

# **Module Manual**

Bachelor of Science (B.Sc.)

## **Process Engineering**

Cohort: Winter Term 2021

Updated: 31st May 2021

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**Program description**

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**Content**

**Core qualification**

**Module M0577: Non-technical Courses for Bachelors**

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

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

**Courses**

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

| Module M0886: Fundamentals of Process Engineering and Material Engineering |  |              |                     |                    |
|--|--|--------------|---------------------|--------------------|
| <b>Courses</b>   |  |              |                     |                    |
| <b>Title</b>   |  | <b>Typ</b>   | <b>Hrs/wk</b>       | <b>CP</b>          |
| Introduction into Process Engineering/Bioprocess Engineering (L0829)       |  | Lecture      | 2                   | 1                  |
| Fundamentals of material engineering (L0830)                               |  | Lecture      | 2                   | 2                  |
| <b>Module Responsible</b>  | Prof. Michael Schlüter   |              |                     |                    |
| <b>Admission Requirements</b>  | None   |              |                     |                    |
| <b>Recommended Previous Knowledge</b>                                      | none   |              |                     |                    |
| <b>Educational Objectives</b>  | After taking part successfully, students have reached the following learning results   |              |                     |                    |
| <b>Professional Competence</b>   |  |              |                     |                    |
| <i>Knowledge</i>   | After passing this module the students have the ability to: <ul style="list-style-type: none"> <li>• give an overview of the most important fields on process and bioprocess engineering,</li> <li>• explain some working methods for different fields in process engineering.</li> </ul>  |              |                     |                    |
| <i>Skills</i>  | After passing this module the students should have the ability to: <ul style="list-style-type: none"> <li>• list and outline the most important fields of process engineering,</li> <li>• name the most important working approaches or methods of the different fields of process engineering,</li> <li>• read and prepare an engineering drawing,</li> <li>• explain the most important technologies for wastewater and exhaust air treatment</li> <li>• scheme typical chemical and biotechnological processes independently with the aid of pointers.</li> </ul> |              |                     |                    |
| <b>Personal Competence</b>   |  |              |                     |                    |
| <i>Social Competence</i>   | The students are able to <ul style="list-style-type: none"> <li>• work out results in groups and document them,</li> <li>• provide appropriate feedback and handle feedback on their own performance constructively.</li> </ul>  |              |                     |                    |
| <i>Autonomy</i>  | The students are able to estimate their progress of learning by themselves and to deliberate their lack of knowledge in Process Engineering and Bioprocess Engineering.  |              |                     |                    |
| <b>Workload in Hours</b>   | Independent Study Time 34, Study Time in Lecture 56  |              |                     |                    |
| <b>Credit points</b>   | 3  |              |                     |                    |
| <b>Course achievement</b>  | <b>Compulsory</b>  | <b>Bonus</b> | <b>Form</b>         | <b>Description</b> |
|  | No   | 5 %          | Written elaboration |                    |
| <b>Examination</b>   | Written exam   |              |                     |                    |
| <b>Examination duration and scale</b>                                      | 90 min   |              |                     |                    |
| <b>Assignment for the Following Curricula</b>                              | General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>Bioprocess Engineering: Core qualification: Compulsory<br>Orientation Studies: Core qualification: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory   |              |                     |                    |

| Course L0829: Introduction into Process Engineering/Bioprocess Engineering |  |
|--|--|
| <b>Typ</b>   | Lecture  |
| <b>Hrs/wk</b>  | 2  |
| <b>CP</b>  | 1  |
| <b>Workload in Hours</b>   | Independent Study Time 2, Study Time in Lecture 28   |
| <b>Lecturer</b>  | Dozenten des SD V  |
| <b>Language</b>  | DE   |
| <b>Cycle</b>   | WiSe   |
| <b>Content</b>   | Introduction into the different research fields of the subject Process Engineering and Bioprocess Engineering. |
| <b>Literature</b>  | s. StudIP  |

| Course L0830: Fundamentals of material engineering |   |
|--|---|
| <b>Typ</b>   | Lecture   |
| <b>Hrs/wk</b>                                      | 2   |
| <b>CP</b>  | 2   |
| <b>Workload in Hours</b>                           | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>                                    | Dr. Marko Hoffmann  |
| <b>Language</b>                                    | DE  |
| <b>Cycle</b>                                       | WiSe  |
| <b>Content</b>                                     | <ul style="list-style-type: none"> <li>• Introduction</li> <li>• Atomic structure and bonding</li> <li>• Structure of solids</li> <li>• Miller indices</li> <li>• Imperfections in solids</li> <li>• Texture</li> <li>• Diffusion</li> <li>• Mechanical properties</li> <li>• Dislocations and strengthening mechanisms</li> <li>• Phase transformations</li> <li>• Phase diagrams, iron-carbon phase diagram</li> <li>• Metallic materials</li> <li>• Corrosion</li> <li>• Polymeric materials</li> <li>• Ceramic materials</li> </ul>                               |
| <b>Literature</b>                                  | <ul style="list-style-type: none"> <li>• Bargel, H.-J.; Schulze, G. (Hrsg.): Werkstoffkunde. Berlin u.a., Springer Vieweg, 2012.</li> <li>• Bergmann, W.: Werkstofftechnik 1. München u.a., Hanser, 2009.</li> <li>• Bergmann, W.: Werkstofftechnik 2. München u.a., Hanser, 2008.</li> <li>• Callister, W. D.; Rethwisch, D. G.: Materialwissenschaften und Werkstofftechnik: eine Einführung, Übersetzungshrsg.: Scheffler, M., 1. Auflage, Weinheim, Wiley-VCH, 2013.</li> <li>• Seidel, W. W., Hahn, F.: Werkstofftechnik. München u.a., Hanser, 2012.</li> </ul> |

