors, segregated flow model, tanks in series model, dispersion model, compartment models) 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) 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) 4. Laboratory measurements in heterogeneous catalysis (temperature, pressure, concentration, mass flow controllers, laboratory reactors, experimental design)
Literature	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 Pubn. 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
Language	EN
Cycle	SoSe
Content	Execution and evaluation of several experiments in chemical reaction engineering. * 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	Skript zur Vorlesung, als Buch in der TU-Bibliothek Praktikumsskript Levenspiel, O.: Chemical reaction engineering; John Wiley & Sons, New York, 3. Ed., 1999 VTM 309(LB) Smith, J. M.: Chemical Engineering Kinetics, McGraw Hill, New York, 1981. Hill, C.: Chemical Engineering Kinetics & Reactor Design, John Wiley, New York, 1977. Fogler, H. S. : Elements of Chemical Reaction Engineering , Prentice Hall, 2006 M. Baerns, A. Behr, A. Brehm, J. Gmehling, H. Hofmann, U. Onken, A. Renken: Technische Chemie, VCH , 2006 G. F. Froment, K. B. Bischoff: Chemical Reactor Analysis and Design, Wiley, 1990

Module M2094: Solid Process Engineering and Air Pollution Abatement in Chemical Industry

Courses

Title	Typ	Hrs/wk	CP
Solid Matter Process in Chemical Industry (L2021)	Lecture	2	3
Air Pollution Abatement (L0203)	Lecture	2	3

Module Responsible	Dr. Swantje Pietsch-Braune
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of process engineering and chemistry Basic knowledge of solids process engineering and separation technology
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After successful completion of the module students are able to • discuss legal regulations in the area of emissions and air quality • explain the effects of air pollutants on the environment, • name and explan off gas tretament processes and to define their area of application • describe and design processes of solid process engineering that are applied on an industrial scale in the chemical industry • comprehensively capture process steps and create process chains
Skills	Students are able to • combine processes for cleaning of off-gases depending on the pollutants contained in the gases • design processes of mechanical process engineering on industrial scale
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory

Course L2021: Solid Matter Process in Chemical Industry

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Frank Kleine Jäger
Language	EN
Cycle	SoSe
Content	
Literature	

Course L0203: Air Pollution Abatement

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Swantje Pietsch-Braune
Language	EN
Cycle	SoSe
Content	In the lecture methods for the reduction of emissions from industrial plants are treated. At the beginning a short survey of the different forms of air pollutants is given. In the second part physical principals for the removal of particulate and gaseous pollutants form flue gases are treated. Industrial applications of these principles are demonstrated with examples showing the removal of specific compounds, e.g. sulfur or mercury from flue gases of incinerators.
Literature	Handbook of air pollution prevention and control, Nicholas P. Cheremisinoff. - Amsterdam [u.a.] : Butterworth-Heinemann, 2002 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 M1033: Special Areas of Process Engineering and Bioprocess Engineering

Courses

Title	Typ	Hrs/wk	CP
Solid Matter Process Technology for Biomass (L0052)	Lecture	2	3
Solid Matter Process in Chemical Industry (L2021)	Lecture	2	3
Safety of Chemical Reactions (L1321)	Lecture	2	3

Module Responsible	Prof. Michael Schlüter
Admission Requirements	None
Recommended Previous Knowledge	The students should have passed the Bachelor modules "Process Engineering" successfully.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to find their way around selected special areas of Process Engineering within the scope of Process Engineering. Students are able to explain technical dependencies and models in selected special areas of Process Engineering.
Skills	Students are able to apply basic methods in selected areas of process engineering.
Personal Competence	
Social Competence	Students can discuss in English in international teams and work out a solution under time pressure.
Autonomy	Students can chose independently, in which field the want to deepen their knowledge and skills through the election of courses.
Workload in Hours	Depends on choice of courses
Credit points	6
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and 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 L0052: Solid Matter Process Technology for Biomass

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	60 min
Lecturer	Prof. Werner Sitzmann
Language	DE
Cycle	SoSe
Content	The industrial application of unit operations as part of process engineering is explained by actual examples of solid biomass processes. Size reduction, transportation and dosing, drying and agglomeration of renewable resources are described as important unit operations when producing solid fuels and bioethanol, producing and refining edible oils, when making Btl - and WPC - products. Aspects of explosion protection and plant design complete the lecture.
Literature	Kaltschmitt M., Hartmann H. (Hrsg.): Energie aus Bioamsse, Springer Verlag, 2001, ISBN 3-540-64853-4 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 L2021: Solid Matter Process in Chemical Industry

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	12 Seiten
Lecturer	Prof. Frank Kleine Jäger
Language	EN
Cycle	SoSe
Content	
Literature	

Course L1321: Safety of Chemical Reactions	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Dr. Marko Hoffmann
Language	DE
Cycle	SoSe
Content	
Literature	

Module M1308: Modelling and Technical Design of Bio Refinery Processes

Courses

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

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

Course L1832: Biorefineries - Technical Design and Optimization	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Oliver Lüdtke
Language	DE
Cycle	SoSe
Content	**I. Repetition of engineering basics** 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 **II. Calculation:** 1. Planning and design of a specific bio-refinery plant section, such as Ethanol distillation and fermentation. This is based on empirical valuse of a real, industrial plant. ◦ 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	Perry, R.;Green, R.: Perry's Chemical Engineers' Handbook, 8 th Edition, McGraw Hill Professional, 2007 Sinnot, R. K.: Chemical Engineering Design, Elsevier, 2014

Course L0022: CAPE in Energy Engineering	
Typ	Projection Course
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Martin Kaltschmitt
Language	DE
Cycle	SoSe
Content	• CAPE = *Computer*-Aided-Project-Engineering • INTRODUCTION TO THE THEORY ◦ 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 ® ◦ 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 Within the seminar, the various tasks are actively discussed and applied to various cases of application.
Literature	• Aspen Plus® - Aspen Plus User Guide • William L. Luyben; Distillation Design and Control Using Aspen Simulation; ISBN-10: 0-471-77888-5

Module M1954: Process Simulation and Process Safety

Courses

Title	Typ	Hrs/wk	CP
CAPE with Computer Exercises (L1039)	Integrated Lecture	3	4
Methods of Process Safety and Dangerous Substances (L1040)	Lecture	2	2

Module Responsible	Prof. Mirko Skiborowski
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	
Knowledge	students can: - 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 accident insurance
Skills	students can: - 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
Personal Competence	
Social Competence	students are able to: - 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
Autonomy	students are able to - act responsible with respect to environment and needs of the society
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	Exam 90 minutes and written report
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 and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory

Course L1039: CAPE with Computer Exercises	
Typ	Integrated Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Mirko Skiborowski
Language	EN
Cycle	SoSe
Content	I. Introduction 1. Fundamentals of steady state process simulation 1.1. Classes of simulation tools 1.2. Sequential-modularer approach 1.3. Operating mode of ASPEN PLUS 2. Introduction in ASPEN PLUS 2.1. GUI 2.2. Estimation methods of physical properties 2.3. Aspen tools (z.B. Designspecification) 2.4. Convergence methods II. Exercices using ASPEN PLUS and ACM 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	**-** 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	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Mirko Skiborowski, Dr. Thomas Waluga
Language	EN
Cycle	SoSe
Content	Practical implementation of safety analyses (methods) Safety-related parameters and methods for their determination Hazard characteristics according to the Chemicals Act GHS (Globally Harmonized System) for the classification and labelling of chemicals Hazardous substances Toxicology Personal safety Safety considerations in plant design Inherently safe process design Technical measures for plant safety
Literature	Bender, H.: Sicherer Umgang mit Gefahrstoffen; Weinheim (2005) Bender, H.: Das Gefahrstoffbuch. Sicherer Umgang mit Gefahrstoffen in der Praxis; Weinheim (2002) Birett, K.: Umgang mit Gefahrstoffen; Heidelberg (2011) Birgersson, B.; Sterner, O.; Zimerson, E.: Chemie und Gesundheit; Weinheim (1988) O. Antelmann, Diss. an der TU Berlin, 2001 R. Dittmeyer, W. Keim, G. Kreysa, A. Oberholz, Chemische Technik, Prozesse und Produkte, Band 1 Methodische Grundlagen, VCH, 2004-2006, S. 719 H. Pohle, Chemische Industrie, Umweltschutz, Arbeitsschutz, Anlagensicherheit, VCH, Weinheim, 1991 J. Steinbach, Chemische Sicherheitstechnik, VCH, Weinheim, 1995 G. Suter, Identifikation sicherheitskritischer Prozesse, P&A Kompendium, 2004

Module M1709: Applied Optimization in Energy and Process Engineering

Courses

Title	Typ	Hrs/wk	CP
Applied optimization in energy and process engineering (L2693)	Integrated Lecture	2	3
Applied optimization in energy and process engineering (L2695)	Recitation Section (small)	3	3

Module Responsible	Prof. Mirko Skiborowski
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals in the field of mathematical modeling and numerical mathematics, as well as a basic understanding of process engineering processes. In particular the contents of the module Process and Plant Engineering II
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The module provides a general introduction to the basics of applied mathematical optimization and deals with application areas on different scales from the identification of kinetic models, to the optimal design of unit operations and the optimization of entire (sub)processes, as well as production planning. In addition to the basic classification and formulation of optimization problems, different solution approaches are discussed and tested during the exercises. Besides deterministic gradient-based methods, metaheuristics such as evolutionary and genetic algorithms and their application are discussed as well. • Introduction to Applied Optimization • Formulation of optimization problems • Linear Optimization • Nonlinear Optimization • Mixed-integer (non)linear optimization • Multi-objective optimization • Global optimization
Skills	After successful participation in the module "Applied Optimization in Energy and Process Engineering", students are able to formulate the different types of optimization problems and to select appropriate solution methods in suitable software such as Matlab and GAMS and to develop improved solution strategies. Furthermore, students will be able to interpret and critically examine the results accordingly.
Personal Competence	
Social Competence	Students are capable of: •develop solutions in heterogeneous small groups
Autonomy	Students are capable of: •taping new knowledge on a special subject by literature research
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	Compulsory: No; Bonus: 10 %; Form: Midterm; Description: Bonuspunkte
Examination	Oral exam
Examination duration and scale	35 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Computational Methods and Machine Learning in Engineering: Core Qualification: Elective Compulsory Energy Systems: Specialisation Energy Systems: Elective Compulsory Environmental Engineering: Specialisation Energy and Resources: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L2693: Applied optimization in energy and process engineering	
Typ	Integrated Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Mirko Skiborowski
Language	EN
Cycle	SoSe
Content	The lecture offers a general introduction to the basics and possibilities of applied mathematical optimization and deals with application areas on different scales from kinetics identification, optimal design of unit operations to the optimization of entire (sub)processes, and production planning. In addition to the basic classification and formulation of optimization problems, different solution approaches are discussed. Besides deterministic gradient-based methods, metaheuristics such as evolutionary and genetic algorithms and their application are discussed as well. - Introduction to Applied Optimization - Formulation of optimization problems - Linear Optimization - Nonlinear Optimization - Mixed-integer (non)linear optimization - Multi-objective optimization - Global optimization
Literature	Weicker, K., Evolutionäre Algortihmen, Springer, 2015 Edgar, T. F., Himmelblau D. M., Lasdon, L. S., Optimization of Chemical Processes, McGraw Hill, 2001 Biegler, L. Nonlinear Programming - Concepts, Algorithms, and Applications to Chemical Processes, 2010 Kallrath, J. Gemischt-ganzzahlige Optimierung: Modellierung in der Praxis, Vieweg, 2002

Course L2695: Applied optimization in energy and process engineering	
Typ	Recitation Section (small)
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Mirko Skiborowski
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

