TUHH
Hamburg
University of
Technology

Module Manual

Master of Science (M.Sc.)

Process Engineering

Cohort: Winter Term 2024

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Program description

Content

Learning target

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

Graduates can:

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

Graduates can:

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

Graduates can:

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

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

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

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

Core Qualification

Module M0519: Particle Technology and Solid Matter Process Technology

Courses

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

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

Course L0051: Advanced Particle Technology II

Typ	Project-/problem-based Learning
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Stefan Heinrich
Language	DE/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 M0523: Business & Management

Module Responsible	Prof. Matthias Meyer
Admission Requirements	None
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
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 M0540: 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	None
Examination	Written exam
Examination duration and scale	15 min Presentation + 90 min multiple choice written examen
Assignment for the Following Curricula	Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory 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 M0542: Fluid Mechanics in Process Engineering

Courses

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

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

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

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

Module M1970: Process modeling 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: Core Qualification: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: 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	DE
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	

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	DE
Cycle	WiSe
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: Core Qualification: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: 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	DE
Cycle	SoSe
Content	1. Real reactors (residence time distribution E(t), F(t)-curve, measurement of E(t) or F(t), residence time distribution of ideal reactors, modeling of real reactors, segregated flow model, tanks in series model, dispersion model, compartment models) 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	DE
Cycle	SoSe
Content	1. Real reactors (residence time distribution E(t), F(t)-curve, measurement of E(t) or F(t), residence time distribution of ideal reactors, modeling of real reactors, segregated flow model, tanks in series model, dispersion model, compartment models) 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	DE/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 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: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: 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, Dr. Johannes Möller
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, Dr. Johannes Möller
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 M0904: Process Design Project

Courses

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

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

Course L1050: Process Design Project

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

Specialization Process Engineering

Module M0513: System Aspects of Renewable Energies

Courses

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

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

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

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

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

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

Module M0874: Wastewater Systems

Courses

Title	Typ	Hrs/wk	CP
Biological Wastewater Treatment (L0517)	Lecture	2	2
Biological Wastewater Treatment (L3122)	Recitation Section (large)	1	1
Advanced Wastewater Treatment (L0357)	Lecture	2	2
Advanced Wastewater Treatment (L0358)	Recitation Section (large)	1	1

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

Course L0517: Biological Wastewater Treatment

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Joachim Behrendt
Language	DE/EN
Cycle	SoSe
Content	Charaterisation of Wastewater Metobolism of Microorganisms Kinetic of mirobiotic processes Calculation of bioreactor for wastewater treatment Concepts of Wastewater treatment Design of WWTP Excursion to a WWTP Biofilms Biofim Reactors Anaerobic Wastewater and sldge treatment resources oriented sanitation technology Future challenges of wastewater treatment
Literature	**Gujer, Willi** Siedlungswasserwirtschaft : mit 84 Tabellen ISBN: 3540343296 (Gb.) URL: http://www.gbv.de/dms/bs/toc/516261924.pdf URL: http://deposit.d-nb.de/cgi-bin/dokserv?id=2842122&prov=M&dok_var=1&dok_ext=htm Berlin [u.a.] : Springer, 2007 TUB_HH_Katalog **Henze, Mogens**

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

Course L3122: Biological Wastewater Treatment	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Joachim Behrendt
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

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

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

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	
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 Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L1278: High pressure 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 M0875: Nexus Engineering - Water, Soil, Food and Energy

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

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

Course L1229: Ecological Town Design - Water, Energy, Soil and Food Nexus

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

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

Module M0714: Numerical Methods for Ordinary Differential Equations

Courses

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

Module Responsible	Prof. Daniel Ruprecht
Admission Requirements	None
Recommended Previous Knowledge	• Mathematik I, II, III for Engineers (German or English) or Analysis & Linear Algebra I + II plus Analysis III for Technomathematiker. • Basic knowledge of MATLAB, Python or a similar programming language.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to • name numerical methods for the solution of ordinary differential equations and explain their core ideas, • formulate convergence statements for the taught numerical methods (including the necessary assumptions about the solved problem), • explain aspects regarding the practical realisation of a method, • select the appropriate numerical method for specific problems, implement the numerical algorithms efficiently and interpret the numerical results.
Skills	Students are able to • implement, apply and compare numerical methods for the solution of ordinary differential equations, • explain the convergence behaviour of numerical methods, taking into consideration the solved problem and selected algorithm, • develop a suitable solution approach for a given problem, if necessary by combining multiple algorithms, realise this approach and critically evaluate results.
Personal Competence	
Social Competence	Students are able to • work together in heterogeneous teams (i.e., teams from different study programs and with different background knowledge), explain theoretical foundations and support each other with practical aspects regarding the implementation of algorithms.
Autonomy	Students are capable • to assess whether the provided theoretical and practical excercises are better solved individually or in a team and • to assess their individual progress and, if necessary, to ask questions and seek help.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Technical Complementary Course: Elective Compulsory Computer Science: Specialisation III. Mathematics: Elective Compulsory Data Science: Specialisation I. Mathematics: Elective Compulsory Data Science: Specialisation IV. Special Focus Area: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Interdisciplinary Mathematics: Specialisation II. Numerical - Modelling Training: Compulsory Mechatronics: Core Qualification: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

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

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

Module M0914: Technical Microbiology

Courses

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

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

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

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

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

Module M0721: Air Conditioning

Courses

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

Module Responsible	Prof. Arne Speerforck
Admission Requirements	None
Recommended Previous Knowledge	Technical Thermodynamics I, II, Fluid Dynamics, Heat Transfer
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students know the different kinds of air conditioning systems for buildings and mobile applications and how these systems are controlled. They are familiar with the change of state of humid air and are able to draw the state changes in a h1+x,x-diagram. They are able to calculate the minimum airflow needed for hygienic conditions in rooms and can choose suitable filters. They know the basic flow pattern in rooms and are able to calculate the air velocity in rooms with the help of simple methods. They know the principles to calculate an air duct network. They know the different possibilities to produce cold and are able to draw these processes into suitable thermodynamic diagrams. They know the criteria for the assessment of refrigerants.
Skills	Students are able to configure air condition systems for buildings and mobile applications. They are able to calculate an air duct network and have the ability to perform simple planning tasks, regarding natural heat sources and heat sinks. They can transfer research knowledge into practice. They are able to perform scientific work in the field of air conditioning.
Personal Competence	
Social Competence	In lectures and exercises, the students can use many examples and experiments to discuss in small groups in a goal-oriented manner, develop a solution and present it. Within the exercises, the students can independently develop further questions and work out targeted solutions.
Autonomy	Students are able to define tasks independently, to develop the necessary knowledge themselves based on the knowledge they have received, and to use suitable means for implementation. In the exercises, the students discuss the methods taught in the lectures using complex tasks and critically analyze 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	60 min
Assignment for the Following Curricula	Energy Systems: Specialisation Energy Systems: Elective Compulsory Energy Systems: Specialisation Marine Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

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

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

Module M1033: Special Areas of Process Engineering and Bioprocess Engineering

Courses

Title	Typ	Hrs/wk	CP
Bioeconomy (L2797)	Lecture	2	2
Chemical Kinetics (L0508)	Lecture	2	2
Solid Matter Process Technology for Biomass (L0052)	Lecture	2	3
Solid Matter Process in Chemical Industry (L2021)	Lecture	2	2
Optics for Engineers (L2437)	Lecture	3	3
Optics for Engineers (L2438)	Project-/problem-based Learning	3	3
Safety of Chemical Reactions (L1321)	Lecture	2	2

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 Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L2797: Bioeconomy

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Garabed Antranikian
Language	EN
Cycle	WiSe/SoSe
Content	Bioeconomy is the production, utilization and conservation of biological resources, including related knowledge, science, technology, and innovation, to provide information products, processes, and services across all economic sectors aiming towards a sustainable biobased technology. In this course the significance of various topics including the production and processing of biomass, economics, logistic as well as management will be discussed. Technologies aiming at the production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products (textiles, bioplastics, chemicals, pharmaceuticals) and bioenergy will be presented. Biological tools including microorganisms and enzymes will be introduced. This approach with a focus on chemical and process engineering will provide a smooth transition from crude oil-based industry to Sustainable Circular Bioeconomy taking into consideration the environmental issues. This sustainable use of renewable resources for industrial purposes will ensure environmental protection and a long-term balance of social and economic gains.
Literature	

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

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	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	12 Seiten
Lecturer	Prof. Frank Kleine Jäger
Language	DE
Cycle	SoSe
Content	
Literature	

Course L2437: Optics for Engineers	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Fachtheoretisch-fachpraktische Arbeit
Examination duration and scale	Vorstellung eines eigenen Optikentwurfs mit anschließender Diskussion, 10 Minuten Vorstellung + maximal 20 Minuten Diskussion
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	WiSe
Content	• Basic values for optical systems and lighting technology • Spectrum, black-bodies, color-perception • Light-Sources und their characterization • Photometrics • Ray-Optics • Matrix-Optics • Stops, Pupils and Windows • Light-field Technology • Introduction to Wave-Optics • Introduction to Holography
Literature	

Course L2438: Optics for Engineers	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Fachtheoretisch-fachpraktische Arbeit
Examination duration and scale	Vorstellung eines eigenen Optikentwurfs mit anschließender Diskussion, 10 Minuten Vorstellung + maximal 20 Minuten Diskussion
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1321: Safety of Chemical Reactions	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Dr. Marko Hoffmann
Language	DE
Cycle	SoSe
Content	
Literature	

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** Yes · **Bonus** None · **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 Chemical and Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process 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 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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process 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 M0657: Computational Fluid Dynamics II

Courses

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

Module Responsible	Prof. Thomas Rung
Admission Requirements	None
Recommended Previous Knowledge	Students should have sound knowledge of engineering mathematics (series expansions, internal & vector calculus), and be familiar with the foundations of partial/ordinary differential equations. They should also be familiar with engineering fluid mechanics and thermodynamics. Basic knowledge of numerical analysis or computational fluid dynamics is of advantage but not necessary.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students will acquire a deeper knowledge of computational fluid dynamics (CFD) and can translate general principles of thermo-/fluid engineering into discrete algorithms on the basis of finite volume methods. They are familiar with the similarities and differences between different discretisation and approximation concepts for investigating coupled systems of non-linear, convective partial differential equations (PDE) on structured and unstructured grids. Students have the required background knowledge to develop, code and apply modelling concepts to numerically describe turbulent and multiphase flow. They establish a thorough understanding of details of the theoretical background of complex CFD algorithms and the parameters used to control and adjust the execution of CFD procedures.
Skills	The students are able choose and apply appropriate finite volume (FV) approximation concepts and flow physics models that integrate the governing thermofluid dynamic PDEs in space and time. They can apply/optimise FV concepts to/for fluid dynamic applications. They acquire the ability to code computational algorithms dedicated to unstructured grid arrangements, apply these codes for parameter investigations and supplement interfaces to extract simulation data for an engineering analysis. They are able to judge different solution strategies.
Personal Competence	
Social Competence	The students are able to discuss problems, present the results of their own analysis, and jointly develop, implement and report on solution strategies that address given technical reference problems in a team.
Autonomy	The students can independently analyse numerical methods to solving fluid engineering problems. They are able to critically analyse own results as well as external data with regards to the plausibility and reliability.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	0.5h-0.75h
Assignment for the Following Curricula	Energy Systems: Core Qualification: Elective Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0237: Computational Fluid Dynamics II