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. Anna-Lena Heins
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of bioprocess engineering and process engineering at bachelor level
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After completion of this module, participants will be able to: • 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.
Skills	After completion of this module, participants will be able to: • 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.
Personal Competence	
Social Competence	After completion of this module, participants will be able to debate technical questions in small teams to enhance the ability to take position to their own opinions and increase their capacity for teamwork. The students can reflect their specific knowledge orally and discuss it with other students and teachers.
Autonomy	After completion of this module, participants will be able to solve a technical problem in teams of approx. 8-12 persons independently including a presentation of the results. •
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Core Qualification: Compulsory

Course L1034: Bioreactor Design and Operation	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Anna-Lena Heins
Language	EN
Cycle	SoSe
Content	**Design of bioreactors and peripheries:** • 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 **Sterile operation:** • 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 **Instrumentation and control:** • 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 **Bioreactor selection and scale-up:** • selection criteria • scale-up and scale-down • reactors for mammalian cell culture **Integrated biosystem:** • interactions and integration of microorganisms, bioreactor and downstream processing • Miniplant technologies **Team work with presentation:** • Operation mode of selected bioprocesses (e.g. fundamentals of batch, fed-batch and continuous cultivation)
Literature	• Storhas, Winfried, Bioreaktoren und periphere Einrichtungen, Braunschweig: Vieweg, 1994 • 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. Anna-Lena Heins
Language	EN
Cycle	SoSe
Content	**Introduction to Biosystems Engineering (Exercise)** **Experimental basis and methods for biosystems analysis** • 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 **Analysis, modelling and simulation of biological networks** • 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) **Modelling and simulation for bioprocess engineering** • Modelling of bioreactors • Dynamic behaviour of bioprocesses **Selected projects for biosystems engineering** • Miniaturisation of bioreaction systems • Miniplant technology for the integration of biosynthesis and downstream processin • Technical and economic overall assessment of bioproduction processes
Literature	E. Klipp et al. Systems Biology in Practice, Wiley-VCH, 2006 R. Dohrn: Miniplant-Technik, Wiley-VCH, 2006 G.N. Stephanopoulos et. al.: Metabolic Engineering, Academic Press, 1998 I.J. Dunn et. al.: Biological Reaction Engineering, Wiley-VCH, 2003 Lecture materials to be distributed

Course L1036: Biosystems Engineering	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Johannes Gescher, Prof. Anna-Lena Heins
Language	EN
Cycle	SoSe
Content	**Introduction to Biosystems Engineering** **Experimental basis and methods for biosystems analysis** • 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 **Analysis, modelling and simulation of biological networks** • 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) **Modelling and simulation for bioprocess engineering** • Modelling of bioreactors • Dynamic behaviour of bioprocesses **Selected projects for biosystems engineering** • Miniaturisation of bioreaction systems • Miniplant technology for the integration of biosynthesis and downstream processin • Technical and economic overall assessment of bioproduction processes
Literature	E. Klipp et al. Systems Biology in Practice, Wiley-VCH, 2006 R. Dohrn: Miniplant-Technik, Wiley-VCH, 2006 G.N. Stephanopoulos et. al.: Metabolic Engineering, Academic Press, 1998 I.J. Dunn et. al.: Biological Reaction Engineering, Wiley-VCH, 2003 Lecture materials to be distributed

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)	Project-/problem-based Learning	2	2

Module Responsible	Prof. Raimund Horn
Admission Requirements	None
Recommended Previous Knowledge	Content of the bachelor-modules "process technology", as well as particle technology, fluidmechanics in process-technology and transport processes.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to apply their knowledge to explain industrial catalytic processes as well as indicate different synthesis routes of established catalyst systems. They are capable to outline dis-/advantages of supported and full-catalysts with respect to their application. Students are able to identify anayltical tools for specific catalytic applications.
Skills	After successfull completition of the module, students are able to use their knowledge to identify suitable analytical tools for specific catalytic applications and to explain their choice. Moreover the students are able to choose and formulate suitable reactor systems for the current synthesis process. Students can apply their knowldege discretely to develop and conduct experiments. They are able to appraise achieved results into a more general context and draw conclusions out of them.
Personal Competence	
Social Competence	The students are able to plan, prepare, conduct and document experiments according to scientific guidelines in small groups. The students can discuss their subject related knowledge among each other and with their teachers.
Autonomy	The students are able to obtain further information for experimental planning and assess their relevance autonomously.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** 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: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective 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	1. Material- and Energybalance of the two-dimensionsal 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	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	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. Heterogeneous catalysis plays also a key role in any future energy scenario (fuel cells, electrocatalytic splitting of water) and in environmental engineering (automotive catalysis, photocatalyic abatement of water pollutants). Heterogeneous catalysis is an interdisciplinary science requiring knowledge of different scientific disciplines such as • 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) The class „Modern Methods in Heterogeneous Catalysis“ will deal with the above listed aspects of heterogeneous catalysis beyond the material presented in the normal curriculum of chemical reaction engineering classes. In the corresponding laboratory will have the opportunity to apply their aquired theoretical knowledge by synthesizing a solid catalyst, characterizing it with a variety of modern instrumental methods (e.g. BET, chemisorption, pore analysis, XRD, Raman-Spectroscopy, Electron Microscopy) and measuring its kinetics. Class and laboratory „Modern Methods in Heterogeneous Catalysis“ in combination with the lecture „Analysis and Design of Heterogeneous Catalytic Reactors“ will give interested students the opportunity to specialize in this vibrant, multifaceted and application oriented field of research.
Literature	• J.M. Thomas, W.J. Thomas: Principles and Practice of Heterogeneous Catalysis, VCH • 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: Spectrocopy 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	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Raimund Horn
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M2029: Process Imaging

Courses

Title	Typ	Hrs/wk	CP
Process Imaging (L2723)	Lecture	3	3
Applied Process Imaging (L2724)	Project-/problem-based Learning	3	3

Module Responsible	Prof. Alexander Penn
Admission Requirements	None
Recommended Previous Knowledge	No special prerequisites needed. An interest in imaging techniques and image processing is helpful but not mandatory.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The module focuses primarily on discussing established imaging techniques including (a) optical and infrared imaging, (b) magnetic resonance imaging, (c) X-ray imaging and tomography. Moreover, it presents and discusses a range of more recent imaging modalities. The students will learn: 1. what these imaging techniques can measure (such as sample density or concentration, material transport, chemical composition, temperature), 2. how the measurement techniques work (physical measurement principles, hardware requirements, image reconstruction), and 3. how to determine the most suited imaging methods for a given problem.
Skills	After the successful completion of the course, the students shall: 1. understand the physical principles and practical aspects of the most common imaging methods, 2. be able to assess the pros and cons of these methods with regard to cost, complexity, expected contrasts, spatial and temporal resolution, and based on this assessment 3. be able to identify the most suited imaging modality for any specific engineering challenge in the field of chemical and bioprocess engineering.
Personal Competence	
Social Competence	In the problem-based interactive course, students work in small teams and set up two process imaging systems and use these systems to measure relevant process parameters in different chemical and bioprocess engineering applications. The teamwork will foster interpersonal communication skills.
Autonomy	Students are guided to work in self-motivation due to the challenge-based character of this module. A final presentation improves presentation skills.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	70% written examination, 30% active participation and final presentation of the problem-based learning units with a 5-10 page report
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory

Course L2723: Process Imaging	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Alexander Penn
Language	EN
Cycle	SoSe
Content	The lecture focuses primarily on presenting and discussing established imaging techniques relevant to the field of engineering including (a) optical and infrared imaging, (b) magnetic resonance imaging, (c) X-ray imaging and tomography. Moreover, it presents and discusses a range of more recent imaging modalities. The students will learn: 1. what these imaging techniques can measure (such as sample density or concentration, material transport, chemical composition, temperature), 2. how the measurement techniques work (physical measurement principles, hardware requirements, image reconstruction), and 3. how to determine the most suited imaging methods for a given problem.
Literature	Wang, M. (2015). Industrial Tomography. Cambridge, UK: Woodhead Publishing. Available as e-book in the library of TUHH: https://katalog.tub.tuhh.de/Record/823579395

Course L2724: Applied Process Imaging	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Alexander Penn, Dr. Stefan Benders
Language	EN
Cycle	SoSe
Content	**Content:** The module focuses primarily on discussing established imaging techniques including (a) optical and infrared imaging, (b) magnetic resonance imaging, (c) X-ray imaging and tomography, and (d) ultrasound imaging and also covers a range of more recent imaging modalities. The students will learn: 1. what these imaging techniques can measure (such as sample density or concentration, material transport, chemical composition, temperature), 2. how the measurements work (physical measurement principles, hardware requirements, image reconstruction), and 3. how to determine the most suited imaging methods for a given problem. **Learning goals:** After the successful completion of the course, the students shall: 1. understand the physical principles and practical aspects of the most common imaging methods, 2. be able to assess the pros and cons of these methods with regard to cost, complexity, expected contrasts, spatial and temporal resolution, and based on this assessment 3. be able to identify the most suited imaging modality for any specific engineering challenge in the field of chemical and bioprocess engineering.
Literature	Wang, M. (2015). Industrial Tomography. Cambridge, UK: Woodhead Publishing. Available as e-book in the library of TUHH: https://katalog.tub.tuhh.de/Record/823579395

Module M0952: Industrial Bioprocess Engineering

Courses

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

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

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

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

Module M2028: Computational Fluid Dynamics in Process Engineering

Courses

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

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

Course L2301: Lagrangian transport in turbulent flows

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Yan Jin
Language	EN
Cycle	SoSe
Content	Contents - Common variables and terms for characterizing turbulence (energy spectra, energy cascade, etc.) - An overview of Lagrange analysis methods and experiments in fluid mechanics