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

Course L0421: Computational Fluid Dynamics II	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Thomas Rung
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1737: Power-to-X Process

Courses

Title	Typ	Hrs/wk	CP
Power-to-X process (L2805)	Lecture	2	2
Power-to-X process (L2806)	Recitation Section (large)	1	2
Practical aspects of energy conversion (L2807)	Practical Course	1	2

Module Responsible	Prof. Jakob Albert
Admission Requirements	None
Recommended Previous Knowledge	• Basic knowledge from the Bachelor's degree course in process engineering • Chemical reaction engineering • Process and plant engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can: • explain the energy transition in Germany, • give an overview of the versatile application possibilities of power-to-X processes, • evaluate different power-to-X concepts with regard to their technical challenges and social benefits.
Skills	The students are able to: • develop concepts for the technical implementation of power-to-X processes, • evaluate practical aspects of energy conversion to platform chemicals using laboratory experiments, • apply the acquired knowledge to various engineering-relevant power-to-X processes.
Personal Competence	
Social Competence	The students: • are able to independently discuss approaches to solutions and problems in the field of the energy transition in Germany in an interdisciplinary small group, • are able to work together in small groups on subject-specific tasks, • are able to work out the practical aspects of energy conversion to platform chemicals on the basis of laboratory experiments, carry out and evaluate the analytics of the products and precisely summarise the results of the experiments in a protocol.
Autonomy	The students • are able to independently obtain extensive literature on the topic and to gain knowledge from it, • are able to independently solve tasks on the topic and assess their learning status based on the feedback given, • are able to independently conduct experimental studies on the topic.
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	30 min
Assignment for the Following Curricula	Chemical and Bioprocess Engineering: Technical Complementary Course: 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

Course L2805: Power-to-X process	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Jakob Albert
Language	DE
Cycle	SoSe
Content	• Regenerative surplus energy • Electrolysis • CO2 sources for Power-to-X • Power-to-heat • Power-to-Power • Power-to-gas (SNG) • Power-to-Syngas • Power-to-Methanol • Power-to-Fuels • Power-to-ammonia • LOHC (Liquid organic hydrogen carrier) • Economic and ecological comparison of different concepts
Literature	1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013 2. H. Watter, „Regenerative Energiesysteme“, Springer, 2015

Course L2806: Power-to-X process	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Stefanie Wesinger
Language	DE
Cycle	SoSe
Content	In exercise, the contents of the lecture are further deepened and transferred into practical application. This is done using example tasks from practice, which are made available to the students. The students are to solve these tasks independently or in groups with the help of the lecture material. The solution is then discussed with students under scientific guidance, with parts of the task being presented on the blackboard.
Literature	1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013 2. H. Watter, „Regenerative Energiesysteme“, Springer, 2015

Course L2807: Practical aspects of energy conversion	
Typ	Practical Course
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Dr. Maximilian Poller
Language	DE
Cycle	SoSe
Content	In the laboratory practical course, practical experiments on power-to-X processes are carried out. The challenges for the technical implementation of power-to-x processes are made clear to the students. The associated analysis of the test samples is also part of the laboratory practical course and is carried out and evaluated by the students themselves. The results are precisely summarised and scientifically presented in an experimental protocol.
Literature	1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013 2. H. Watter, „Regenerative Energiesysteme“, Springer, 2015

Module M2029: Process Imaging

Courses

Title	Typ	Hrs/wk	CP
Process Imaging (L2723)	Lecture	3	3
Process Imaging Practicals (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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: Elective Compulsory Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory 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: Process Imaging Practicals	
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 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 Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process 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 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 Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process 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 Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: 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 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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: 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 M0633: Industrial Process Automation

Courses

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

Module Responsible	Prof. Alexander Schlaefer
Admission Requirements	None
Recommended Previous Knowledge	mathematics and optimization methods principles of automata principles of algorithms and data structures programming skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can evaluate and assess discrete event systems. They can evaluate properties of processes and explain methods for process analysis. The students can compare methods for process modelling and select an appropriate method for actual problems. They can discuss scheduling methods in the context of actual problems and give a detailed explanation of advantages and disadvantages of different programming methods. The students can relate process automation to methods from robotics and sensor systems as well as to recent topics like 'cyberphysical systems' and 'industry 4.0'.
Skills	The students are able to develop and model processes and evaluate them accordingly. This involves taking into account optimal scheduling, understanding algorithmic complexity, and implementation using PLCs.
Personal Competence	
Social Competence	The students can independently define work processes within their groups, distribute tasks within the group and develop solutions collaboratively.
Autonomy	The students are able to assess their level of knowledge and to document their work results adequately.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** No · **Bonus** 10 % · **Form** Excercises · **Description**
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

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

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

Module M0900: Examples in Solid Process Engineering

Courses

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

Module Responsible	Prof. Stefan Heinrich
Admission Requirements	None
Recommended Previous Knowledge	Knowledge from the module particle technology
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After completion of the module the students will be able to describe based on examples the assembly of solids engineering processes consisting of multiple apparatuses and subprocesses. They are able to describe the coaction and interrelation of subprocesses.
Skills	Students are able to analyze tasks in the field of solids process engineering and to combine suitable subprocesses in a process chain.
Personal Competence	
Social Competence	Students are able to discuss technical problems in a scientific manner.
Autonomy	Students are able to acquire scientific knowledge independently and discuss technical problems in a scientific manner.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / None / Written elaboration / drei Berichte (pro Versuch ein Bericht) à 5-10 Seiten
Examination	Written exam
Examination duration and scale	120 minutes
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0431: Fluidization Technology

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

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

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

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

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

Courses

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

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

Course L0942: Rural Development and Resources Oriented Sanitation for different Climate Zones

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

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

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: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: 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 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	1 Stunde Gruppenprüfung
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process 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 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 Bio process 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. Stefan Palzer
Language	DE/EN
Cycle	WiSe
Content	In the frame of the course the basics of fermentation, fluid processing and process engineering will be repeated. 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 M0662: Numerical Mathematics I

Courses

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

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

Course L0417: Numerical Mathematics I	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sabine Le Borne
Language	EN
Cycle	WiSe
Content	1. Finite precision arithmetic, error analysis, conditioning and stability 2. Linear systems of equations: LU and Cholesky factorization, condition 3. Interpolation: polynomial, spline and trigonometric interpolation 4. Nonlinear equations: fixed point iteration, root finding algorithms, Newton's method 5. Linear and nonlinear least squares problems: normal equations, Gram Schmidt and Householder orthogonalization, singular value decomposition, regularizatio, Gauss-Newton and Levenberg-Marquardt methods 6. Eigenvalue problems: power iteration, inverse iteration, QR algorithm 7. Numerical differentiation 8. Numerical integration: Newton-Cotes rules, error estimates, Gauss quadrature, adaptive quadrature
Literature	• Gander/Gander/Kwok: Scientific Computing: An introduction using Maple and MATLAB, Springer (2014) • Stoer/Bulirsch: Numerische Mathematik 1, Springer • Dahmen, Reusken: Numerik für Ingenieure und Naturwissenschaftler, Springer

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

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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: 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	DE/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 M0802: Membrane Technology

Courses

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

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

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

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

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

Module M0801: Water Resources and -Supply

Courses

Title	Typ	Hrs/wk	CP
Chemistry of Drinking Water Treatment (L0311)	Lecture	2	1
Chemistry of Drinking Water Treatment (L0312)	Recitation Section (large)	1	2
Water Resource Management (L0402)	Lecture	2	2
Water Resource Management (L0403)	Recitation Section (small)	1	1

Module Responsible	Prof. Mathias Ernst
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of water management and the key processes involved in water treatment.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students will be able to outline key areas of conflict in water management, as well as their mutual dependence for sustainable water supply. They will understand relevant economic, environmental and social factors. Students will be able to explain and outline the organisational structures of water companies. They will be able to explain the available water treatment processes and the scope of their application.
Skills	Students will be able to assess complex problems in drinking water production and establish solutions involving water management and technical measures. They will be able to assess the evaluation methods that can be used for this. Students will be able to carry out chemical calculations for selected treatment processes and apply generally accepted technical rules and standards to these processes.
Personal Competence	
Social Competence	Working in a diverse group of specialists, students will be able to develop and document complex solutions for the management and treatment of drinking water. They will be able to take an appropriate professional position, for example representing user interests. They will be able to develop joint solutions in teams of diverse experts and present these solutions to others.
Autonomy	Students will be in a position to work on a subject independently and present on this subject.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	60 min (chemistry) + presentation
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Technical Complementary Course: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory

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

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

Course L0402: Water Resource Management	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Mathias Ernst
Language	DE
Cycle	WiSe
Content	The lecture provides comprehensive knowledge on interaction of water ressource management and drinking water supply. Content overview: • Current situation of global water resources - User and Stakeholder conflicts - Wasserressourcenmanagement in urbane Gebieten - Rechtliche Aspekte, Organisationsformen Trinkwasserversorgungsunternehmen. - Ökobilanzierung, Benchmarking in der Wasserversorgung
Literature	• Aktuelle UN World Water Development Reports • Branchenbild der deutschen Wasserwirtschaft, VKU (2011) • Aktuelle Artikel wissenschaftlicher Zeitschriften • Ppt der Vorlesung

Course L0403: Water Resource Management	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Mathias Ernst
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0658: Innovative CFD Approaches