	- Critical examination of the concept of turbulence and turbulent structures. -Calculation of the transport of ideal fluid elements and associated analysis methods (absolute and relative diffusion, Lagrangian Coherent Structures, etc.) - Implementation of a Runge-Kutta 4th-order in Matlab - Introduction to particle integration using ODE solver from Matlab - Problems from turbulence research - Application analytical methods with Matlab. Structure: - 14 units a 2x45 min. - 10 units lecture - 4 Units Matlab Exercise- Go through the exercises Matlab, Peer2Peer? Explain solutions to your colleague Learning goals: Students receive very specific, in-depth knowledge from modern turbulence research and transport analysis. → Knowledge The students learn to classify the acquired knowledge, they study approaches to further develop the knowledge themselves and to relate different data sources to each other. → Knowledge, skills The students are trained in the personal competence to independently delve into and research a scientific topic. → Independence Matlab exercises in small groups during the lecture and guided Peer2Peer discussion rounds train communication skills in complex situations. The mixture of precise language and intuitive understanding is learnt. → Knowledge, social competence Required knowledge: Fluid mechanics 1 and 2 advantageous Programming knowledge advantageous
Literature	Bakunin, Oleg G. (2008): Turbulence and Diffusion. Scaling Versus Equations. Berlin [u. a.]: Springer Verlag. Bourgoin, Mickaël; Ouellette, Nicholas T.; Xu, Haitao; Berg, Jacob; Bodenschatz, Eberhard (2006): The role of pair dispersion in turbulent flow. In: Science (New York, N.Y.) 311 (5762), S. 835-838. DOI: 10.1126/science.1121726. Davidson, P. A. (2015): Turbulence. An introduction for scientists and engineers. Second edition. Oxford: Oxford Univ. Press. Graff, L. S.; Guttu, S.; LaCasce, J. H. (2015): Relative Dispersion in the Atmosphere from Reanalysis Winds. In: J. Atmos. Sci. 72 (7), S. 2769-2785. DOI: 10.1175/JAS-D-14-0225.1. Grigoriev, Roman (2011): Transport and Mixing in Laminar Flows. Weinheim, Germany: Wiley-VCH Verlag GmbH & Co. KGaA. Haller, George (2015): Lagrangian Coherent Structures. In: Annu. Rev. Fluid Mech. 47 (1), S. 137-162. DOI: 10.1146/annurev-fluid-010313-141322. Kameke, A. von; Huhn, F.; Fernández-García, G.; Muñuzuri, A. P.; Pérez-Muñuzuri, V. (2010): Propagation of a chemical wave front in a quasi-two-dimensional superdiffusive flow. In: Physical review. E, Statistical, nonlinear, and soft matter physics 81 (6 Pt 2), S. 66211. DOI: 10.1103/PhysRevE.81.066211. Kameke, A. von; Huhn, F.; Fernández-García, G.; Muñuzuri, A. P.; Pérez-Muñuzuri, V. (2011): Double cascade turbulence and Richardson dispersion in a horizontal fluid flow induced by Faraday waves. In: Physical review letters 107 (7), S. 74502. DOI: 10.1103/PhysRevLett.107.074502. Kameke, A.v.; Kastens, S.; Rüttinger, S.; Herres-Pawlis, S.; Schlüter, M. (2019): How coherent structures dominate the residence time in a bubble wake: An experimental example. In: Chemical Engineering Science 207, S. 317-326. DOI: 10.1016/j.ces.2019.06.033. Klages, Rainer; Radons, Günter; Sokolov, Igor M. (2008): Anomalous Transport: Wiley. LaCasce, J. H. (2008): Statistics from Lagrangian observations. In: Progress in Oceanography 77 (1), S. 1-29. DOI: 10.1016/j.pocean.2008.02.002. Neufeld, Zoltán; Hernández-García, Emilio (2009): Chemical and Biological Processes in Fluid Flows: PUBLISHED BY IMPERIAL COLLEGE PRESS AND DISTRIBUTED BY WORLD SCIENTIFIC PUBLISHING CO. Onu, K.; Huhn, F.; Haller, G. (2015): LCS Tool: A computational platform for Lagrangian coherent structures. In: Journal of Computational Science 7, S. 26-36. DOI: 10.1016/j.jocs.2014.12.002. Ouellette, Nicholas T.; Xu, Haitao; Bourgoin, Mickaël; Bodenschatz, Eberhard (2006): An experimental study of turbulent relative dispersion models. In: New J. Phys. 8 (6), S. 109. DOI: 10.1088/1367-2630/8/6/109. Pope, Stephen B. (2000): Turbulent Flows. Cambridge: Cambridge University Press.

	Rivera, M. K.; Ecke, R. E. (2005): Pair dispersion and doubling time statistics in two-dimensional turbulence. In: Physical review letters 95 (19), S. 194503. DOI: 10.1103/PhysRevLett.95.194503. Vallis, Geoffrey K. (2010): Atmospheric and oceanic fluid dynamics. Fundamentals and large-scale circulation. 5. printing. Cambridge: Cambridge Univ. Press.

Course L1375: Computational Fluid Dynamics - Exercises in OpenFoam	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	SoSe
Content	• generation of numerical grids with a common grid generator • 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	• 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	Paschedag A.R.: CFD in der Verfahrenstechnik: Allgemeine Grundlagen und mehrphasige Anwendungen, Wiley-VCH, 2004 ISBN 3-527-30994-2. Ferziger, J.H.; Peric, M.: Numerische Strömungsmechanik. Springer-Verlag, Berlin, 2008, ISBN: 3540675868. Ferziger, J.H.; Peric, M.: Computational Methods for Fluid Dynamics. Springer, 2002, ISBN 3-540-42074-6

Module M1777: Introduction to model-based industrial process development for biopharmaceuticals

Courses

Title	Typ	Hrs/wk	CP
Design and Scale up of aerated bioreactors for biopharmaceutical products (L2922)	Seminar	2	3
Insights into biopharmaceutical production (L2921)	Seminar	2	3

Module Responsible	Prof. Michael Schlüter
Admission Requirements	None
Recommended Previous Knowledge	All lectures from the undergraduate studies, especially mathematics, chemistry, thermodynamics, fluid mechanics, heat- and mass transfer, transport processes
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students will be able to: • describe and evaluate pharmaceutical processes from a process engineering perspective. • name and use the essential models for process development • describe and evaluate bioreactors for pharmaceutical processes, especially gassed stirred tank reactors. • describe various pharmaceutical processes and contrast their modes of operation and essential characteristics.
Skills	Students will be able to: • Describe, optimize and design biopharmaceutical processes using models, • Describe, optimize and design gassed stirred reactors as a typical type of apparatus.
Personal Competence	
Social Competence	The students are able to discuss in international teams in english and develop an approach under pressure of time.
Autonomy	Students are able to independently define tasks for working on the overall problem of "Modeling a process for biopharmaceutical production". The knowledge required for this is acquired by the students themselves, building on the knowledge imparted in the lecture, and they decide which equations and models from the lecture are to be used for implementation. They can organize themselves in a team and assign priorities for subtasks.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L2922: Design and Scale up of aerated bioreactors for biopharmaceutical products

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Jürgen Fitschen, Dr. Thomas Wucherpfennig
Language	EN
Cycle	SoSe
Content	• Introduction to aerated stirred tank reactors and alternative reactor concepts • Mixing and mass transfer performance (example with M-STAR) • Energy dissipation rates and shear stress • Gas holdup and bubble size distribution • Experimental methods for the characterization of aerated stirred tank reactors • Common design and scale up concepts • Concept of compartments • Design and scale up assisted by Computational Fluid Dynamics
Literature	

Course L2921: Insights into biopharmaceutical production	
Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Jürgen Fitschen, Dr. Thomas Wucherpfennig
Language	EN
Cycle	SoSe
Content	• Introduction to biopharma including biopharmaceutical products (e.g. vaccine) • Biopharma market • Clinical studies • Quality of products • Drug substance process development (cell therapy) • Drug product development • Insilico process development (equipment, process, digital twin) • Scale-up, transfer and production of biopharmaceutical products • Regulatory topics and market authorization • Biopharma lab & production planning • Data, handling, statistics, Experiment Planning (DOE) • Capacity modeling, Software “Bio-G”
Literature	

Module M1778: Special Topics on Fluid Mechanics

Courses

Title	Typ	Hrs/wk	CP
Application of numerical methods in process engineering (L2923)	Lecture	2	2
Non invasive measurement techniques for Multiphase Flows (L2924)	Lecture	2	2
Non invasive measurement techniques for Multiphase Flows (L2925)	Practical Course	2	2

Module Responsible	Prof. Michael Schlüter
Admission Requirements	None
Recommended Previous Knowledge	All lectures from the undergraduate studies, especially mathematics, chemistry, thermodynamics, fluid mechanics, heat- and mass transfer.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students will be able to: • apply numerical simulations to concrete flow problems in process engineering. • experimentally analysis of basic parameters in industrial multiphase flows • critically assess how reliably numerical methods work and decide which quantities need to be validated with experimental data.
Skills	Students are able to: • perform numerical simulations in single and multiphase flows especially in technical applications • choose and apply experimental methods in multiphase flows especially in industrial aparatuses
Personal Competence	
Social Competence	The students are able to discuss in international teams in english and develop an approach under pressure of time.
Autonomy	Students are able to independently define tasks for working on the overall problem "Experimental and numerical analysis of multiphase reactors". The knowledge required for this is acquired by the students themselves, building on the knowledge imparted in the lecture, and they decide which experimental and numerical methods from the lecture and the practical course are to be used for implementation. They can organize themselves in a team and assign priorities for subtasks.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Computational Methods and Machine Learning in Engineering: Core Qualification: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L2923: Application of numerical methods in process engineering	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Yan Jin, Prof. Michael Schlüter
Language	EN
Cycle	WiSe
Content	This lecture introduces a number of significant research topics in fluid mechanics and their up-to-date progresses. Through the lecture, students will learn how to solve real scientific and engineering flow problems using numerical and experimental methods. The lecture helps the students to prepare for their master thesis. The detailed contents include: • Wall bounded flows (channel flows; pipe flows; wall roughness) • Convection in porous media (multiscale physics; flow instabilities) • Flows in turbomachinery (compressor/turbine cascades; wind turbines) • Flows in biological and physiological processes (digestion in stomach; respiratory system • Interfacial mass transfer of bubbly flows • Comparison between experiments and simulation, experimental validation • Combustion in engines (optional)
Literature	Numerische Strömungsmechanik, Joel H. Ferziger, Milovan Perić & Robert L. Street, Springer Vieweg, 2020 Strömungsmechanik, Heinz Herwig & Bastian Schmandt, Springer Vieweg, 2015. Fundamentals of Multiphase Flow, Christopher E. Brennen, Cambridge University Press, 2005. OpenFOAM User Guide, version 11, 11th July 2023. OpenFOAM Programmer’s Guide, Version 3.0.1, 2015

Course L2924: Non invasive measurement techniques for Multiphase Flows	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Felix Kexel
Language	EN
Cycle	WiSe
Content	• Flow measurement techniques (Particle Image Velocimetry, Particle Tracking Velocimetry,...) • Concentration measurement techniques (Laser Induced Fluorescence, UV/VIS Imaging, ...) • Measurement of Particle Size Distribution (Bubbles, Droplets, Particles) • Measurement techniques for Microflows • Measurement techniques for Multiphase flows in industrial application
Literature	Raffel, M.; Willert, C.E.; Wereley, S.T.; Kompenhans, J.: Particle Image Velocimetry, Springer Berlin, Heidelberg (2007), ISBN 978-3-642-43166-1, DOI: https://doi.org/10.1007/978-3-540-72308-0. Schlüter, M. (2011). Lokale Messverfahren für Mehrphasenströmungen. Chemie Ingenieur Technik. 83. (7), 1084-1095. https://doi.org/10.1002/cite.201100039

Course L2925: Non invasive measurement techniques for Multiphase Flows	
Typ	Practical Course
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Felix Kexel
Language	EN
Cycle	WiSe
Content	Exemplary measurements in the laboratory of the Institute of Multiphase Flows: • Flow measurements(Particle Image Velocimetry, Particle Tracking Velocimetry,...) • Concentration measurements (Laser Induced Fluorescence, UV/VIS Imaging, ...) • Particle Size Distribution measurements (Bubbles, Droplets, Particles) • Measurements in microflows
Literature	Raffel, M.; Willert, C.E.; Wereley, S.T.; Kompenhans, J.: Particle Image Velocimetry, Springer Berlin, Heidelberg (2007), ISBN 978-3-642-43166-1, DOI: https://doi.org/10.1007/978-3-540-72308-0. Schlüter, M. (2011). Lokale Messverfahren für Mehrphasenströmungen. Chemie Ingenieur Technik. 83. (7), 1084-1095. https://doi.org/10.1002/cite.201100039

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. Simon Müller
Admission Requirements	None
Recommended Previous Knowledge	Thermodynamics III
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are capable to formulate thermodynamic problems and to specify possible solutions. Furthermore, they can describe the current state of research in thermodynamic property predictions.
Skills	The students are capable to apply modern thermodynamic calculation methods to multi-component mixtures and relevant biological systems. They can calculate phase equilibria and partition coefficients by applying equations of state, gE models, and COSMO-RS methods. They can provide a comparison and a critical assessment of these methods with regard to their industrial relevance. The students are capable to use the software COSMOtherm and relevant property tools of ASPEN and to write short programs for the specific calculation of different thermodynamic properties. They can judge and evaluate the results from thermodynamic calculations/predictions for industrial processes.
Personal Competence	
Social Competence	Students are capable to develop and discuss solutions in small groups; further they can translate these solutions into calculation algorithms.
Autonomy	Students can rank the field of “Applied Thermodynamics” within the scientific and social context. They are capable to define research projects within the field of thermodynamic data calculation.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** None; **Form** Written elaboration; **Description**
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective 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	Prof. Ralf Dohrn
Language	EN
Cycle	WiSe
Content	• Phase equilibria in multicomponent systems • Partioning 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 Potenitials • 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. Simon Müller
Language	EN
Cycle	WiSe
Content	exercises in computer pool, see lecture description for more details
Literature	-