Courses

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

Module Responsible	Prof. Thomas Rung
Admission Requirements	None
Recommended Previous Knowledge	Students should have sound knowledge of engineering mathematics (series expansions, internal & vector calculus), and be familiar with the foundations of partial/ordinary differential equations. They are expected to be familiar with engineering fluid mechanics. Basic knowledge of numerical analysis or computational fluid dynamics, e.g. acquired in previous CFD courses, is of advantage but not necessary.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students will acquire a deeper knowledge of recent trends in computational fluid dynamics (CFD), i.e. finite volume, smoothed particle hydrodynamics and lattice Boltzmann approaches, and can relate recent innovations with present challenges in computational fluid mechanics. They are familiar with the similarities and differences between different Eulerian and Lagrangian discretisation and approximation concepts for investigating on the basis of continuum and kinetic theories. Students have the required knowledge to develop, explain, code and apply numerical models concepts to approximate multiphase and multifield problems with grid and particle based methods, respectively. Students know the fundamentals of simulation based PDE constraint optimisation.
Skills	The students are able choose and apply appropriate discretisation concepts and flow physics models. They acquire the ability to code computational algorithms dedicated to finite volumes on unstructured grids & particle-based discretisations & structured lattice Boltzmann arrangements, apply these codes for parameter investigations and supplement interfaces to extract simulation data for an engineering analysis. They are able to sophisticatedly judge different solution strategies.
Personal Competence	
Social Competence	The students are able to discuss problems, present the results of their own analysis, and jointly develop, implement and report on solution strategies that address given technical reference problems in a team. They to lead team sessions and present solutions to experts.
Autonomy	The students can independently analyse innovative methods to solving fluid engineering problems. They are able to critically analyse own results as well as external data with regards to the plausibility and reliability. Students are able to structure and perform a simulation-based investigation.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** Yes · **Bonus** 20 % · **Form** Written elaboration · **Description**
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Energy Systems: Core Qualification: Elective Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory Ship and Offshore Technology: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

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

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

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

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

Module M0742: Thermal Energy Systems

Courses

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

Module Responsible	Prof. Arne Speerforck
Admission Requirements	None
Recommended Previous Knowledge	Technical Thermodynamics I, II, Fluid Dynamics, Heat Transfer
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students know the different energy conversion stages and the difference between efficiency and annual efficiency. They have increased knowledge in heat and mass transfer, especially in regard to buildings and mobile applications. They are familiar with German energy saving code and other technical relevant rules. They know to differ different heating systems in the domestic and industrial area and how to control such heating systems. They are able to model a furnace and to calculate the transient temperatures in a furnace. They have the basic knowledge of emission formations in the flames of small burners and how to conduct the flue gases into the atmosphere. They are able to model thermodynamic systems with object oriented languages.
Skills	Students are able to calculate the heating demand for different heating systems and to choose the suitable components. They are able to calculate a pipeline network and have the ability to perform simple planning tasks, regarding solar energy. They can write Modelica programs and can transfer research knowledge into practice. They are able to perform scientific work in the field of thermal engineering.
Personal Competence	
Social Competence	In lectures and exercises, the students can use many examples and experiments to discuss in small groups in a goal-oriented manner, develop a solution and present it. Within the exercises, the students can independently develop further questions and work out targeted solutions.
Autonomy	Students are able to define tasks independently, to develop the necessary knowledge themselves based on the knowledge they have received, and to use suitable means for implementation. In the exercises, the students discuss the methods taught in the lectures using complex tasks and critically analyze 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	60 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Energy Systems: Specialisation Energy Systems: Compulsory Energy Systems: Specialisation Marine Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

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

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

Module M0975: Industrial Bioprocesses in Practice

Courses

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

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

Course L2276: Industrial biotechnology in Chemical Industriy

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Stephan Freyer
Language	EN
Cycle	WiSe
Content	This course gives an insight into the applications, processes, structures and boundary conditions in industrial practice. Various concrete applications of the technology, markets and other questions that will significantly influence the plant and process design will be shown.
Literature	Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen] 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 L2275: Practice in bioprocess engineering	
Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Wilfried Blümke
Language	EN
Cycle	WiSe
Content	Content of this course is a concrete insight into the principles, processes and structures of an industrial biotechnology company. In addition to practical illustrative examples, aspects beyond the actual process engineering area are also addressed, such as e.g. Sustainability and engineering.
Literature	Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen] 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 M1736: Industrial Homogeneous Catalysis

Courses

Title	Typ	Hrs/wk	CP
Homogeneous catalysis in application (L2804)	Practical Course	1	2
Industrial homogeneous catalysis (L2802)	Lecture	2	2
Industrial homogeneous catalysis (L2803)	Recitation Section (large)	1	2

Module Responsible	Prof. Jakob Albert
Admission Requirements	None
Recommended Previous Knowledge	• Basic knowledge from the Bachelor's degree course in process engineering • Chemical reaction engineering • Process and plant engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can: • explain the principle of homogeneous catalysis, • give an overview of the versatile applications of homogeneous catalysis in industry • evaluate different homogeneously catalysed reactions with regard to their technical challenges and economic significance.
Skills	The students are able to • develop concepts for the technical implementation of homogeneously catalysed reactions, • evaluate practical aspects of homogeneous catalysis using laboratory experiments, • apply the acquired knowledge to different homogeneously catalysed reactions.
Personal Competence	
Social Competence	The students: • are able to work out the practical aspects of homogeneous catalysis on the basis of laboratory experiments, to carry out and evaluate the analytics of the products and to precisely summarise the results of the experiments in a protocol. • are able to independently discuss approaches to solutions and problems in the field of homogeneous catalysis in an interdisciplinary small group, • are able to work together in small groups on subject-specific tasks, Translated with www.DeepL.com/Translator (free version)
Autonomy	The students • are able to independently obtain extensive literature on the topic and to gain knowledge from it, • are able to independently solve tasks on the topic and assess their learning status based on the feedback given, • are able to independently conduct experimental studies on the topic.
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	30 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Technical Complementary Course: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory

Course L2804: Homogeneous catalysis in application

Typ	Practical Course
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Jakob Albert
Language	EN
Cycle	WiSe
Content	In the laboratory practical course, practical experiments are carried out with reference to industrial application of homogeneous catalysis. The hurdles to the technical implementation of homogeneously catalysed reactions are made clear to the students. The associated analysis of the experimental samples is also part of the laboratory practical course and is carried out and evaluated by the students themselves. The results are precisely summarised and scientifically presented in an experimental protocol.
Literature	1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013 2. A. Behr, „Angewandte homogene Katalyse“, Wiley-VCH, 2008

Course L2802: Industrial homogeneous catalysis	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Maximilian Poller
Language	EN
Cycle	WiSe
Content	• Introduction to homogeneous catalysis • Elementary steps of catalysis • Homogeneous transition metal catalysis • Hydroformylation • Wacker process • Monsanto process • Shell higher olefin process (SHOP) • Extractive-oxidative desulphurisation (ECODS) • Phase transfer catalysis • Liquid-liquid two-phase catalysis • Catalyst recycling • Reactor concepts
Literature	1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013 2. A. Behr, „Angewandte homogene Katalyse“, Wiley-VCH, 2008

Course L2803: Industrial homogeneous catalysis	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Samrin Shaikh, Dr. Maximilian Poller
Language	EN
Cycle	WiSe
Content	In this exercise the contents of the lecture are further deepened and transferred into practical application. This is done using example tasks from practice, which are made available to the students. The students are to solve these tasks independently or in groups with the help of the lecture material. The solution is then discussed with students under scientific guidance, with parts of the task being presented on the blackboard.
Literature	1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013 2. A. Behr, „Angewandte homogene Katalyse“, Wiley-VCH, 2008

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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: Elective Compulsory Materials Science and Engineering: Specialisation Engineering Materials: Elective Compulsory Materials Science: Specialisation Engineering Materials: Elective Compulsory Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: 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 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	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	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 Bio process Engineering: Elective Compulsory Energy Systems: Specialisation Energy Systems: 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	Prof. Martin Kaltschmitt
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 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	2	4

Module Responsible	Prof. Mirko Skiborowski
Admission Requirements	None
Recommended Previous Knowledge	Process and Plant Engineering 1 Process and Plant Engineering 2 Basics in Process Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to evaluate hybrid processes
Skills	Students are able to evaluate processes with regard to their suitability as hybrid processes and to interpret them accordingly.
Personal Competence	
Social Competence	Students are able to apply the principles of project management for small groups.
Autonomy	Students are able to acquire and discuss specialized knowledge about hybrid processes.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	Project report incl. PM-documents and Midterm
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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process 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	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Dr. Thomas Waluga, Prof. Mirko Skiborowski
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0899: Synthesis and Design of Industrial Processes

Courses

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

Module Responsible	Prof. Mirko Skiborowski
Admission Requirements	None
Recommended Previous Knowledge	process and plant engineering I and II thermal separation processes heat and mass transport processes CAPE (absolut necessarily!)
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 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	Engineering Handbook and oral exam (20 min)
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L1048: Synthesis and Design of Industrial Facilities	
Typ	Lecture
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Mirko Skiborowski, Dr. Thomas Waluga
Language	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: Industrial Plant Design and Economics	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Mirko Skiborowski, Dr. Thomas Waluga
Language	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 M0905: Research Project Process Engineering

Courses

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

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

Course L1051: Research Project in Process Engineering

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

Module M0822: Process Modeling in Water Technology

Courses

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

Module Responsible	Dr. Klaus Johannsen
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of the most important processes in drinking water and waste water treatment.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to explain selected processes of drinking water and waste water treatment in detail. They are able to explain basics as well as possibilities and limitations of dynamic modeling.
Skills	Students are able to use the most important features Modelica offers. They are able to transpose selected processes in drinking water and waste water treatment into a mathematical model in Modelica with respect to equilibrium, kinetics and mass balances. They are able to set up and apply models and assess their possibilities and limitations.
Personal Competence	
Social Competence	Students are able to solve problems and document solutions in a group with members of different technical background. They are able to give appropriate feedback and can work constructively with feedback concerning their work.
Autonomy	Students are able to define a problem, gain the required knowledge and set up a model.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Chemical and Bioprocess Engineering: Technical Complementary Course: Elective Compulsory Environmental Engineering: Specialisation Water Quality and Water Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory

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

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

Module M1966: Mathematical Image Processing

Courses

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

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

Course L0991: Mathematical Image Processing

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

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

Module 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** Yes · **Bonus** None · **Form** Presentation · **Description**
Examination	Written exam
Examination duration and scale	120 minutes; theoretical questions and calculations
Assignment for the Following Curricula	Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0093: Chromatographic Separation Processes	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Monika Johannsen
Language	EN
Cycle	WiSe
Content	• 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 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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process 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	Dr. Johannes Möller
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	Dr. Johannes Möller
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 M2033: Subsurface Processes

Courses

Title	Typ	Hrs/wk	CP
Modeling of Subsurface Processes (L2731)	Recitation Section (small)	3	3
Subsurface Solute Transport (L2728)	Lecture	2	2
Subsurface Solute Transport (L2729)	Recitation Section (large)	1	1

Module Responsible	Prof. Nima Shokri
Admission Requirements	None
Recommended Previous Knowledge	Basic Mathematics, Hydrology
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Upon completion of this module, the students will understand the mechanisms controlling solute transport in soil and natural porous media and will be able to work with the equations that govern the fate and transport of solutes in porous media. Analytical, numerical and experimental tools and techniques will be used in this module.
Skills	In addition to the physical insights, the students will be exposed to analytical, experimental and numerical tools and techniques in this module. This provides them with an excellent opportunity to improve their skills on multiple fronts which will be useful in their future career.
Personal Competence	
Social Competence	Teamwork & problem solving
Autonomy	The students will be involved in writing individual reports and presentation. This will contribute to the students' ability and willingness to work independently and responsibly.
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	Report
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Civil Engineering: Specialisation Computational Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Technical Complementary Course: Elective Compulsory Environmental Engineering: Core Qualification: Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory

Course L2731: Modeling of Subsurface Processes

Typ	Recitation Section (small)
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Dr. Milad Aminzadeh
Language	EN
Cycle	WiSe
Content	Basic usage and background of chosen computer software to calculate flow and transport in the saturated and unsaturated zone and to analyze field data like pumping test data
Literature	

Course L2728: Subsurface Solute Transport

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Nima Shokri
Language	EN
Cycle	WiSe
Content	Basic physical properties of soil: Definition and quantification; Liquid flow in soils (Darcy's law); Solute transport in soils; Practical analysis to measure dispersion coefficient in soil under different boundary conditions; Advanced topics (e.g. Application of Artificial Intelligence to predict soil salinization)
Literature	- Environmental Soil Physics, by Daniel Hillel - Soil Physics, Sixth Edition, by William A. Jury and Robert Horton

Course L2729: Subsurface Solute Transport	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Hannes Nevermann
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: 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 M2019: Nonlinear Model Predictive Control - Theory and Application

Courses

Title	Typ	Hrs/wk	CP
Nonlinear Model Predictive Control - Theory and Application (L3283)	Lecture	3	6
Nonlinear Model Predictive Control - Theory and Application (L3284)	Project-/problem-based Learning	2	3

Module Responsible	Prof. Timm Faulwasser
Admission Requirements	None
Recommended Previous Knowledge	Basisc of control engineering (stability, simple control designs), state space models in control, differential equations.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Static and dynamic optimization methods, optimal control and numerical solution methods, design and implementation of model predictive control schemes in sampled-data fashion, dissipativity notions for optimal control.
Skills	The students are able to formulate and to solve problems of operation and control of technical systems on their own. The students are able to understand and to analyze the interplay of problem formulation and efficiency aspects of numerical solutions and to deduce problem-specific formulations. They know how to apply and to implement optimization methods to practical problems. Furthermore, the students can tackle complex problems of predictive control by means of abstraction, they are able to document their results in written form. The students are able to design predictive controllers for nonlinear systems and to validate them by means of simulation.
Personal Competence	
Social Competence	Interaction in interdisciplinary teams, meeting of project deadlines.
Autonomy	**Compare to Fachkopentenz (Fertigkeiten)**
Workload in Hours	Independent Study Time 200, Study Time in Lecture 70
Credit points	9
Course achievement	**Compulsory** No · **Bonus** 20 % · **Form** Subject theoretical and practical work · **Description**
Examination	Oral exam
Examination duration and scale	40 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: 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 L3283: Nonlinear Model Predictive Control - Theory and Application

Typ	Lecture
Hrs/wk	3
CP	6
Workload in Hours	Independent Study Time 138, Study Time in Lecture 42
Lecturer	Prof. Timm Faulwasser
Language	EN
Cycle	WiSe
Content	
Literature	

Course L3284: Nonlinear Model Predictive Control - Theory and Application

Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Timm Faulwasser
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Specialization Chemical Process Engineering

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

Workload in Hours: Independent Study Time 96, Study Time in Lecture 84

Credit points: 6

Course achievement

Compulsory	Bonus	Form	Description
Yes	15 %	Presentation	

Examination: Written exam

Examination duration and scale: 120 min

Assignment for the Following Curricula

Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory
Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory
Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory
Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory
Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: Elective Compulsory
International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory
Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory
Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L1278: High pressure 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 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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process 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 M0714: Numerical Methods for Ordinary Differential Equations

Courses

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

Module Responsible	Prof. Daniel Ruprecht
Admission Requirements	None
Recommended Previous Knowledge	• Mathematik I, II, III for Engineers (German or English) or Analysis & Linear Algebra I + II plus Analysis III for Technomathematiker. • Basic knowledge of MATLAB, Python or a similar programming language.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to • name numerical methods for the solution of ordinary differential equations and explain their core ideas, • formulate convergence statements for the taught numerical methods (including the necessary assumptions about the solved problem), • explain aspects regarding the practical realisation of a method, • select the appropriate numerical method for specific problems, implement the numerical algorithms efficiently and interpret the numerical results.
Skills	Students are able to • implement, apply and compare numerical methods for the solution of ordinary differential equations, • explain the convergence behaviour of numerical methods, taking into consideration the solved problem and selected algorithm, • develop a suitable solution approach for a given problem, if necessary by combining multiple algorithms, realise this approach and critically evaluate results.
Personal Competence	
Social Competence	Students are able to • work together in heterogeneous teams (i.e., teams from different study programs and with different background knowledge), explain theoretical foundations and support each other with practical aspects regarding the implementation of algorithms.
Autonomy	Students are capable • to assess whether the provided theoretical and practical excercises are better solved individually or in a team and • to assess their individual progress and, if necessary, to ask questions and seek help.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Technical Complementary Course: Elective Compulsory Computer Science: Specialisation III. Mathematics: Elective Compulsory Data Science: Specialisation I. Mathematics: Elective Compulsory Data Science: Specialisation IV. Special Focus Area: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Interdisciplinary Mathematics: Specialisation II. Numerical - Modelling Training: Compulsory Mechatronics: Core Qualification: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

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

Course L0582: Numerical Treatment of Ordinary Differential Equations	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Daniel Ruprecht
Language	DE/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
Process Imaging Practicals (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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: Elective Compulsory Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory 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: Process Imaging Practicals	
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 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** Yes · **Bonus** None · **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 Chemical and Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process 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 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 Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: 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 M1737: Power-to-X Process

Courses

Title	Typ	Hrs/wk	CP
Power-to-X process (L2805)	Lecture	2	2
Power-to-X process (L2806)	Recitation Section (large)	1	2
Practical aspects of energy conversion (L2807)	Practical Course	1	2

Module Responsible	Prof. Jakob Albert
Admission Requirements	None
Recommended Previous Knowledge	• Basic knowledge from the Bachelor's degree course in process engineering • Chemical reaction engineering • Process and plant engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can: • explain the energy transition in Germany, • give an overview of the versatile application possibilities of power-to-X processes, • evaluate different power-to-X concepts with regard to their technical challenges and social benefits.
Skills	The students are able to: • develop concepts for the technical implementation of power-to-X processes, • evaluate practical aspects of energy conversion to platform chemicals using laboratory experiments, • apply the acquired knowledge to various engineering-relevant power-to-X processes.
Personal Competence	
Social Competence	The students: • are able to independently discuss approaches to solutions and problems in the field of the energy transition in Germany in an interdisciplinary small group, • are able to work together in small groups on subject-specific tasks, • are able to work out the practical aspects of energy conversion to platform chemicals on the basis of laboratory experiments, carry out and evaluate the analytics of the products and precisely summarise the results of the experiments in a protocol.
Autonomy	The students • are able to independently obtain extensive literature on the topic and to gain knowledge from it, • are able to independently solve tasks on the topic and assess their learning status based on the feedback given, • are able to independently conduct experimental studies on the topic.
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	30 min
Assignment for the Following Curricula	Chemical and Bioprocess Engineering: Technical Complementary Course: 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

Course L2805: Power-to-X process	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Jakob Albert
Language	DE
Cycle	SoSe
Content	• Regenerative surplus energy • Electrolysis • CO2 sources for Power-to-X • Power-to-heat • Power-to-Power • Power-to-gas (SNG) • Power-to-Syngas • Power-to-Methanol • Power-to-Fuels • Power-to-ammonia • LOHC (Liquid organic hydrogen carrier) • Economic and ecological comparison of different concepts
Literature	1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013 2. H. Watter, „Regenerative Energiesysteme“, Springer, 2015

Course L2806: Power-to-X process	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Stefanie Wesinger
Language	DE
Cycle	SoSe
Content	In exercise, the contents of the lecture are further deepened and transferred into practical application. This is done using example tasks from practice, which are made available to the students. The students are to solve these tasks independently or in groups with the help of the lecture material. The solution is then discussed with students under scientific guidance, with parts of the task being presented on the blackboard.
Literature	1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013 2. H. Watter, „Regenerative Energiesysteme“, Springer, 2015

Course L2807: Practical aspects of energy conversion	
Typ	Practical Course
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Dr. Maximilian Poller
Language	DE
Cycle	SoSe
Content	In the laboratory practical course, practical experiments on power-to-X processes are carried out. The challenges for the technical implementation of power-to-x processes are made clear to the students. The associated analysis of the test samples is also part of the laboratory practical course and is carried out and evaluated by the students themselves. The results are precisely summarised and scientifically presented in an experimental protocol.
Literature	1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013 2. H. Watter, „Regenerative Energiesysteme“, Springer, 2015

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 Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process 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 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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: 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 M0633: Industrial Process Automation

Courses

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

Module Responsible	Prof. Alexander Schlaefer
Admission Requirements	None
Recommended Previous Knowledge	mathematics and optimization methods principles of automata principles of algorithms and data structures programming skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can evaluate and assess discrete event systems. They can evaluate properties of processes and explain methods for process analysis. The students can compare methods for process modelling and select an appropriate method for actual problems. They can discuss scheduling methods in the context of actual problems and give a detailed explanation of advantages and disadvantages of different programming methods. The students can relate process automation to methods from robotics and sensor systems as well as to recent topics like 'cyberphysical systems' and 'industry 4.0'.
Skills	The students are able to develop and model processes and evaluate them accordingly. This involves taking into account optimal scheduling, understanding algorithmic complexity, and implementation using PLCs.
Personal Competence	
Social Competence	The students can independently define work processes within their groups, distribute tasks within the group and develop solutions collaboratively.
Autonomy	The students are able to assess their level of knowledge and to document their work results adequately.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** No / **Bonus** 10 % / **Form** Excercises / **Description**
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

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

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

Module M0899: Synthesis and Design of Industrial Processes

Courses

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

Module Responsible	Prof. Mirko Skiborowski
Admission Requirements	None
Recommended Previous Knowledge	process and plant engineering I and II thermal separation processes heat and mass transport processes CAPE (absolut necessarily!)
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 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	Engineering Handbook and oral exam (20 min)
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L1048: Synthesis and Design of Industrial Facilities	
Typ	Lecture
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Mirko Skiborowski, Dr. Thomas Waluga
Language	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: Industrial Plant Design and Economics	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Mirko Skiborowski, Dr. Thomas Waluga
Language	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 M0900: Examples in Solid Process Engineering