Module M1354: Advanced Fuels

Courses

Title	Typ	Hrs/wk	CP
Second generation biofuels and electricity based fuels (L2414)	Lecture	2	2
Carbon dioxide as an economic determinant in the mobility sector (L1926)	Lecture	1	1
Mobility and climate protection (L2416)	Recitation Section (small)	2	2
Sustainability aspects and regulatory framework (L2415)	Lecture	1	1

Module Responsible	Dr. Marvin Scherzinger
Admission Requirements	None
Recommended Previous Knowledge	Bachelor degree in Process Engineering, Bioprocess Engineering or Energy- and Environmental Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Within the module, students learn about different provision pathways for the production of advanced fuels (biofuels like e.g. alcohol-to-jet; electricity-based fuels like e.g. power-to-liquid). The different processes chains are explained and the regulatory framework for sustainable fuel production is examined. This includes, for example, the requirements of the Renewable Energies Directive II and the conditions and aspects for a market ramp-up of these fuels. For the holistic assessment of the various fuel options, they are also examined under environmental and economic factors.
Skills	After successfully participating, the students are able to solve simulation and application tasks of renewable energy technology: • Module-spanning solutions for the design and presentation of fuel production processes resp. the fuel provision chains • Comprehensive analysis of various fuel production options in technical, ecological and economic terms Through active discussions of the various topics within the lectures and exercises of the module, the students improve their understanding and application of the theoretical foundations and are thus able to transfer the learned to the practice.
Personal Competence	
Social Competence	The students can discuss scientific tasks in a subject-specific and interdisciplinary way and develop joint solutions.
Autonomy	The students are able to access independent sources about the questions to be addressed and to acquire the necessary knowledge. They are able to assess their respective learning situation concretely in consultation with their supervisor and to define further questions and solutions.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** Yes · **Bonus** 20 % · **Form** Written elaboration · **Description** Details werden in der ersten Veranstaltung bekannt gegeben.
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 Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Environmental Engineering: Specialisation Energy and Resources: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory

Course L2414: Second generation biofuels and electricity based fuels	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Marvin Scherzinger
Language	DE/EN
Cycle	WiSe
Content	• General overview of various power-based fuels and their process paths, including power-to-liquid process (Fischer-Tropsch synthesis, methanol synthesis), power-to-gas (Sabatier process) • Origin, production and use of these fuels
Literature	• Vorlesungsskript

Course L1926: Carbon dioxide as an economic determinant in the mobility sector	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Karsten Wilbrand
Language	DE/EN
Cycle	WiSe
Content	• General overview of various advanced biofuels and their process pathways (including gas-to-liquid, HEFA and Alcohol-to-Jet processes) • Origin, production and use of these fuels
Literature	• Babu, V.: Biofuels Production. Beverly, Mass: Scrivener [u.a.], 2013 • Olsson, L.: Biofuels. Berlin, Heidelberg: Springer-Verlag Berlin Heidelberg, 2007 • William, L. L.: Distillation Design and Control Using Aspen Simulation; ISBN-10: 0-471-77888-5 • Perry, R.; Green, R.: Perry's Chemical Engineers' Handbook, 8th Edition, McGraw Hill Professional, 20 • Sinnot, R. K.: Chemical Engineering Design, Elsevier, 2014 • Kaltschmitt, M.; Neuling, U. (Ed.): Biokerosene - Status and Prospects; Springer, Berlin, Heidelberg, 2018

Course L2416: Mobility and climate protection	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Benedikt Buchspies, Dr. Karsten Wilbrand
Language	DE/EN
Cycle	WiSe
Content	Application of the acquired theoretical knowledge from the respective lectures on the basis of concrete tasks from practice • Design and simulation of sub-processes of production processes in Aspen Plus ® • Ecological and economic analysis of fuel supply paths • Classification of case studies into applicable regulations
Literature	• Skriptum zur Vorlesung • Aspen Plus® - Aspen Plus User Guide

Course L2415: Sustainability aspects and regulatory framework	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Benedikt Buchspies
Language	DE/EN
Cycle	WiSe
Content	Holistic examination of the different fuel paths with the following main topics, among others: • Consideration of the environmental impact of the various alternative fuels • Economic consideration of the different alternative fuels • Regulatory framework for alternative fuels • Certification of alternative fuels • Market introduction models of alternative fuels
Literature	• European Commission - Joint Research Center (2010): International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance. Joint Research Center (JRC) Institut for Environment and Sustainability, Luxembourg • Richtlinie (EU) 2018/2001 des Europäischen Parlaments und des Rates vom 11. Dezember 2018 zur Förderung der Nutzung von Energie aus erneuerbaren Quellen

Module M2006: Waste Treatment and Recycling

Courses

Title	Typ	Hrs/wk	CP
Planning of waste treatment plants (L3267)	Project-/problem-based Learning	3	3
Recycling technologies and thermal waste treatment (L3265)	Lecture	2	2
Recycling technologies and thermal waste treatment (L3266)	Recitation Section (small)	1	1

Module Responsible	Prof. Kerstin Kuchta
Admission Requirements	None
Recommended Previous Knowledge	• Basics of thermo dynamics • Basics of fluid dynamics • fluid dynamics chemistry
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can name, describe current issue and problems in the field of waste treatment (mechanical, chemical and thermal) and contemplate them in the context of their field. The industrial application of unit operations as part of process engineering is explained by actual examples of waste technologies . Compostion, particle sizes, transportation and dosing of wastes are described as important unit operations . Students will be able to design and design waste treatment technology equipment.
Skills	The students are able to select suitable processes for the treatment of wastes or raw material with respect to their characteristics and the process aims. They can evaluate the efforts and costs for processes and select economically feasible treatment concepts.
Personal Competence	
Social Competence	Students can • 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.
Autonomy	Students can independently tap knowledge of the subject area and transform it to new questions. They are capable, in consultation with supervisors, to assess their learning level and define further steps on this basis. Furthermore, they can define targets for new application-or research-oriented duties in accordance with the potential social, economic and cultural impact.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Energy Systems: Specialisation Green Energy Technologies: Elective Compulsory Environmental Engineering: Specialisation Energy and Resources: 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 L3267: Planning of waste treatment plants	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Rüdiger Siechau
Language	EN
Cycle	WiSe
Content	The focus is on getting to know the organization and practice of waste management companies. Topics such as planning, financing and logistics will be discussed and there will be an excursion (waste incineration plant, vehicle fleet and collection systems / containers). Project based learning: You will be given a task to work on independently in groups of 4 to 6 students. All tools and data needed for the project work will be discussed in the lecture "Recycling Technologies and Thermal Waste Treatment". Course documents can be downloaded from StudIP. Communication during the project work also takes place via StudIP.
Literature	• Einführung in die Abfallwirtschaft; Martin Kranert, Klaus Cord-Landwehr (Hrsg.); Vieweg + Teubner Verlag; 2010 • PowerPoint Präsentationen in Stud IP

Course L3265: Recycling technologies and thermal waste treatment	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	WiSe
Content	• 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 L3266: Recycling technologies and thermal waste treatment	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1294: Bioenergy

Courses

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

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

Course L0061: Biofuels Process Technology	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Oliver Lüdtke
Language	DE
Cycle	WiSe

Content	• General introduction
	• What are biofuels?
	• Markets & trends
	• Legal framework
	• Greenhouse gas savings
	• Generations of biofuels
	  ◦ first-generation bioethanol
	    ▪ raw materials
	    ▪ fermentation distillation
	  ◦ biobutanol / ETBE
	  ◦ second-generation bioethanol
	    ▪ bioethanol from straw
	  ◦ first-generation biodiesel
	    ▪ raw materials
	    ▪ Production Process
	    ▪ Biodiesel & Natural Resources
	  ◦ HVO / HEFA
	  ◦ second-generation biodiesel
	    ▪ Biodiesel from Algae
	• Biogas as fuel
	  ◦ the first biogas generation
	    ▪ raw materials
	    ▪ fermentation
	    ▪ purification to biomethane
	  ◦ Biogas second generation and gasification processes
	• Methanol / DME from wood and Tall oil ©

Literature	• 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	Prof. Oliver Lüdtke
Language	DE
Cycle	WiSe

Content	• Life Cycle Assessment
	  ◦ Good example for the evaluation of CO2 savings potential by alternative fuels - Choice of system boundaries and databases
	• Bioethanol production
	  ◦ 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
	  ◦ Procedural options for solid / liquid separation, including basic equations for estimating power, energy demand, selectivity and throughput
	• Biomethane production
	  ◦ Chemical reactions that are relevant in the production of biofuels, including equilibria, activation energies, shift reactions

Literature	Skriptum zur Vorlesung

Course L1769: World Market for Commodities from Agriculture and Forestry	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Michael Köhl, Bernhard Chilla
Language	DE
Cycle	WiSe
Content	1) Markets for Agricultural Commodities 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. 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. 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.
Literature	Lecture material

Course L1767: Thermal Biomass Utilization	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Marvin Scherzinger
Language	DE
Cycle	WiSe

Content	Goal of this course is it to discuss the physical, chemical, and biological as well as the technical, economic, and environmental basics of all options to provide energy from biomass from a German and international point of view. Additionally different system approaches to use biomass for energy, aspects to integrate bioenergy within the energy system, technical and economic development potentials, and the current and expected future use within the energy system are presented.
	
	The course is structured as follows:
	
	• 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
	  ◦ 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
	  ◦ 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 L2386: Thermal Biomass Utilization	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Marvin Scherzinger
Language	DE
Cycle	WiSe
Content	The experiments of the practical lab course illustrate the different aspects of heat generation from biogenic solid fuels. First, different biomasses (e.g. wood, straw or agricultural residues) will be investigated; the focus will be on the calorific value of the biomass. Furthermore, the used biomass will be pelletized, the pellet properties analysed and a combustion test carried out on a pellet combustion system. The gaseous and solid pollutant emissions, especially the particulate matter emissions, are measured and the composition of the particulate matter is investigated in a further experiment. Another focus of the practical course is the consideration of options for the reduction of particulate matter emissions from biomass combustion. In the practical course, a method for particulate matter reduction will be developed and tested. All experiments will be evaluated and the results presented. Within the practical lab course the students discuss different technical-scientific tasks, both subject-specifically and interdisciplinary. They discuss various approaches to solving the problem and advise on the theoretical or practical implementation.
Literature	- Kaltschmitt, Martin; Hartmann, Hans; Hofbauer, Hermann: Energie aus Biomasse: Grundlagen, Techniken und Verfahren. 3. Auflage. Berlin Heidelberg: Springer Science & Business Media, 2016. -ISBN 978-3-662-47437-2 - Versuchsskript

Module M2050: Cellular and Molecular Biotechnology

Courses

Title	Typ	Hrs/wk	CP
Applications of whole cell biocatalysts in biotechnology (L3301)	Seminar	1	1
Advanced microbial genetics (L3302)	Lecture	1	1
Challenges for genetic engineering in biotechnology (L3303)	Seminar	1	1
Microbial Diversity in Applications (L3300)	Lecture	1	1
Parctical course: Cellular and molecular biotechnology (L3304)	Practical Course	2	2