Courses

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

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

Course L0431: Fluidization Technology

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

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

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

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

Module M1033: Special Areas of Process Engineering and Bioprocess Engineering

Courses

Title	Typ	Hrs/wk	CP
Bioeconomy (L2797)	Lecture	2	2
Chemical Kinetics (L0508)	Lecture	2	2
Solid Matter Process Technology for Biomass (L0052)	Lecture	2	3
Solid Matter Process in Chemical Industry (L2021)	Lecture	2	2
Optics for Engineers (L2437)	Lecture	3	3
Optics for Engineers (L2438)	Project-/problem-based Learning	3	3
Safety of Chemical Reactions (L1321)	Lecture	2	2

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 Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L2797: Bioeconomy

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Garabed Antranikian
Language	EN
Cycle	WiSe/SoSe
Content	Bioeconomy is the production, utilization and conservation of biological resources, including related knowledge, science, technology, and innovation, to provide information products, processes, and services across all economic sectors aiming towards a sustainable biobased technology. In this course the significance of various topics including the production and processing of biomass, economics, logistic as well as management will be discussed. Technologies aiming at the production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products (textiles, bioplastics, chemicals, pharmaceuticals) and bioenergy will be presented. Biological tools including microorganisms and enzymes will be introduced. This approach with a focus on chemical and process engineering will provide a smooth transition from crude oil-based industry to Sustainable Circular Bioeconomy taking into consideration the environmental issues. This sustainable use of renewable resources for industrial purposes will ensure environmental protection and a long-term balance of social and economic gains.
Literature	

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

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	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	12 Seiten
Lecturer	Prof. Frank Kleine Jäger
Language	DE
Cycle	SoSe
Content	
Literature	

Course L2437: Optics for Engineers	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Fachtheoretisch-fachpraktische Arbeit
Examination duration and scale	Vorstellung eines eigenen Optikentwurfs mit anschließender Diskussion, 10 Minuten Vorstellung + maximal 20 Minuten Diskussion
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	WiSe
Content	• Basic values for optical systems and lighting technology • Spectrum, black-bodies, color-perception • Light-Sources und their characterization • Photometrics • Ray-Optics • Matrix-Optics • Stops, Pupils and Windows • Light-field Technology • Introduction to Wave-Optics • Introduction to Holography
Literature	

Course L2438: Optics for Engineers	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Fachtheoretisch-fachpraktische Arbeit
Examination duration and scale	Vorstellung eines eigenen Optikentwurfs mit anschließender Diskussion, 10 Minuten Vorstellung + maximal 20 Minuten Diskussion
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1321: Safety of Chemical Reactions	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Dr. Marko Hoffmann
Language	DE
Cycle	SoSe
Content	
Literature	

Module M0905: Research Project Process Engineering

Courses

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

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

Course L1051: Research Project in Process Engineering

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

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** / **Bonus** / **Form** / **Description** Yes / None / Written elaboration /
Examination	Oral exam
Examination duration and scale	1 Stunde Gruppenprüfung
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process 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 M0975: Industrial Bioprocesses in Practice

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

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

Course L2276: Industrial biotechnology in Chemical Industriy

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Stephan Freyer
Language	EN
Cycle	WiSe
Content	This course gives an insight into the applications, processes, structures and boundary conditions in industrial practice. Various concrete applications of the technology, markets and other questions that will significantly influence the plant and process design will be shown.
Literature	Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen] 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 L2275: Practice in bioprocess engineering	
Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Wilfried Blümke
Language	EN
Cycle	WiSe
Content	Content of this course is a concrete insight into the principles, processes and structures of an industrial biotechnology company. In addition to practical illustrative examples, aspects beyond the actual process engineering area are also addressed, such as e.g. Sustainability and engineering.
Literature	Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen] 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 M1736: Industrial Homogeneous Catalysis

Courses

Title	Typ	Hrs/wk	CP
Homogeneous catalysis in application (L2804)	Practical Course	1	2
Industrial homogeneous catalysis (L2802)	Lecture	2	2
Industrial homogeneous catalysis (L2803)	Recitation Section (large)	1	2

Module Responsible	Prof. Jakob Albert
Admission Requirements	None
Recommended Previous Knowledge	• Basic knowledge from the Bachelor's degree course in process engineering • Chemical reaction engineering • Process and plant engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can: • explain the principle of homogeneous catalysis, • give an overview of the versatile applications of homogeneous catalysis in industry • evaluate different homogeneously catalysed reactions with regard to their technical challenges and economic significance.
Skills	The students are able to • develop concepts for the technical implementation of homogeneously catalysed reactions, • evaluate practical aspects of homogeneous catalysis using laboratory experiments, • apply the acquired knowledge to different homogeneously catalysed reactions.
Personal Competence	
Social Competence	The students: • are able to work out the practical aspects of homogeneous catalysis on the basis of laboratory experiments, to carry out and evaluate the analytics of the products and to precisely summarise the results of the experiments in a protocol. • are able to independently discuss approaches to solutions and problems in the field of homogeneous catalysis in an interdisciplinary small group, • are able to work together in small groups on subject-specific tasks, Translated with www.DeepL.com/Translator (free version)
Autonomy	The students • are able to independently obtain extensive literature on the topic and to gain knowledge from it, • are able to independently solve tasks on the topic and assess their learning status based on the feedback given, • are able to independently conduct experimental studies on the topic.
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	30 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Technical Complementary Course: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory

Course L2804: Homogeneous catalysis in application

Typ	Practical Course
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Jakob Albert
Language	EN
Cycle	WiSe
Content	In the laboratory practical course, practical experiments are carried out with reference to industrial application of homogeneous catalysis. The hurdles to the technical implementation of homogeneously catalysed reactions are made clear to the students. The associated analysis of the experimental samples is also part of the laboratory practical course and is carried out and evaluated by the students themselves. The results are precisely summarised and scientifically presented in an experimental protocol.
Literature	1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013 2. A. Behr, „Angewandte homogene Katalyse“, Wiley-VCH, 2008

Course L2802: Industrial homogeneous catalysis	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Maximilian Poller
Language	EN
Cycle	WiSe
Content	• Introduction to homogeneous catalysis • Elementary steps of catalysis • Homogeneous transition metal catalysis • Hydroformylation • Wacker process • Monsanto process • Shell higher olefin process (SHOP) • Extractive-oxidative desulphurisation (ECODS) • Phase transfer catalysis • Liquid-liquid two-phase catalysis • Catalyst recycling • Reactor concepts
Literature	1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013 2. A. Behr, „Angewandte homogene Katalyse“, Wiley-VCH, 2008

Course L2803: Industrial homogeneous catalysis	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Samrin Shaikh, Dr. Maximilian Poller
Language	EN
Cycle	WiSe
Content	In this exercise the contents of the lecture are further deepened and transferred into practical application. This is done using example tasks from practice, which are made available to the students. The students are to solve these tasks independently or in groups with the help of the lecture material. The solution is then discussed with students under scientific guidance, with parts of the task being presented on the blackboard.
Literature	1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013 2. A. Behr, „Angewandte homogene Katalyse“, Wiley-VCH, 2008

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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: Elective Compulsory Materials Science and Engineering: Specialisation Engineering Materials: Elective Compulsory Materials Science: Specialisation Engineering Materials: Elective Compulsory Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: 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 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	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	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 Bio process Engineering: Elective Compulsory Energy Systems: Specialisation Energy Systems: 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	Prof. Martin Kaltschmitt
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 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	2	4

Module Responsible	Prof. Mirko Skiborowski
Admission Requirements	None
Recommended Previous Knowledge	Process and Plant Engineering 1 Process and Plant Engineering 2 Basics in Process Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to evaluate hybrid processes
Skills	Students are able to evaluate processes with regard to their suitability as hybrid processes and to interpret them accordingly.
Personal Competence	
Social Competence	Students are able to apply the principles of project management for small groups.
Autonomy	Students are able to acquire and discuss specialized knowledge about hybrid processes.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	Project report incl. PM-documents and Midterm
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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process 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	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Dr. Thomas Waluga, Prof. Mirko Skiborowski
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: 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 M2019: Nonlinear Model Predictive Control - Theory and Application

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Nonlinear Model Predictive Control - Theory and Application (L3283)	Lecture	3	6
Nonlinear Model Predictive Control - Theory and Application (L3284)	Project-/problem-based Learning	2	3

Module Responsible	Prof. Timm Faulwasser
Admission Requirements	None
Recommended Previous Knowledge	Basisc of control engineering (stability, simple control designs), state space models in control, differential equations.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Static and dynamic optimization methods, optimal control and numerical solution methods, design and implementation of model predictive control schemes in sampled-data fashion, dissipativity notions for optimal control.
Skills	The students are able to formulate and to solve problems of operation and control of technical systems on their own. The students are able to understand and to analyze the interplay of problem formulation and efficiency aspects of numerical solutions and to deduce problem-specific formulations. They know how to apply and to implement optimization methods to practical problems. Furthermore, the students can tackle complex problems of predictive control by means of abstraction, they are able to document their results in written form. The students are able to design predictive controllers for nonlinear systems and to validate them by means of simulation.
Personal Competence	
Social Competence	Interaction in interdisciplinary teams, meeting of project deadlines.
Autonomy	**Compare to Fachkopentenz (Fertigkeiten)**
Workload in Hours	Independent Study Time 200, Study Time in Lecture 70
Credit points	9
Course achievement	**Compulsory:** No; **Bonus:** 20 %; **Form:** Subject theoretical and practical work; **Description:**
Examination	Oral exam
Examination duration and scale	40 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: 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 L3283: Nonlinear Model Predictive Control - Theory and Application

Typ	Lecture
Hrs/wk	3
CP	6
Workload in Hours	Independent Study Time 138, Study Time in Lecture 42
Lecturer	Prof. Timm Faulwasser
Language	EN
Cycle	WiSe
Content	
Literature	

Course L3284: Nonlinear Model Predictive Control - Theory and Application

Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Timm Faulwasser
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Specialization Environmental Process Engineering

Module M0513: System Aspects of Renewable Energies

Courses

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

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

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

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

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

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

Module M0874: Wastewater Systems

Courses

Title	Typ	Hrs/wk	CP
Biological Wastewater Treatment (L0517)	Lecture	2	2
Biological Wastewater Treatment (L3122)	Recitation Section (large)	1	1
Advanced Wastewater Treatment (L0357)	Lecture	2	2
Advanced Wastewater Treatment (L0358)	Recitation Section (large)	1	1