Module Responsible	Prof. Johannes Gescher
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in microbiology, molecular biology, and biochemistry. Familiarity with molecular biology methods such as PCR, cloning, and DNA sequencing is required.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students understand the molecular and cellular basis of biotechnological processes. They know modern genetic engineering methods and their application in industrial biotechnology. They can evaluate microbial diversity in the context of biotechnological applications.
Skills	Students can independently plan and conduct molecular biology and microbiology experiments. They master techniques for genetic manipulation of microorganisms and optimization of whole-cell biocatalysts. They can critically analyze and interpret experimental data.
Personal Competence	
Social Competence	Students can work effectively in multidisciplinary teams and present scientific results. They are able to conduct professional discussions and give and receive constructive feedback.
Autonomy	Students can independently research and evaluate scientific literature. They are able to develop research questions and plan experiments independently. They can efficiently organize their time and resources in the laboratory.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** Yes · **Bonus** None · **Form** Presentation · **Description** Vortrag
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess 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 L3301: Applications of whole cell biocatalysts in biotechnology

Typ	Seminar
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Johannes Gescher
Language	EN
Cycle	WiSe
Content	
Literature	

Course L3302: Advanced microbial genetics

Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Johannes Gescher
Language	EN
Cycle	WiSe
Content	
Literature	

Course L3303: Challenges for genetic engineering in biotechnology	
Typ	Seminar
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Johannes Gescher
Language	EN
Cycle	WiSe
Content	
Literature	

Course L3300: Microbial Diversity in Applications	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Johannes Gescher
Language	EN
Cycle	WiSe
Content	
Literature	

Course L3304: Parctical course: Cellular and molecular biotechnology	
Typ	Practical Course
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Johannes Gescher
Language	EN
Cycle	WiSe
Content	
Literature	

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	Dr. Pavel Gurikov
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	
Knowledge	On completion of the module, students are able to present an overview of the basic thermal process technology operations that are used, in particular, in the separation and purification of biochemically manufactured products. Students can describe chromatographic separation techniques and classic and new basic operations in thermal process technology and their areas of use. In their choice of separation operation students are able to take the specific properties and limitations of biomolecules into consideration. Using different phase diagrams they can explain the principle behind the basic operation and its suitability for bioseparation problems.
Skills	On completion of the module, students are able to assess the separation processes for bio- and pharmaceutical products that have been dealt with for their suitability for a specific separation problem. They can use simulation software to establish the productivity and economic efficiency of bioseparation processes. In small groups they are able to jointly design a downstream process and to present their findings in plenary and summarize them in a joint report.
Personal Competence	
Social Competence	Students are able in small heterogeneous groups to jointly devise a solution to a technical problem by using project management methods such as keeping minutes and sharing tasks and information.
Autonomy	Students are able to prepare for a group assignment by working their way into a given problem on their own. They can procure the necessary information from suitable literature sources and assess its quality themselves. They are also capable of independently preparing the information gained in a way that all participants can understand (by means of reports, minutes, and presentations).
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** / **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: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective 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. Daniel Ohde, Dr. Paul Bubenheim
Language	EN
Cycle	WiSe
Content	• 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	• 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	Dr. Pavel Gurikov
Language	EN
Cycle	WiSe
Content	Contents: • 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 Learning Outcomes: • 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	"Handbook of Bioseparations", Ed. S. Ahuja http://www.elsevier.com/books/handbook-of-bioseparations-2/ahuja/978-0-12-045540-9 "Bioseparations Engineering" M. R. Ladish http://eu.wiley.com/WileyCDA/WileyTitle/productCd-0471244767.html

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

Module M0973: Biocatalysis

Courses

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

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

Course L1158: Biocatalysis and Enzyme Technology

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Andreas Liese
Language	EN
Cycle	WiSe
Content	1. Introduction: Impact and potential of enzyme-catalysed processes in biotechnology. 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	• 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, Woley-VCH, 2003

Course L1157: Technical Biocatalysis	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Andreas Liese
Language	EN
Cycle	WiSe
Content	1. Introduction 2. Production and Down Stream Processing of Biocatalysts 3. Analytics (offline/online) 4. Reaction Engineering & Process Control • Definitions • Reactors • Membrane Processes • Immobilization 5. Process Optimization • Simplex / DOE / GA 6. Examples of Industrial Processes • food / feed • fine chemicals 7. Non-Aqueous Solvents as Reaction Media • ionic liquids • scCO2 • solvent free
Literature	• 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, Woley-VCH, 2003

Module M2003: Biological Waste Treatment

Courses

Title	Typ	Hrs/wk	CP
Waste and Environmental Chemistry (L0328)	Practical Course	2	2
Biological Waste Treatment (L0318)	Project-/problem-based Learning	3	4

Module Responsible	Prof. Kerstin Kuchta
Admission Requirements	None
Recommended Previous Knowledge	chemical and biological basics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The module aims possess knowledge concerning the planning of biological waste treatment plants. Students are able to explain the design and layout of anaerobic and aerobic waste treatment plants in detail, describe different techniques for waste gas treatment plants for biological waste treatment plants and explain different methods for waste analytics.
Skills	The students are able to discuss the compilation of design and layout of plants. They can critically evaluate techniques and quality control measurements. The students can recherché and evaluate literature and date connected to the tasks given in der module and plan additional tests. They are capable of reflecting and evaluating findings in the group.
Personal Competence	
Social Competence	Students can participate in subject-specific and interdisciplinary discussions, develop cooperated solutions and defend their own work results in front of others and promote the scientific development in front of colleagues. Furthermore, they can give and accept professional constructive criticism.
Autonomy	Students can independently tap knowledge from literature, business or test reports and transform it to the course projects. They are capable, in consultation with supervisors as well as in the interim presentation, to assess their learning level and define further steps on this basis. Furthermore, they can define targets for new application-or research-oriented duties in accordance with the potential social, economic and cultural impact.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** None; **Form** Subject theoretical and practical work; **Description**
Examination	Presentation
Examination duration and scale	Elaboration and Presentation (15-25 minutes in groups)
Assignment for the Following Curricula	Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Environmental Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory

Course L0328: Waste and Environmental Chemistry	
Typ	Practical Course
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	WiSe
Content	The participants are divided into groups. Each group prepares a transcript on the experiment performed, which is then used as basis for discussing the results and to evaluate the performance of the group and the individual student. In some experiments the test procedure and the results are presented in seminar form, accompanied by discussion and results evaluation. Experiments ar e.g. Screening and particle size determination Fos/Tac AAS Chalorific value
Literature	Scripte

Course L0318: Biological Waste Treatment	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	WiSe
Content	1. Introduction 2. biological basics 3. determination process specific material characterization 4. aerobic degradation (Composting, stabilization) 5. anaerobic degradation (Biogas production, fermentation) 6. Technical layout and process design 7. Flue gas treatment 8. Plant design practical phase
Literature	

Module M0636: Cell and Tissue Engineering

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

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

Course L0355: Fundamentals of Cell and Tissue Engineering	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Anna-Lena Heins, Dr. Lukas Arndt, Dr. Neele Meyer-Heydecke
Language	EN
Cycle	WiSe
Content	Overview of cell culture technology and tissue engineering (cell culture product manufacturing, complexity of protein therapeutics, examples of tissue engineering) (Pörtner, Zeng) Fundamentals of cell biology for process engineering (cells: source, composition and structure. interactions with environment, growth and death - cell cycle, protein glycolysation) (Pörtner) Cell physiology for process engineering (Overview of central metabolism, genomics etc.) (Zeng) Medium design (impact of media on the overall cell culture process, basic components of culture medium, serum and protein-free media) (Pörtner) Stochiometry and kinetics of cell growth and product formation (growth of mammalian cells, quantitative description of cell growth & product formation, kinetics of growth)
Literature	Butler, M (2004) Animal Cell Culture Technology - The basics, 2nd ed. Oxford University Press 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. Anna-Lena Heins, Dr. Lukas Arndt, Dr. Neele Meyer-Heydecke
Language	EN
Cycle	WiSe
Content	Requirements for cell culture processess, shear effects, microcarrier technology Reactor systems for mammalian cell culture (production systems) (design, layout, scale-up: suspension reactors (stirrer, aeration, cell retention), fixed bed, fluidized bed (carrier), hollow fiber reactors (membranes), dialysis reactors, Reactor systems for Tissue Engineering, Prozess strategies (batch, fed-batch, continuous, perfusion, mathematical modelling), control (oxygen, substrate etc.) • Downstream
Literature	Butler, M (2004) Animal Cell Culture Technology - The basics, 2nd ed. Oxford University Press 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 M2084: Scaling of Bioprocesses

Courses

Title	Typ	Hrs/wk	CP
Practical Scaling of Bioprocesses (L3357)	Practical Course	2	2
Scaling of Bioprocesses (L3355)	Lecture	2	2
Scaling of Bioprocesses (Exercise) (L3356)	Recitation Section (small)	2	2

Module Responsible	Prof. Anna-Lena Heins
Admission Requirements	None
Recommended Previous Knowledge	• Content of the module “Biological and biochemical basics" • Content of the module “Bioprocess Engineering I” • Content of the module “Bioprocess Engineering II” • Content of the module “Bioprocess and Biosystems Engineering”
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After completing the module, participants will be able to • Describe and evaluate microfluidic cultivations and the phenomena to be investigated therein • Define ideally mixed bioprocesses on a laboratory scale as a reference stat • Describe and design different multi-compartment bioreactors (advantages and disadvantages of each setup, process examples and characterization of the setups • Name phenomena at pilot scale and industrial scale (examples of unsuccessful and successful scaling, Gradients of process parameters and mixing insufficiencies that are relevant in industrial scale bioreactors, how to scale today and in the future) in comparison to laboratory scal • Define and objectively quantify phenotypic population heterogeneity • Describe modeling techniques to describe mixing insufficiencies and cell responses
Skills	After completing the module, participants will be able to • describe scaling concepts for bioreactors from laboratory scale to industrial scale and select a suitable strategy for a given proces • plan and calculate a bioreactor system including peripherals from laboratory to pilot plant scale • transfer an existing industrial bioprocess to a multi-compartment bioreactor, taking into account the characteristics for detailed investigation of cell physiology • combine the analytical methods covered to investigate heterogeneities and mixed insufficiencies, apply them to specific problems and critically evaluate the results obtained • break down a complex overall problem into sub-problems, paying particular attention to the interface proble • subject the process chain of scaling from bioprocess development to industrial production to a critical overall assessment
Personal Competence	
Social Competence	After completion of this module, participants will be able to debate technical questions in small interdisciplinary teams to enhance the ability to take position to their own opinions and increase their capacity for teamwork. The students can reflect their specific knowledge orally and discuss it with other students and teachers.
Autonomy	After completion of this module, participants will be able to solve a technical problem in teams of approx. up to 5 persons independently including a presentation of the results.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory**: Yes; **Bonus**: None; **Form**: Written elaboration; **Description**: Protokoll
Examination	Written exam
Examination duration and scale	90 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 and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Energy Systems: Specialisation Green Energy Technologies: Elective Compulsory

Course L3357: Practical Scaling of Bioprocesses	
Typ	Practical Course
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Anna-Lena Heins
Language	EN
Cycle	SoSe
Content	The multi-compartment bioreactor concept designed in the exercise is to be implemented in practice in the laboratory in small groups. Subsequently, an experiment on the physiological characterization of cells in the bioreactor system will be carried out. The results of the various experiments will be presented to the other groups in a final “student conference” and discussed in the plenum
Literature	Aktuelle publizierte Literatur zu den Vorlesungsinhalten

Course L3355: Scaling of Bioprocesses	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Anna-Lena Heins
Language	EN
Cycle	WiSe
Content	• Microfluidic cultivations and the phenomena investigated therein • Ideally mixed bioprocesses on a laboratory scale • Different multi-compartment bioreactors (advantages and disadvantages of each setup, bioprocess examples and characterization of the setups) • Pilot scale and industrial scale phenomena (examples of unsuccessful and successful scaling, gradients and mixing insufficiencies relevant in industrial bioreactors, how to scale today and in the future) compared to laboratory scal • Phenotypic population heterogeneity and objective quantificatio • Modeling techniques to describe mixing insufficiencies and cell responses in bioreactors at different scales
Literature	Aktuelle Publikationen zu den Vorlesungsinhalten Current published studies on the lecture contents

Course L3356: Scaling of Bioprocesses (Exercise)	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Anna-Lena Heins
Language	EN
Cycle	WiSe
Content	In-depth exercises (using relevant software tools) on the contents of the reated lecture and application to bioprocess examples Design of a multi-compartment bioreactor for specific bioprocess examples in small groups
Literature	Aktuelle publizierte Literature zu den Übungsthemen

Module M1017: Food Technology

Courses

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

Module Responsible	Prof. Stefan Heinrich
Admission Requirements	None
Recommended Previous Knowledge	• Basic knowledge of partice technology • Separation Technique; Heat and Mass Transfer I
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After successful completion of the module students are able to • discuss the material properties of food • explain basic of production processes in food engineering • describe some selected processes
Skills	Students are able to • choose and design process chains for the processing of food • asses the effect of the single process steps on the material properties of food
Personal Competence	
Social Competence	Students are enabled to discuss knowledge in a scientific environment.
Autonomy	Students are able to acquire scientific knowledge independently and knowledge in a scientific manner.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory**: Yes; **Bonus**: None; **Form**: Written elaboration; **Description**: 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 Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and 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	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. Andreas Liese
Language	DE/EN
Cycle	WiSe
Content	In the frame of the course the basics of fermentation, fluid processing and process engineering will be repeated. 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. The students will perform all unit operations in pilot scale. The objective is that student experience and adopt a holistic view of food manufacturing.
Literature	Ludwig Narziss: Abriss der Bierbrauerei, 7. Auflage, Wiley VCH

Module M1955: Process Intensification in Process Engineering

Courses

Title	Typ	Hrs/wk	CP
Process Intensification in Process Engineering (L1978)	Lecture	2	2
Process Intensification in Process Engineering (L1715)	Project-/problem-based Learning	3	4

Module Responsible	Prof. Mirko Skiborowski
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of process engineering, in particular reaction engineering, separation technology, process design, process modelling and control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to recognise potential for intensified processes and to name the type of intensification.
Skills	Students are able to design a conceptual design for various intensified processes and evaluate different options against each other.
Personal Competence	
Social Competence	Students are able to apply the principles of project management for small groups.
Autonomy	Students are able to acquire and discuss specialized knowledge about intensified processes.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	Project report incl. PM-documents and written Exam (45 minutes)
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 and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory

Course L1978: Process Intensification 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, Prof. Mirko Skiborowski
Language	EN
Cycle	WiSe
Content	Introduction to integrated and hybrid processes in chemical and biotechnological process engineering; advantages and disadvantages, process windows, differentiation criteria; Process synthesis and process modeling Process examples from industry and research: reactive distillation, dividing wall columns, reactive dividing wall columns, SHOP and MerOX, centrifuges, membrane-supported processes
Literature	- 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 L1715: Process Intensification in Process Engineering	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Dr. Thomas Waluga, Prof. Mirko Skiborowski
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M2004: Sustainable Circular Economy

Courses

Title	Typ	Hrs/wk	CP
Circular Economy (L3264)	Seminar	2	3
Environment and Sustainability (L0319)	Lecture	2	3

Module Responsible	Prof. Kerstin Kuchta
Admission Requirements	None
Recommended Previous Knowledge	none
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe single techniques and to give an overview for the field of safety and risk assessment, Circular Economy as well as environmental and sustainable engineering, in detail: • basics in safety and reliability of technical facilities • risk assessment and reliability analysis methods • Circularity of material • Identification and evaluation of material flows • energy production and supply • sustainable product design
Skills	Students are able apply interdisciplinary system-oriented methods for Circularity and risk assessment as well as sustainability reporting. They can evaluate the effort and costs for processes and select economically feasible treatment concepts.
Personal Competence	
Social Competence	
Autonomy	Students can gain knowledge of the subject area from given sources and transform it to new questions. Furthermore, they can define targets for new application or research-oriented duties in for risk management and sustainability concepts accordance with the potential social, economic and cultural impact.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Elaboration and presentation (45 minutes in groups)
Assignment for the Following Curricula	Civil Engineering: Core Qualification: Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Management and Controlling: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Environmental Engineering: Specialisation Energy and Resources: Elective Compulsory Mechanical Engineering - Product Development and Production: Specialisation Product Development: Elective Compulsory Mechanical Engineering - Product Development and Production: Specialisation Production: Elective Compulsory Mechanical Engineering - Product Development and Production: Specialisation Materials: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Water and Environmental Engineering: Core Qualification: Compulsory

Course L3264: Circular Economy

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Marco Ritzkowski
Language	EN
Cycle	WiSe
Content	The seminar deals with the basic idea as well as with core elements, advantages and challenges of the circular economy using concrete examples. The transition from linear to circular material flows is illustrated using the aspects of product design, reuse, recycling, avoidance (resource conservation) and the sharing economy. The concepts and examples presented are discussed with the students, deepened in group work and then presented.
Literature	Suitable literature will be announced in the course.

Course L0319: Environment and Sustainability	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	WiSe
Content	This course presents actual methodologies and examples of environmental relevant, sustainable technologies, concepts and strategies in the field of energy supply, product design, water supply, waste water treatment or mobility. The following list shows examples: • Production and use of biochar • Energy production with algae • Environmentally friendly product design • Clean development mechanisms • Democracy and energy • Alternative mobility
Literature	Wird in der Veranstaltung bekannt gegeben.

Module M2048: Technical Complementary Course for Chemical and Bioprocess Engineering (according to Subject Specific Regulations)

Courses			
Title	**Typ**	**Hrs/wk**	**CP**

Module Responsible	Prof. Alexander Penn
Admission Requirements	None
Recommended Previous Knowledge	See selected module according to Subject Specific Regulations
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	See selected module according to Subject Specific Regulations
Skills	See selected module according to Subject Specific Regulations
Personal Competence	
Social Competence	See selected module according to Subject Specific Regulations
Autonomy	See selected module according to Subject Specific Regulations
Workload in Hours	Depends on choice of courses
Credit points	6
Assignment for the Following Curricula	Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory

Module M0900: Examples in Solid Process Engineering

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Fluidization Technology (L0431)	Lecture	2	2
Practical Course Fluidization Technology and Drying Technology (L1369)	Practical Course	1	1
Drying Technology (L3366)	Lecture	2	2
Exercises in Fluidization Technology and Drying Technology (L1372)	Recitation Section (small)	1	1

Module Responsible	Prof. Stefan Heinrich
Admission Requirements	None
Recommended Previous Knowledge	Knowledge from the module particle technology
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After completion of the module the students will be able to describe based on examples the assembly of solids engineering processes consisting of multiple apparatuses and subprocesses. They are able to describe the coaction and interrelation of subprocesses.
Skills	Students are able to analyze tasks in the field of solids process engineering and to combine suitable subprocesses in a process chain.
Personal Competence	
Social Competence	Students are able to discuss technical problems in a scientific manner.
Autonomy	Students are able to acquire scientific knowledge independently and discuss technical problems in a scientific manner.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory**: Yes; **Bonus**: None; **Form**: Written elaboration; **Description**: 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 Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Energy Systems: Specialisation Green Energy Technologies: 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 and Drying 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: • Determination of the minimum fluidization velocity • Heat transfer in fluidized beds • Granulation • Spray drying • Freeze drying
Literature	Kunii, D.; Levenspiel, O.: Fluidization Engineering. Butterworth Heinemann, Boston, 1991.

Course L3366: Drying Technology	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Swantje Pietsch-Braune
Language	EN
Cycle	WiSe
Content	• Fundamental knowledge different drying technologies • Understand and calculate heat and mass transfer processes involved in the different drying technologies • Learn about most important types of dryers for industrial applications
Literature	• Mujumdar, A. S., & Tsotsas, E. (2007). Modern drying technology. Weinheim: Wiley-VCH. • Krischer, O., Kast, W., & Kröll, K. (1978). Die wissenschaftlichen Grundlagen der Trocknungstechnik (3., neubearb. Aufl.). Berlin [u.a.]: Springer.

Course L1372: Exercises in Fluidization Technology and Drying 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 lectures Fluidization Technology and Drying Technology
Literature	Kunii, D.; Levenspiel, O.: Fluidization Engineering. Butterworth Heinemann, Boston, 1991.

Module M1796: Magnetic Resonance in Engineering

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Fundamentals of Magnetic Resonance (L2968)	Lecture	3	3
Magnetic Resonance in Engineering (L2969)	Project-/problem-based Learning	3	3

Module Responsible	Dr. Stefan Benders
Admission Requirements	None
Recommended Previous Knowledge	No special previous knowledge is necessary.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	This module covers the fundamentals of nuclear magnetic resonance spectroscopy (NMR) and magnetic resonance imaging (MRI) and their applications in engineering disciplines. The module consists of a classical lecture complemented by a problem-based learning course that includes practical hands-on experience on magnetic resonance devices. The module will be held in English.
Skills	After the successful completion of the course the students shall: 1. Understand the physical principles and practical aspects of magnetic resonance in engineering. 2. Know how to safely operate NMR and MRI systems. 3. Know how to run standard experimental sequences and how to implement more advanced sequence protocols. 4. Have an overview of the current capabilities and limits of the MR technique
Personal Competence	
Social Competence	In the problem-based course Magnetic Resonance in Engineering, the students will obtain hands-on experience on how to operate NMR spectrometers and high-field and low-field MRI systems. The course will cover safety aspects, pulse sequence design, spectral image analysis, and image reconstruction. The students will work in small groups on practical tasks on different NMR and MRI systems located at the campus of TUHH.
Autonomy	Through the practical character of the PBL course, the student shall improve their communication skills.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	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 Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Materials Science and Engineering: Specialisation Engineering Materials: Elective Compulsory Materials Science and Engineering: Specialisation Nano and Hybrid Materials: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory

Course L2968: Fundamentals of Magnetic Resonance	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Dr. Stefan Benders
Language	EN
Cycle	WiSe
Content	This lecture covers the fundamentals magnetic resonance imaging (MRI) and magnetic resonance spectroscopy (NMR). It focuses on the following topics: 1. The fundamentals of magnetic resonance: magnetism, magnetic fields, radiofrequency, spin, relaxation 2. Hardware for magnetic resonance: magnets (high-field and low-field), radiofrequency coil design, magnetic field gradients 3. NMR-Spectroscopy: chemical shift, J-Coupling, 2D NMR, solid-state, MAS 4. Relaxometry: single-sided NMR, contrasts, 5. Magnetic resonance imaging (MRI): gradients, coils, k-space, imaging sequences, ultrafast Imaging, parallel imaging, velocimetry, CEST 6. Hyperpolarization techniques: DNP, p-H2, optical pumping with Xe 7. Applications of magnetic resonance in chemical engineering 8. Applications of magnetic resonance in material science and engineering 9. Applications of magnetic resonance in biomedical engineering
Literature	Stapf, S., & Han, S. (2006). NMR imaging in chemical engineering. Weinheim: Wiley-VCH. ISBN: 978-3-527-60719-8 Blümich B., (2003) NMR imaging of materials. Oxford University Press, Online- ISBN: 9780191709524 , doi: https://doi.org/10.1093/acprof:oso/9780198526766.001.0001 Brown R. W., Cheng Y. N., Haacke E. M., Thompson M. R., Venkatesan R., (2014) Magnetic Resonance Imaging: Physical Principles and Sequence Design, Second Edition, John Wiley & Sons, Inc., doi: 10.1002/9781118633953 Haber-Pohlmeier, Sabina, Bernhard Blumich, and Luisa Ciobanu, (2022) Magnetic Resonance Microscopy: Instrumentation and Applications in Engineering, Life Science, and Energy Research. John Wiley & Sons