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

Course L0517: Biological Wastewater Treatment

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Joachim Behrendt
Language	DE/EN
Cycle	SoSe
Content	Charaterisation of Wastewater Metobolism of Microorganisms Kinetic of mirobiotic processes Calculation of bioreactor for wastewater treatment Concepts of Wastewater treatment Design of WWTP Excursion to a WWTP Biofilms Biofim Reactors Anaerobic Wastewater and sldge treatment resources oriented sanitation technology Future challenges of wastewater treatment
Literature	**Gujer, Willi** Siedlungswasserwirtschaft : mit 84 Tabellen ISBN: 3540343296 (Gb.) URL: http://www.gbv.de/dms/bs/toc/516261924.pdf URL: http://deposit.d-nb.de/cgi-bin/dokserv?id=2842122&prov=M&dok_var=1&dok_ext=htm Berlin [u.a.] : Springer, 2007 TUB_HH_Katalog **Henze, Mogens**

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

Course L3122: Biological Wastewater Treatment	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Joachim Behrendt
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

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

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

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

Courses

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

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

Course L1229: Ecological Town Design - Water, Energy, Soil and Food Nexus

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

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

Module M0512: Use of Solar Energy

Courses

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

Module Responsible	Prof. Martin Kaltschmitt
Admission Requirements	None
Recommended Previous Knowledge	none
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	With the completion of this module, students will be able to deal with technical foundations and current issues and problems in the field of solar energy and explain and evaulate these critically in consideration of the prior curriculum and current subject specific issues. In particular they can professionally describe the processes within a solar cell and explain the specific features of application of solar modules. Furthermore, they can provide an overview of the collector technology in solar thermal systems.
Skills	Students can apply the acquired theoretical foundations of exemplary energy systems using solar radiation. In this context, for example they can assess and evaluate potential and constraints of solar energy systems with respect to different geographical assumptions. They are able to dimension solar energy systems in consideration of technical aspects and given assumptions. Using module-comprehensive knowledge students can evalute the economic and ecologic conditions of these systems. They can select calculation methods within the radiation theory for these topics.
Personal Competence	
Social Competence	Students are able to discuss issues in the thematic fields in the renewable energy sector addressed within the module.
Autonomy	Students can independently exploit sources and acquire the particular knowledge about the subject area with respect to emphasis fo the lectures. Furthermore, with the assistance of lecturers, they can discrete use calculation methods for analysing and dimensioning solar energy systems. Based on this procedure they can concrete assess their specific learning level and can consequently define the further workflow.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** 20 %; **Form** Written elaboration; **Description** Ausarbeitung Kollektortechnik
Examination	Written exam
Examination duration and scale	180 min
Assignment for the Following Curricula	Energy Systems: Specialisation Energy Systems: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory

Course L0016: Energy Meteorology	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Volker Matthias, Dr. Beate Geyer
Language	DE
Cycle	SoSe

Content	• Introduction: radiation source Sun, Astronomical Foundations, Fundamentals of radiation
	• Structure of the atmosphere
	• Properties and laws of radiation
	  ◦ Polarization
	  ◦ Radiation quantities
	  ◦ Planck's radiation law
	  ◦ Wien's displacement law
	  ◦ Stefan-Boltzmann law
	  ◦ Kirchhoff's law
	  ◦ Brightness temperature
	  ◦ Absorption, reflection, transmission
	• Radiation balance, global radiation, energy balance
	• Atmospheric extinction
	• Mie and Rayleigh scattering
	• Radiative transfer
	• Optical effects in the atmosphere
	• Calculation of the sun and calculate radiation on inclined surfaces

Literature	• Helmut Kraus: Die Atmosphäre der Erde • Hans Häckel: Meteorologie • Grant W. Petty: A First Course in Atmosheric Radiation • Martin Kaltschmitt, Wolfgang Streicher, Andreas Wiese: Renewable Energy • Alexander Löw, Volker Matthias: Skript Optik Strahlung Fernerkundung

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

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

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

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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: 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 M1287: Risk Management, Hydrogen and Fuel Cell Technology

Courses

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

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

Course L1831: Applied Fuel Cell Technology

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

Course L1748: Risk Management in the Energy Industry	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Christian Wulf
Language	DE
Cycle	SoSe

Content	• Basics of risk management
	  ◦ Definition of terms
	  ◦ Risk types
	  ◦ Risk management process
	  ◦ Enterprise risk management
	• Markets and instruments in energy trading
	  ◦ Basics of futures and spot trading
	  ◦ Notation in energy markets
	  ◦ Options
	• Kennzahlendefinition
	  ◦ Assessing of market risks
	  ◦ Assessing of credit risks
	  ◦ Assessing of operational risks
	  ◦ Assessing of liquidy risks
	• Risk monitoring and reporting
	• Risk treatment

Literature	• Roggi, O. (2012): Risk Taking: A Corporate Governance Perspective, International Finance Corporation, New York • Hull, J. C. (2012): Options, Futures, and other Derivatives, 8. Auflage, Pearson Verlag, New York • Albrecht, P.; Maurer, R. (2008): Investment- und Risikomanagement, 3. Auflage, Schäffer-Poeschel Verlag, Stuttgart • Rittenberg, L.; Martens, F. (2012): Understanding and Communicating Risk Appetite, Treadway Commission, Durham

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

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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process 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 M1737: Power-to-X Process

Courses

Title	Typ	Hrs/wk	CP
Power-to-X process (L2805)	Lecture	2	2
Power-to-X process (L2806)	Recitation Section (large)	1	2
Practical aspects of energy conversion (L2807)	Practical Course	1	2

Module Responsible	Prof. Jakob Albert
Admission Requirements	None
Recommended Previous Knowledge	• Basic knowledge from the Bachelor's degree course in process engineering • Chemical reaction engineering • Process and plant engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can: • explain the energy transition in Germany, • give an overview of the versatile application possibilities of power-to-X processes, • evaluate different power-to-X concepts with regard to their technical challenges and social benefits.
Skills	The students are able to: • develop concepts for the technical implementation of power-to-X processes, • evaluate practical aspects of energy conversion to platform chemicals using laboratory experiments, • apply the acquired knowledge to various engineering-relevant power-to-X processes.
Personal Competence	
Social Competence	The students: • are able to independently discuss approaches to solutions and problems in the field of the energy transition in Germany in an interdisciplinary small group, • are able to work together in small groups on subject-specific tasks, • are able to work out the practical aspects of energy conversion to platform chemicals on the basis of laboratory experiments, carry out and evaluate the analytics of the products and precisely summarise the results of the experiments in a protocol.
Autonomy	The students • are able to independently obtain extensive literature on the topic and to gain knowledge from it, • are able to independently solve tasks on the topic and assess their learning status based on the feedback given, • are able to independently conduct experimental studies on the topic.
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	30 min
Assignment for the Following Curricula	Chemical and Bioprocess Engineering: Technical Complementary Course: 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

Course L2805: Power-to-X process	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Jakob Albert
Language	DE
Cycle	SoSe
Content	• Regenerative surplus energy • Electrolysis • CO2 sources for Power-to-X • Power-to-heat • Power-to-Power • Power-to-gas (SNG) • Power-to-Syngas • Power-to-Methanol • Power-to-Fuels • Power-to-ammonia • LOHC (Liquid organic hydrogen carrier) • Economic and ecological comparison of different concepts
Literature	1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013 2. H. Watter, „Regenerative Energiesysteme“, Springer, 2015

Course L2806: Power-to-X process	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Stefanie Wesinger
Language	DE
Cycle	SoSe
Content	In exercise, the contents of the lecture are further deepened and transferred into practical application. This is done using example tasks from practice, which are made available to the students. The students are to solve these tasks independently or in groups with the help of the lecture material. The solution is then discussed with students under scientific guidance, with parts of the task being presented on the blackboard.
Literature	1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013 2. H. Watter, „Regenerative Energiesysteme“, Springer, 2015

Course L2807: Practical aspects of energy conversion	
Typ	Practical Course
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Dr. Maximilian Poller
Language	DE
Cycle	SoSe
Content	In the laboratory practical course, practical experiments on power-to-X processes are carried out. The challenges for the technical implementation of power-to-x processes are made clear to the students. The associated analysis of the test samples is also part of the laboratory practical course and is carried out and evaluated by the students themselves. The results are precisely summarised and scientifically presented in an experimental protocol.
Literature	1. A. Jess, P. Wasserscheid, „Chemical Technology“, Wiley VCH, 2013 2. H. Watter, „Regenerative Energiesysteme“, Springer, 2015

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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process 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 M1878: Sustainable energy from wind and water

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Offshore Geotechnical Engineering (L0067)	Lecture	1	1
Hydro Power Use (L0013)	Lecture	1	1
Wind Turbine Plants (L0011)	Lecture	2	3
Wind Energy Use - Focus Offshore (L0012)	Lecture	1	1

Module Responsible	Dr. Marvin Scherzinger
Admission Requirements	None
Recommended Previous Knowledge	Module: Technical Thermodynamics I, Module: Technical Thermodynamics II, Module: Fundamentals of Fluid Mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	By ending this module students can explain in detail knowledge of wind turbines with a particular focus of wind energy use in offshore conditions and can critical comment these aspects in consideration of current developments. Furthermore, they are able to describe fundamentally the use of water power to generate electricity. The students reproduce and explain the basic procedure in the implementation of renewable energy projects in countries outside Europe. Through active discussions of various topics within the seminar of the module, students improve their understanding and the application of the theoretical background and are thus able to transfer what they have learned in practice.
Skills	Students are able to apply the acquired theoretical foundations on exemplary water or wind power systems and evaluate and assess technically the resulting relationships in the context of dimensioning and operation of these energy systems. They can in compare critically the special procedure for the implementation of renewable energy projects in countries outside Europe with the in principle applied approach in Europe and can apply this procedure on exemplary theoretical projects.
Personal Competence	
Social Competence	Students can discuss scientific tasks subjet-specificly and multidisciplinary within a seminar.
Autonomy	Students can independently exploit sources in the context of the emphasis of the lecture material to clear the contents of the lecture and to acquire the particular knowledge about the subject area.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	180 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: 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 Renewable Energies: Core Qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: 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 Water and Environmental Engineering: Specialisation Water: Elective Compulsory

Course L0067: Offshore Geotechnical Engineering	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Jan Dührkop
Language	DE
Cycle	SoSe
Content	• Overview and Introduction Offshore Geotechnics • Introduction to Soil Mechanics • Offshore soil investigation • Focus on cyclical effects • Geotechnical design of offshore foundations • Monopiles • Jackets • Heavyweight foundations • Geotechnical preliminary exploration for the use of lift boats and platforms
Literature	• Randolph, M. and Gourvenec, S (2011): Offshore Geotechnical Engineering. Spon Press. • Poulos H.G. (1988): Marine Geotechnics. Unwin Hyman, London • BSH-Standard Baugrunderkundung für Offshore-Windenergieparks • Lesny K. (2010): Foundations for Offshore Wind Turbines. VGE Verlag, Essen. • EA-Pfähle (2012): Empfehlungen des Arbeitskreises Pfähle der DGGT. Ernst & Sohn, Berlin.

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

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

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

Module M2029: Process Imaging

Courses

Title	Typ	Hrs/wk	CP
Process Imaging (L2723)	Lecture	3	3
Process Imaging Practicals (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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Core Qualification: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: Elective Compulsory Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory 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: Process Imaging Practicals	
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 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 Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process 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 M1888: Environmental protection management

Courses

Title	Typ	Hrs/wk	CP
Health, Safety and Environmental Management (L0387)	Integrated Lecture	3	3
Air Pollution Abatement (L0203)	Lecture	2	3

Module Responsible	Dr. Swantje Pietsch-Braune
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 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Management and Controlling: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory

Course L0387: Health, Safety and Environmental Management

Typ	Integrated Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Hans-Joachim Nau
Language	EN
Cycle	WiSe
Content	• Objectives of and benefit from HSE management • From dilution and end-of-pipe technology to eco-efficiency and eco-effectiveness Behaviour control: regulations, economic instruments and voluntary initiatives • Fundamentals of HSE legislation ISO 14001, EMAS and Responsible Care ISO 14001 requirements Environmental performance evaluation Risk management: hazard, risk and safety Health and safety at the workplace • Crisis management
Literature	C. Stephan: Industrial Health, Safety and Environmental Management, MV-Verlag, Münster, 2007/2012 (can be found in the library under GTG 315) Exercises can be downloaded from StudIP

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, Christian Eichler
Language	EN
Cycle	WiSe
Content	In the lecture methods for the reduction of emissions from industrial plants are treated. At the beginning a short survey of the different forms of air pollutants is given. In the second part physical principals for the removal of particulate and gaseous pollutants form flue gases are treated. Industrial applications of these principles are demonstrated with examples showing the removal of specific compounds, e.g. sulfur or mercury from flue gases of incinerators.
Literature	Handbook of air pollution prevention and control, Nicholas P. Cheremisinoff. - Amsterdam [u.a.] : Butterworth-Heinemann, 2002 Atmospheric pollution : history, science, and regulation, Mark Zachary Jacobson. - Cambridge [u.a.] : Cambridge Univ. Press, 2002 Air pollution control technology handbook, Karl B. Schnelle. - Boca Raton [u.a.] : CRC Press, c 2002 Air pollution, Jeremy Colls. - 2. ed. - London [u.a.] : Spon, 2002

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

Courses

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

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

Course L0942: Rural Development and Resources Oriented Sanitation for different Climate Zones

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

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

Module M1033: Special Areas of Process Engineering and Bioprocess Engineering

Courses

Title	Typ	Hrs/wk	CP
Bioeconomy (L2797)	Lecture	2	2
Chemical Kinetics (L0508)	Lecture	2	2
Solid Matter Process Technology for Biomass (L0052)	Lecture	2	3
Solid Matter Process in Chemical Industry (L2021)	Lecture	2	2
Optics for Engineers (L2437)	Lecture	3	3
Optics for Engineers (L2438)	Project-/problem-based Learning	3	3
Safety of Chemical Reactions (L1321)	Lecture	2	2

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 Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L2797: Bioeconomy

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Garabed Antranikian
Language	EN
Cycle	WiSe/SoSe
Content	Bioeconomy is the production, utilization and conservation of biological resources, including related knowledge, science, technology, and innovation, to provide information products, processes, and services across all economic sectors aiming towards a sustainable biobased technology. In this course the significance of various topics including the production and processing of biomass, economics, logistic as well as management will be discussed. Technologies aiming at the production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products (textiles, bioplastics, chemicals, pharmaceuticals) and bioenergy will be presented. Biological tools including microorganisms and enzymes will be introduced. This approach with a focus on chemical and process engineering will provide a smooth transition from crude oil-based industry to Sustainable Circular Bioeconomy taking into consideration the environmental issues. This sustainable use of renewable resources for industrial purposes will ensure environmental protection and a long-term balance of social and economic gains.
Literature	

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

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	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	12 Seiten
Lecturer	Prof. Frank Kleine Jäger
Language	DE
Cycle	SoSe
Content	
Literature	

Course L2437: Optics for Engineers	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Fachtheoretisch-fachpraktische Arbeit
Examination duration and scale	Vorstellung eines eigenen Optikentwurfs mit anschließender Diskussion, 10 Minuten Vorstellung + maximal 20 Minuten Diskussion
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	WiSe
Content	• Basic values for optical systems and lighting technology • Spectrum, black-bodies, color-perception • Light-Sources und their characterization • Photometrics • Ray-Optics • Matrix-Optics • Stops, Pupils and Windows • Light-field Technology • Introduction to Wave-Optics • Introduction to Holography
Literature	

Course L2438: Optics for Engineers	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Fachtheoretisch-fachpraktische Arbeit
Examination duration and scale	Vorstellung eines eigenen Optikentwurfs mit anschließender Diskussion, 10 Minuten Vorstellung + maximal 20 Minuten Diskussion
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1321: Safety of Chemical Reactions	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Dr. Marko Hoffmann
Language	DE
Cycle	SoSe
Content	
Literature	

Module M0905: Research Project Process Engineering

Courses

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

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

Course L1051: Research Project in Process Engineering

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

Module M1294: Bioenergy

Courses

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

Module Responsible	Prof. Martin Kaltschmitt
Admission Requirements	None
Recommended Previous Knowledge	none
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to reproduce an in-depth outline of energy production from biomass, aerobic and anaerobic waste treatment processes, the gained products and the treatment of produced emissions.
Skills	Students can apply the learned theoretical knowledge of biomass-based energy systems to explain relationships for different tasks, like dimesioning and design of biomass power plants. In this context, students are also able to solve computational tasks for combustion, gasification and biogas, biodiesel and bioethanol use.
Personal Competence	
Social Competence	Students can participate in discussions to design and evaluate energy systems using biomass as an energy source.
Autonomy	Students can independently exploit sources with respect to the emphasis of the lectures. They can choose and aquire the for the particular task useful knowledge. Furthermore, they can solve computational tasks of biomass-based energy systems independently with the assistance of the lecture. Regarding to this they can assess their specific learning level and can consequently define the further workflow.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / None / Subject theoretical and practical work / No / 10 % / Presentation /
Examination	Written exam
Examination duration and scale	3 hours written exam
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: Elective Compulsory Energy Systems: Specialisation Energy Systems: Elective 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	Prof. Martin Kaltschmitt
Language	DE
Cycle	WiSe

Content	Goal of this course is it to discuss the physical, chemical, and biological as well as the technical, economic, and environmental basics of all options to provide energy from biomass from a German and international point of view. Additionally different system approaches to use biomass for energy, aspects to integrate bioenergy within the energy system, technical and economic development potentials, and the current and expected future use within the energy system are presented.
	
	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	Prof. Martin Kaltschmitt, 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 M1303: Energy Projects - Development and Assessment

Courses

Title	Typ	Hrs/wk	CP
Aspects of Sustainability Management (L0007)	Lecture	1	1
Development of Energy Projects (L0003)	Lecture	2	2
Renewable Energy Projects in Emerged Markets (L0014)	Project Seminar	2	2
Economic Aspects of Energy Projects (L0005)	Lecture	1	1

Module Responsible	Prof. Martin Kaltschmitt
Admission Requirements	None
Recommended Previous Knowledge	Environmental Assessment
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	By ending this module, students can describe the planning and development of projects using renewable energy sources. Furthermore they are able to explain the special emphasis on the economic and legal aspects in this context. The learning content of the different topics of the module are use-oriented; thus students can apply them i.a. in professional fields of consultation or supervision of energy projects.
Skills	By ending the module the students can apply the learned theoretical foundations of the development of renewable energy projects to exemplary energy projects and can explain technically and conceptually the resulting correlations with respect to legal and economic requirements. As a basis for the design of renewable energy systems they can calculate the demand for thermal and/or electrical energy at operating and regional level. Regarding to this calculation they can choose and dimension possible energy systems. To assess sustainability aspects of renewable energy projects, the students can choose and discuss the right methodology according to the particular task. Through active discussions of various topics within the seminars and exercises of the module, students improve their understanding and the application of the theoretical background and are thus able to transfer what they have learned in practice.
Personal Competence	
Social Competence	Students will be able to edit scientific tasks in the context of the economic analysis of renewable energy projects in a group with a high number of participants and can organize the processing time within the group. They can perform subject-specific and interdisciplinary discussions. Consequently, they can asses the knowledge of their fellow students and are able to deal with feedback on their own performance. Students can present their group results in front of others.
Autonomy	Regarding to the contents of the lectures and to solve the tasks for the economical analysis of renewable energy projects the students are able to exploit sources and acquire the particular knowledge about the subject area independently and self-organized. Based on this expertise they are able to use indenpendently calculation methods for these tasks. Regarding to these calculations, guided by the lecturers, the students can recognize self-organized theri personal level of knowledge.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	150 minutes written exam + Written assay from project seminar
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory

Course L0007: Aspects of Sustainability Management	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Charlotte Weinspach
Language	DE
Cycle	WiSe
Content	The lecture "Sustainability Management" gives an insight into the different aspects and dimensions of sustainability. First, essential terms and definitions, significant developments of the last years, and legal framework conditions are explained. The various aspects of sustainability are then presented and discussed in detail. The lecture mainly focuses on concepts for the implementation of the topic sustainability in companies: • What is "sustainability"? • Why is this concept an important topic for companies? • What opportunities and business risks are addressed or are associated with it? • How can the often mentioned three pillars of sustainability - economy, ecology, and social- be meaningfully integrated into corporate management despite their sometimes contradictory tendencies, and how a corresponding compromise can be found? • What concepts or frameworks exist for the implementation of sustainability management in companies? • Which sustainability labels exist for products or companies? What do they have in common, and where do they differ? Furthermore, the lecture is intended to provide insights into the concrete implementation of sustainability aspects into business practice. External lecturers from companies will be invited to report on how sustainability is integrated into their daily processes. In the course of an independently carried out group work, the students will analyze and discuss the implementation of sustainability aspects based on short case studies. By studying and comparing best practice examples, the students will learn about corporate decisions' effects and implications. It should become clear which risks or opportunities are associated if sustainability aspects are taken into account in management decisions.
Literature	Die folgenden Bücher bieten einen Überblick: Engelfried, J. (2011) Nachhaltiges Umweltmanagement. München: Oldenbourg Verlag. 2. Auflage Corsten H., Roth S. (Hrsg.) (2011) Nachhaltigkeit - Unternehmerisches Handeln in globaler Verantwortung. Wiesbaden: Gabler Verlag.