Course L2969: Magnetic Resonance in Engineering	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Dr. Stefan Benders
Language	EN
Cycle	WiSe
Content	In this course, the theoretical basics of magnetic resonance spectroscopy and magnetic resonance tomography are supplemented with practical experiments on the respective devices. The practical handling and operation of the equipment will be learned.
Literature	Stapf, S., & Han, S. (2006). NMR imaging in chemical engineering. Weinheim: Wiley-VCH. ISBN: 978-3-527-60719-8 Blümich B., (2003) NMR imaging of materials. Oxford University Press, Online- ISBN: 9780191709524, doi: https://doi.org/10.1093/acprof:oso/9780198526766.001.0001 Brown R. W., Cheng Y. N., Haacke E. M., Thompson M. R., Venkatesan R., (2014) Magnetic Resonance Imaging: Physical Principles and Sequence Design, Second Edition, John Wiley & Sons, Inc., doi: 10.1002/9781118633953

Module M1970: Process Modelling and Control

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Process modeling and control (L3220)	Lecture	2	3
Process modeling and control (L3221)	Recitation Section (small)	3	3

Module Responsible	Prof. Mirko Skiborowski
Admission Requirements	None
Recommended Previous Knowledge	Engineering fundamentals Unit operations of mechanical and thermal process engineering as well as chemical reaction engineering Conceptual Process Design
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to - classify types of process models and model equations - explain numerical methods for simulation - explain the solution system for flow diagram simulation - classify control structures and present process control concepts for different apparatus and complex process engineering systems
Skills	Students are able to - formulate and implement process control objectives - design and evaluate control strategies and structures - analyze model structure and model parameters from the simulation of processes
Personal Competence	
Social Competence	Students are enabled to develop solutions together in groups
Autonomy	Students are enabled to acquire knowledge on the basis of further literature
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** No · **Bonus** 10 % · **Form** Midterm · **Description**
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Process Engineering: Core Qualification: Compulsory

Course L3220: Process modeling and control

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Mirko Skiborowski
Language	EN
Cycle	WiSe
Content	Process modeling: introduction, mathematical modeling, model building blocks, structured model development, analysis of model equations Process simulation: numeric, validation, flow sheet simulation, solution strategies Process control: process variables, control loops, model-based methods, plant-wide control
Literature	C. Eck, et al., Mathematische Modellierung, Springer, 2017 W. Luyben, Process Modeling, Simulation and Control for Chemical Engineers, 1990 H. Schuler, Prozesssimulation, VCH, 1995 H. Schuler, Prozessführung, Oldenburg, 1999

Course L3221: Process modeling and control	
Typ	Recitation Section (small)
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Mirko Skiborowski
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M2171: Sustainable Process Design Project

Courses

Title	Typ	Hrs/wk	CP
Sustainable Process Design Project (L1048)	Integrated Lecture	2	2
Sustainable Process Design Project (L1977)	Project-/problem-based Learning	3	4

Module Responsible	Prof. Mirko Skiborowski
Admission Requirements	None
Recommended Previous Knowledge	Process Design and Process Modelling thermal separation processes heat and mass transport processes Process simulation, in particular the use of flow chart simulators, is strongly recommended
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	students can: - 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
Skills	students are capable of: -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	
Social Competence	students are able to discuss and develop in groups the design of an industrial process
Autonomy	students are able to reflect the consequences of their professional activity
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	Written report, presentation and oral exam (30 min)
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 Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L1048: Sustainable Process Design Project	
Typ	Integrated Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Mirko Skiborowski, Dr. Thomas Waluga
Language	EN
Cycle	WiSe
Content	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
Literature	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

Course L1977: Sustainable Process Design Project	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Mirko Skiborowski, Dr. Thomas Waluga
Language	EN
Cycle	WiSe
Content	Creation of a flowsheet for an industrial process Calculation of the mass and energy balance Calculation of investment and manufacturing costs Possibilities of process intensification Comparison of conventional and intensified processes
Literature	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

Module M0519: Particle Technology and Solids Process Engineering

Courses

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

Module Responsible	Prof. Stefan Heinrich
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of solids processes and particle technology
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After completion of the module the students will be able to describe and explain processes for solids processing in detail based on microprocesses on the particle level.
Skills	Students are able to choose process steps and apparatuses for the focused treatment of solids depending on the specific characteristics. They furthermore are able to adapt these processes and to simulate them.
Personal Competence	
Social Competence	Students are able to present results from small teamwork projects in an oral presentation and to discuss their knowledge with scientific researchers.
Autonomy	Students are able to analyze and solve problems regarding solid particles independently or in small groups.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory**: Yes; **Bonus**: None; **Form**: Written elaboration; **Description**: 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 B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Materials Science and Engineering: 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/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0050: Advanced Particle Technology II

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Stefan Heinrich
Language	DE/EN
Cycle	WiSe
Content	• Exercise in form of "Project based Learning" • 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 methids, Descrete Particle Modeling • Treatment of simulation problems with distributed properties, solution of population balances
Literature	Schubert, H.; Heidenreich, E.; Liepe, F.; Neeße, T.: Mechanische Verfahrenstechnik. Deutscher Verlag für die Grundstoffindustrie, Leipzig, 1990. Stieß, M.: Mechanische Verfahrenstechnik I und II. Springer Verlag, Berlin, 1992.

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

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. Anna-Lena Heins
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	
Knowledge	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.
Skills	The students can perform practical tasks in a chemical / biotechnological laboratory. This especially includes the fermentation of filamentous fungi in submersed 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.
Personal Competence	
Social Competence	Sudents can reflect their specific knowledge orally and discuss this with other students and teachers.
Autonomy	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.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Written report
Assignment for the Following Curricula	Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective 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. Anna-Lena Heins, Prof. Andreas Liese
Language	EN
Cycle	WiSe
Content	This experimental course focuses on a complete process from starting material like glucose over several production steps to a valuable final product. 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 Penicillium chrysogenum 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 (Escherichia coli) 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. A colloquium is part of the course.
Literature	Liese A, Seelbach K, Wandrey C, Industrial Biotransformations, Wiley-VCH, 2006 Chmiel H, Einführung in die Bioverfahrenstechnik, Elsevier Spektrum Akademischer Verlag, 2006 Schügerl K, Bioreaktionstechnik: Bioprozesse mit Mikroorganismen und Zellen. Prozeßüberwachung, Birkhäuser, 1997

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	Prof. Johannes Gescher, Dr. Barbara Klippel
Language	EN
Cycle	WiSe
Content	Participation in actual projects: - From gene to product in heterologous hosts - Molecular biology - Enzyme assays - Taxonomy
Literature	-Molekulare Biotechnologie: Grundlagen und Anwendungen David Clark. -Watson Molekularbiologie 6., aktualisierte Auflage. James D. Watson, Tania A. Baker, Stephen P. Bell, Alexander Gann, Michael Levine, Richard Losick -Allgemeine Mikrobiologie. Georg Fuchs, Marc Bramkamp, Petra Dersch, Thomas Eitinger, Johann Heider -Course Script of the respective lecture and practical course script

Module M2049: Research project Chemical and Bioprocess Engineering

Courses

Title	Typ	Hrs/wk	CP
Research project Chemical and Bioprocess Engineering (L3299)	Project-/problem-based Learning	12	12

Module Responsible	Dozenten des SD V
Admission Requirements	None
Recommended Previous Knowledge	Advanced level of knowledge in the Master's degree programme in Chemical and Bioengineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are familiar with current research projects at the institutes in the specialisation. They can name the basic scientific methods used to work on them.
Skills	The students are able to carry out an independent sub-project in current research projects of the institutes in the specialisation. The students can reason their approach to solving a task, draw conclusions from the results obtained and, if necessary, find new working methods. Students are able to compare and evaluate alternative solution concepts with the chosen approach with regard to specified criteria. Students are able to scientifically document the findings of their work in a suitable form.
Personal Competence	
Social Competence	Students are able to discuss the progress of their work with employees of the supervising institutes and present their final results in a manner appropriate to the target audience.
Autonomy	Students are able to independently define meaningful tasks from current research projects, acquire the necessary knowledge and select suitable solution methods based on the competences acquired in their previous studies.
Workload in Hours	Independent Study Time 192, Study Time in Lecture 168
Credit points	12
Course achievement	None
Examination	Study work
Examination duration and scale	approx. 6-15 pages
Assignment for the Following Curricula	Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory

Course L3299: Research project Chemical and Bioprocess Engineering

Typ	Project-/problem-based Learning
Hrs/wk	12
CP	12
Workload in Hours	Independent Study Time 192, Study Time in Lecture 168
Lecturer	Dozenten des SD V
Language	DE/EN
Cycle	WiSe/SoSe
Content	In this research project, students are to be introduced to independent scientific work. Current research projects offered by the institutes of the Faculty of Process Engineering are provided and published on their websites.
Literature	Die Betreuungspersonen eines jeden Forschungsprojektes stellen die dazu gehörigen Fachliteratur zur Verfügung. Dies ist vor allem Primärliteratur (peer-reviewed journal publications) sowie Fachbücher im jeweiligen Forschungsgebiet.

Module M2175: Transport Processes

Courses

Title	Typ	Hrs/wk	CP
Multiphase Flows (L0104)	Lecture	2	2
Reactor design under consideration of local transport processes (L0105)	Project-/problem-based Learning	2	2
Heat & Mass Transfer in Process Engineering (L0103)	Lecture	2	2

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

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

Course L0105: Reactor design under consideration of local transport processes	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	WiSe
Content	In this Problem-Based Learning unit the students have to design a multiphase reactor for a fast chemical reaction concerning optimal hydrodynamic conditions of the multiphase flow. The four students in each team have to: • 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. This exposé will be used as basis for the discussion within the oral group examen of each team.
Literature	Bird, R.B.; Stewart, W.R.; Lightfoot, E.N.: Transport Phenomena, John Wiley & Sons Inc (2007), ISBN 978-0-470-11539-8. Brauer, H.; Mewes, D.: Stoffaustausch einschließlich chemischer Reaktion; Verlag Sauerländer, Aarau und Frankfurt am Main (1971), ISBN: 3794100085. Brauer, H.: Grundlagen der Einphasen- und Mehrphasenströmungen, Sauerländer, 1971, Clift, R.; Grace, J.R.; Weber, M.E.: Bubbles, Drops, and Particles, Verlag Academic Press, 1978, ISBN 012176950X, 9780121769505 Deckwer, W.-D.: Reaktionstechnik in Blasensäulen, Salle Verlag und Verlag Sauerländer, Aarau, Frankfurt am Main, Berlin, München, Salzburg (1985), DOI 10.1002/CITE.330590530 Deckwer, W.-D.: Bubble Column Reactors. Wiley, New York (1992), DOI 10.1002/AIC.690380821. Fan, L.; Tsuchiya, K.: Bubble wake dynamics in liquids and liquid-solid suspension. Butterworth-Heinemann, (1990), DOI 10.1016/c2009-0-24002-5. Kraume, M., Transportvorgänge in der Verfahrenstechnik, Springer Berlin, 2020, ISBN 978-3-662-60392-5. Lienhard, J. H. (2019). A Heat Transfer Textbook, Dover Publications. ISBN:9780486837352, 0486837351.