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

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

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

Module M0822: Process Modeling in Water Technology

Courses

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

Module Responsible	Dr. Klaus Johannsen
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of the most important processes in drinking water and waste water treatment.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to explain selected processes of drinking water and waste water treatment in detail. They are able to explain basics as well as possibilities and limitations of dynamic modeling.
Skills	Students are able to use the most important features Modelica offers. They are able to transpose selected processes in drinking water and waste water treatment into a mathematical model in Modelica with respect to equilibrium, kinetics and mass balances. They are able to set up and apply models and assess their possibilities and limitations.
Personal Competence	
Social Competence	Students are able to solve problems and document solutions in a group with members of different technical background. They are able to give appropriate feedback and can work constructively with feedback concerning their work.
Autonomy	Students are able to define a problem, gain the required knowledge and set up a model.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Chemical and Bioprocess Engineering: Technical Complementary Course: Elective Compulsory Environmental Engineering: Specialisation Water Quality and Water Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory

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

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

Module M0801: Water Resources and -Supply

Courses

Title	Typ	Hrs/wk	CP
Chemistry of Drinking Water Treatment (L0311)	Lecture	2	1
Chemistry of Drinking Water Treatment (L0312)	Recitation Section (large)	1	2
Water Resource Management (L0402)	Lecture	2	2
Water Resource Management (L0403)	Recitation Section (small)	1	1

Module Responsible	Prof. Mathias Ernst
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of water management and the key processes involved in water treatment.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students will be able to outline key areas of conflict in water management, as well as their mutual dependence for sustainable water supply. They will understand relevant economic, environmental and social factors. Students will be able to explain and outline the organisational structures of water companies. They will be able to explain the available water treatment processes and the scope of their application.
Skills	Students will be able to assess complex problems in drinking water production and establish solutions involving water management and technical measures. They will be able to assess the evaluation methods that can be used for this. Students will be able to carry out chemical calculations for selected treatment processes and apply generally accepted technical rules and standards to these processes.
Personal Competence	
Social Competence	Working in a diverse group of specialists, students will be able to develop and document complex solutions for the management and treatment of drinking water. They will be able to take an appropriate professional position, for example representing user interests. They will be able to develop joint solutions in teams of diverse experts and present these solutions to others.
Autonomy	Students will be in a position to work on a subject independently and present on this subject.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	60 min (chemistry) + presentation
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Technical Complementary Course: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory

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

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

Course L0402: Water Resource Management	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Mathias Ernst
Language	DE
Cycle	WiSe
Content	The lecture provides comprehensive knowledge on interaction of water ressource management and drinking water supply. Content overview: • Current situation of global water resources - User and Stakeholder conflicts - Wasserressourcenmanagement in urbane Gebieten - Rechtliche Aspekte, Organisationsformen Trinkwasserversorgungsunternehmen. - Ökobilanzierung, Benchmarking in der Wasserversorgung
Literature	• Aktuelle UN World Water Development Reports • Branchenbild der deutschen Wasserwirtschaft, VKU (2011) • Aktuelle Artikel wissenschaftlicher Zeitschriften • Ppt der Vorlesung

Course L0403: Water Resource Management	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Mathias Ernst
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0802: Membrane Technology

Courses

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

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

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

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

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

Module M0975: Industrial Bioprocesses in Practice

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

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

Course L2276: Industrial biotechnology in Chemical Industriy

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Stephan Freyer
Language	EN
Cycle	WiSe
Content	This course gives an insight into the applications, processes, structures and boundary conditions in industrial practice. Various concrete applications of the technology, markets and other questions that will significantly influence the plant and process design will be shown.
Literature	Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen] 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 L2275: Practice in bioprocess engineering	
Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Wilfried Blümke
Language	EN
Cycle	WiSe
Content	Content of this course is a concrete insight into the principles, processes and structures of an industrial biotechnology company. In addition to practical illustrative examples, aspects beyond the actual process engineering area are also addressed, such as e.g. Sustainability and engineering.
Literature	Chmiel H (ed). Bioprozesstechnik, Springer 2011, ISBN: 978-3-8274-2476-1 [Titel anhand dieser ISBN in Citavi-Projekt übernehmen] 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 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: 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

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	Bonus	Form	Description
Yes	20 %	Written elaboration	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 Bio process Engineering: Elective Compulsory
Energy Systems: Specialisation Energy Systems: 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	Prof. Martin Kaltschmitt
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 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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: Elective Compulsory Materials Science and Engineering: Specialisation Engineering Materials: Elective Compulsory Materials Science: Specialisation Engineering Materials: Elective Compulsory Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: 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 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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process 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 M2033: Subsurface Processes

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Modeling of Subsurface Processes (L2731)	Recitation Section (small)	3	3
Subsurface Solute Transport (L2728)	Lecture	2	2
Subsurface Solute Transport (L2729)	Recitation Section (large)	1	1

Module Responsible	Prof. Nima Shokri
Admission Requirements	None
Recommended Previous Knowledge	Basic Mathematics, Hydrology
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Upon completion of this module, the students will understand the mechanisms controlling solute transport in soil and natural porous media and will be able to work with the equations that govern the fate and transport of solutes in porous media. Analytical, numerical and experimental tools and techniques will be used in this module.
Skills	In addition to the physical insights, the students will be exposed to analytical, experimental and numerical tools and techniques in this module. This provides them with an excellent opportunity to improve their skills on multiple fronts which will be useful in their future career.
Personal Competence	
Social Competence	Teamwork & problem solving
Autonomy	The students will be involved in writing individual reports and presentation. This will contribute to the students' ability and willingness to work independently and responsibly.
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	Report
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Civil Engineering: Specialisation Computational Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Technical Complementary Course: Elective Compulsory Environmental Engineering: Core Qualification: Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory

Course L2731: Modeling of Subsurface Processes

Typ	Recitation Section (small)
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Dr. Milad Aminzadeh
Language	EN
Cycle	WiSe
Content	Basic usage and background of chosen computer software to calculate flow and transport in the saturated and unsaturated zone and to analyze field data like pumping test data
Literature	

Course L2728: Subsurface Solute Transport

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Nima Shokri
Language	EN
Cycle	WiSe
Content	Basic physical properties of soil: Definition and quantification; Liquid flow in soils (Darcy's law); Solute transport in soils; Practical analysis to measure dispersion coefficient in soil under different boundary conditions; Advanced topics (e.g. Application of Artificial Intelligence to predict soil salinization)
Literature	- Environmental Soil Physics, by Daniel Hillel - Soil Physics, Sixth Edition, by William A. Jury and Robert Horton

Course L2729: Subsurface Solute Transport	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Hannes Nevermann
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M2019: Nonlinear Model Predictive Control - Theory and Application

Courses

Title	Typ	Hrs/wk	CP
Nonlinear Model Predictive Control - Theory and Application (L3283)	Lecture	3	6
Nonlinear Model Predictive Control - Theory and Application (L3284)	Project-/problem-based Learning	2	3

Module Responsible	Prof. Timm Faulwasser
Admission Requirements	None
Recommended Previous Knowledge	Basisc of control engineering (stability, simple control designs), state space models in control, differential equations.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Static and dynamic optimization methods, optimal control and numerical solution methods, design and implementation of model predictive control schemes in sampled-data fashion, dissipativity notions for optimal control.
Skills	The students are able to formulate and to solve problems of operation and control of technical systems on their own. The students are able to understand and to analyze the interplay of problem formulation and efficiency aspects of numerical solutions and to deduce problem-specific formulations. They know how to apply and to implement optimization methods to practical problems. Furthermore, the students can tackle complex problems of predictive control by means of abstraction, they are able to document their results in written form. The students are able to design predictive controllers for nonlinear systems and to validate them by means of simulation.
Personal Competence	
Social Competence	Interaction in interdisciplinary teams, meeting of project deadlines.
Autonomy	**Compare to Fachkopentenz (Fertigkeiten)**
Workload in Hours	Independent Study Time 200, Study Time in Lecture 70
Credit points	9
Course achievement	**Compulsory**: No; **Bonus**: 20 %; **Form**: Subject theoretical and practical work; **Description**:
Examination	Oral exam
Examination duration and scale	40 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: 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 L3283: Nonlinear Model Predictive Control - Theory and Application

Typ	Lecture
Hrs/wk	3
CP	6
Workload in Hours	Independent Study Time 138, Study Time in Lecture 42
Lecturer	Prof. Timm Faulwasser
Language	EN
Cycle	WiSe
Content	
Literature	

Course L3284: Nonlinear Model Predictive Control - Theory and Application

Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Timm Faulwasser
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

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 General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical and Bio process Engineering: 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

Thesis

Module M-002: Master Thesis

Courses			
Title	Typ	Hrs/wk	CP

Module Responsible	Professoren der TUHH
Admission Requirements	• According to General Regulations §21 (1): At least 60 credit points have to be achieved in study programme. The examinations board decides on exceptions.
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• The students can use specialized knowledge (facts, theories, and methods) of their subject competently on specialized issues. • The students can explain in depth the relevant approaches and terminologies in one or more areas of their subject, describing current developments and taking up a critical position on them. • The students can place a research task in their subject area in its context and describe and critically assess the state of research.
Skills	The students are able: • To select, apply and, if necessary, develop further methods that are suitable for solving the specialized problem in question. • To apply knowledge they have acquired and methods they have learnt in the course of their studies to complex and/or incompletely defined problems in a solution-oriented way. • To develop new scientific findings in their subject area and subject them to a critical assessment.
Personal Competence	
Social Competence	Students can • Both in writing and orally outline a scientific issue for an expert audience accurately, understandably and in a structured way. • Deal with issues competently in an expert discussion and answer them in a manner that is appropriate to the addressees while upholding their own assessments and viewpoints convincingly.
Autonomy	Students are able: • To structure a project of their own in work packages and to work them off accordingly. • To work their way in depth into a largely unknown subject and to access the information required for them to do so. • To apply the techniques of scientific work comprehensively in research of their own.
Workload in Hours	Independent Study Time 900, Study Time in Lecture 0
Credit points	30
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 Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Global Innovation Management: Thesis: Compulsory Computer Science in Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory Interdisciplinary Mathematics: Thesis: Compulsory International Production Management: Thesis: Compulsory International Management and Engineering: Thesis: Compulsory Joint European Master in Environmental Studies - Cities and Sustainability: Thesis: Compulsory Logistics, Infrastructure and Mobility: Thesis: Compulsory Aeronautics: Thesis: Compulsory Materials Science and Engineering: Thesis: Compulsory Materials Science: Thesis: Compulsory Mechanical Engineering and Management: Thesis: Compulsory Mechatronics: Thesis: Compulsory

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