Course L0103: Heat & Mass Transfer in Process Engineering	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	WiSe
Content	• Introduction - Transport Processes in Chemical Engineering • 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	1. Baehr, Stephan: Heat and Mass Transfer, Wiley 2002. 2. Bird, Stewart, Lightfood: 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 M2170: SMART Reactors

Courses

Title	Typ	Hrs/wk	CP
Special Features of SMART Reactors (L3475)	Seminar	2	2
Introduction to SMART Reactors (L3473)	Seminar	2	2
Lattice Boltzmann Simulations for SMART Reactors (L3474)	Seminar	2	2

Module Responsible	Prof. Michael Schlüter
Admission Requirements	None
Recommended Previous Knowledge	lectures from the undergraduate studies, especially mathematics, chemistry, thermodynamics, fluid mechanics, heat- and mass transfer
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to experimentally analyse, model and simulate transport processes in SMART Reactors as well as identify and further develop components for SMART Reactors.
Skills	The students are able to to describe and optimize SMART Reactors.
Personal Competence	
Social Competence	The students are able to discuss in international teams in english and develop an approach under pressure of time.
Autonomy	Students are able to independently define tasks for working on the overall problem of “Components for SMART reactors”. Based on the knowledge provided in the lecture, students acquire the necessary knowledge themselves and decide which methods from the lecture are to be used for implementation. They can organise themselves in a team and assign priorities for subtasks.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	Poster presentation, 1 hour
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory

Course L3475: Special Features of SMART Reactors

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter, Weitere Mitarbeiter
Language	EN
Cycle	WiSe
Content	Reports from current research in the subprojects of the DFG research field
Literature	Publikationen aus dem SFB s. https://www.tuhh.de/sfb1615/publications

Course L3473: Introduction to SMART Reactors

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	WiSe
Content	Introduction, Influences on yield & selectivity of chemical & biochemical reactions, Demands of chemical & biochemical reactions on SMART reactors, Sensing components, Actuating components, Tailoring Multiscale Transport Processes, Modeling and Simulation of Processes in SMART Reactors, Manufacturing and integration of components, Innovative Reactor Concepts, SMART Reactors LabTour
Literature	Bird, Stewart, Lightfood, Transport Phenomena Wiley, 2002

Course L3474: Lattice Boltzmann Simulations for SMART Reactors	
Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Christian Weiland
Language	EN
Cycle	WiSe
Content	In this lecture, the fundamentals of the Lattice Boltzmann Method (LBM) will be presented. The students will learn the mechanisms of the LBM, how to set up and conduct a simulation, and how to interpret the results. A focus will lie on the simulation of multiphase flows. For this purpose, models describing both, the breakup and coalescence of bubbles will be examined.
Literature	The Lattice Boltzmann Method - Principles and Practice, Timm Krüger , Halim Kusumaatmaja , Alexandr Kuzmin , Orest Shardt , Goncalo Silva , Erlend Magnus Viggen, Springer, 2017 The Lattice Boltzmann Equation, Sauro Succi, Oxford University Press, 2018 A literature review of theoretical models for drop and bubble breakup in turbulent dispersions, Yixiang Liao, Dirk Lucas, Chemical Engineering Science, 64, 3389-4306, 2009 A literature review on mechanisms and models for the coalescence process of fluid particles, Yixiang Liao, Dirk Lucas, Chemical Engineering Science, 65, 2851-2864, 2010 Hinze, J.O. Fundamentals of the hydrodynamic mechanism of splitting in dispersion processes. AIChE Journal, 1(3):289-295, 1955. ISSN 0001-1541, 1547-5905

Module M2205: Fluid Dynamics to Face Climate Change

Courses

Title	Typ	Hrs/wk	CP
Fluid Dynamics to Face Climate Change (L3534)	Seminar	2	2
Fluid Mechanics to Face Climate Change I (L3535)	Lecture	2	2
Fluid Mechanics to Face Climate Change II (L3537)	Lecture	2	2

Module Responsible	Prof. Michael Schlüter
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics I-III • Fundamentals in Fluid Mechanics • Technical Thermodynamics I-II • Heat- and Mass Transfer
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can describe various applications of fluid mechanics in chemical and bioprocess engineering. They can assign the fundamentals of fluid mechanics to the various applications and adapt them for specific calculations. Students can assess which fluid mechanics problems can be calculated using analytical solutions and which alternative options are available (e.g. self-similarity using the example of free jets, empirical solutions using the example of the Forchheimer equation, numerical methods using the example of large eddy simulation).
Skills	Students are able to apply the fundamentals of fluid mechanics to processes in nature and technology. In particular, they can establish momentum and mass balances in order to optimise technical processes in terms of fluid dynamics. They can recognise the connections between fluid mechanics aspects in technical processes and climate change and develop possible solutions. They are able to translate a verbally described connection into abstract formalism.
Personal Competence	
Social Competence	The students are able to discuss a given problem in small groups and to develop an approach. They are able to solve a problem within a team, to prepare a poster with the results and to present the poster.
Autonomy	Students are able to define independently tasks for problems related to fluid mechanics. They are able to work out the knowledge that is necessary to solve the problem by themselves on the basis of the existing knowledge from the lecture.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	Preparation of a short report (at least 10 pages), Poster presentation (5 minutes), Discussion (10 minutes)
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bioprocess Engineering: Elective Compulsory Energy Systems: Core Qualification: 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 Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Core Qualification: Compulsory

Course L3534: Fluid Dynamics to Face Climate Change	
Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter, Dr. Robinson Peric
Language	EN
Cycle	WiSe
Content	Fluid Dynamics to Face Climate Change' is a seminar that revisits the basic principles of fluid mechanics and places them in the context of urgent climate-related challenges. It introduces potential flow theory and demonstrates its application to ocean wave energy systems. The course covers the fundamentals of turbulence and turbulence modelling using examples from sustainable industrial processes and flow phenomena in nature. Free convection is explained using basic principles and linked to technical and natural systems that are of immediate relevance to climate change. Other topics include the flow dynamics of wind and hydro turbines, refrigerants in heat pumps, pipelines for natural gas transport, and flows through porous media in technical applications and in nature, e.g. for carbon capture and storage (CCS). The lecture concludes with an introduction to computational fluid dynamics (CFD) as an important tool for the analysis and design of sustainable energy and climate technologies.
Literature	• Ward-Smith, J. (2012). Mechanics of Fluids (9th ed.). London: CRC Press/Taylor & Francis. • Darby, R., & Chhabra, R. P. (2016). Chemical Engineering Fluid Mechanics (3rd ed.). Boca Raton: CRC Press. • Ferziger, J. H., Perić, M., & Street, R. L. (2020). Computational Methods for Fluid Dynamics (4th ed.). Cham: Springer Nature Switzerland. • White, F. M., & Xue, H. (2021). Fluid Mechanics (9th ed.). McGraw-Hill Education. ISBN-13: 978-1260446555 • Herwig, H. (2016). Fluid Mechanics: Introduction to the Physics of Technical Flows. Berlin, Heidelberg: Springer. • Ward-Smith, J. (2012). Mechanics of Fluids (9th ed.). London: CRC Press/Taylor & Francis. • Computing the Climate: How We Know What We Know About Climate Change; Steve M. Easterbrook, Cambridge University Press (ISBN-978-1-107-58992-6 oder 978-1-107-13348-8).

Course L3535: Fluid Mechanics to Face Climate Change I	
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	• Application of fluid mechanics, potential theory and turbulence modelling to climate topics. • Flows in heat pumps, efficient industrial processes and carbon capture and storage (CCS). • Free convection and flows in porous media. • Introduction to CFD for the development of sustainable climate solutions.
Literature	• Ward-Smith, J. (2012). Mechanics of Fluids (9th ed.). London: CRC Press/Taylor & Francis. • Darby, R., & Chhabra, R. P. (2016). Chemical Engineering Fluid Mechanics (3rd ed.). Boca Raton: CRC Press. • Ferziger, J. H., Perić, M., & Street, R. L. (2020). Computational Methods for Fluid Dynamics (4th ed.). Cham: Springer Nature Switzerland. • White, F. M., & Xue, H. (2021). Fluid Mechanics (9th ed.). McGraw-Hill Education. ISBN-13: 978-1260446555 • Herwig, H. (2016). Fluid Mechanics: Introduction to the Physics of Technical Flows. Berlin, Heidelberg: Springer. • Ward-Smith, J. (2012). Mechanics of Fluids (9th ed.). London: CRC Press/Taylor & Francis. • Computing the Climate: How We Know What We Know About Climate Change; Steve M. Easterbrook, Cambridge University Press (ISBN-978-1-107-58992-6 oder 978-1-107-13348-8).

Course L3537: Fluid Mechanics to Face Climate Change II	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Moustafa Abdel-Maksoud, Dr. Robinson Peric
Language	EN
Cycle	WiSe
Content	
Literature	

Thesis

Module M1801: Master Thesis (Dual Study Program)

Courses	
Title	**Typ** **Hrs/wk** **CP**
Module Responsible	Professoren der TUHH
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... • ... use the specialised knowledge (facts, theories and methods) from their field of study and the acquired professional knowledge confidently to deal with technical and practical professional issues. • ... can explain the relevant approaches and terminologies in depth in one or more of their subject's specialist areas, describe current developments and take a critical stance. • ... formulate their own research assignment to tackle a professional problem and contextualise it within their subject area. They ascertain the current state of research and critically assess it.
Skills	Dual students ... • ... can select suitable methods for the respective subject-related professional problem, apply them and develop them further as required. • ... assess knowledge and methods acquired during their studies (including practical phases) and apply their expertise to complex and/or incompletely defined problems in a solution- and application-oriented manner. • ... acquire new academic knowledge in their subject area and critically evaluate it.
Personal Competence	
Social Competence	Dual students ... • ... can present a professional problem in the form of an academic question in a structured, comprehensible and factually correct manner, both in writing and orally, for a specialist audience and for professional stakeholders. • ... answer questions as part of a professional discussion in an expert, appropriate manner. They represent their own points of view and assessments convincingly.
Autonomy	Dual students ... • ... can structure their own project into work packages, work through them at an academic level and reflect on them with regard to feasible courses of action for professional practice. • ... work in-depth in a partially unknown area within the discipline and acquire the information required to do so. • ... apply the techniques of academic work comprehensively in their own research work when dealing with an operational problem and question.
Workload in Hours	Independent Study Time 900, Study Time in Lecture 0
Credit points	30
Course achievement	None
Examination	Thesis
Examination duration and scale	According to General Regulations
Assignment for the Following Curricula	Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computational Methods and Machine Learning in Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory Electrical Engineering and Information Technology: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Computer Science in Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory International Management and Engineering: Thesis: Compulsory Logistics, Infrastructure and Mobility: Thesis: Compulsory Aeronautics: Thesis: Compulsory Mechanical Engineering - Product Development and Production: Thesis: Compulsory Materials Science and Engineering: Thesis: Compulsory Mechanical Engineering and Management: Thesis: Compulsory Mechatronics: Thesis: Compulsory Biomedical Engineering: Thesis: Compulsory Microelectronics and Microsystems: Thesis: Compulsory Naval Architecture and Ocean Engineering: Thesis: Compulsory Product Development, Materials and Production: Thesis: Compulsory

	Renewable Energies: Thesis: Compulsory Naval Architecture and Ocean Engineering: Thesis: Compulsory Theoretical Mechanical Engineering: Thesis: Compulsory Process Engineering: Thesis: Compulsory Water and Environmental Engineering: Thesis: Compulsory