| Module M0850: Mathematics I                   |  |        |    |  |
|---|--|--------|----|--|
| Courses                                       |  |        |    |  |
| Title   | Typ  | Hrs/wk | CP |  |
| Analysis I (L1010)                            | Lecture  | 2      | 2  |  |
| Analysis I (L1012)                            | Recitation Section (small)   | 1      | 1  |  |
| Analysis I (L1013)                            | Recitation Section (large)   | 1      | 1  |  |
| Linear Algebra I (L0912)                      | Lecture  | 2      | 2  |  |
| Linear Algebra I (L0913)                      | Recitation Section (small)   | 1      | 1  |  |
| Linear Algebra I (L0914)                      | Recitation Section (large)   | 1      | 1  |  |
| <b>Module Responsible</b>                     | Prof. Anusch Taraz   |        |    |  |
| <b>Admission Requirements</b>                 | None   |        |    |  |
| <b>Recommended Previous Knowledge</b>         | School mathematics   |        |    |  |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results   |        |    |  |
| <b>Professional Competence</b>                | <ul style="list-style-type: none"> <li>• Students can name the basic concepts in analysis and linear algebra. They are able to explain them using appropriate examples.</li> <li>• Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples.</li> <li>• They know proof strategies and can reproduce them.</li> </ul>   |        |    |  |
| <i>Knowledge</i>                              |  |        |    |  |
| <i>Skills</i>                                 |  |        |    |  |
| <b>Personal Competence</b>                    |  |        |    |  |
| <i>Social Competence</i>                      | <ul style="list-style-type: none"> <li>• Students can model problems in analysis and linear algebra with the help of the concepts studied in this course. Moreover, they are capable of solving them by applying established methods.</li> <li>• Students are able to discover and verify further logical connections between the concepts studied in the course.</li> <li>• For a given problem, the students can develop and execute a suitable approach, and are able to critically evaluate the results.</li> </ul>  |        |    |  |
| <i>Autonomy</i>                               | <ul style="list-style-type: none"> <li>• Students are able to work together in teams. They are capable to use mathematics as a common language.</li> <li>• In doing so, they can communicate new concepts according to the needs of their cooperating partners. Moreover, they can design examples to check and deepen the understanding of their peers.</li> </ul>  |        |    |  |
| <b>Workload in Hours</b>                      | Independent Study Time 128, Study Time in Lecture 112  |        |    |  |
| <b>Credit points</b>                          | 8  |        |    |  |
| <b>Course achievement</b>                     | None   |        |    |  |
| <b>Examination</b>                            | Written exam   |        |    |  |
| <b>Examination duration and scale</b>         | 60 min (Analysis I) + 60 min (Linear Algebra I)  |        |    |  |
| <b>Assignment for the Following Curricula</b> | General Engineering Science (German program, 7 semester): Core qualification: Compulsory<br>Civil- and Environmental Engineering: Core qualification: Compulsory<br>Bioprocess Engineering: Core qualification: Compulsory<br>Digital Mechanical Engineering: Core qualification: Compulsory<br>Electrical Engineering: Core qualification: Compulsory<br>Energy and Environmental Engineering: Core qualification: Compulsory<br>Green Technologies: Energy, Water, Climate: Core qualification: Compulsory<br>Computational Science and Engineering: Core qualification: Compulsory<br>Logistics and Mobility: Core qualification: Compulsory<br>Mechanical Engineering: Core qualification: Compulsory<br>Mechatronics: Core qualification: Compulsory<br>Orientation Studies: Core qualification: Elective Compulsory<br>Naval Architecture: Core qualification: Compulsory<br>Process Engineering: Core qualification: Compulsory<br>Engineering and Management - Major in Logistics and Mobility: Core qualification: Compulsory |        |    |  |



| Course L1010: Analysis I |   |
|--------------------------|---|
| <b>Typ</b>               | Lecture   |
| <b>Hrs/wk</b>            | 2   |
| <b>CP</b>                | 2   |
| <b>Workload in Hours</b> | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>          | Dozenten des Fachbereiches Mathematik der UHH   |
| <b>Language</b>          | DE  |
| <b>Cycle</b>             | WiSe  |
| <b>Content</b>           | Foundations of differential and integrational calculus of one variable <ul style="list-style-type: none"> <li>• statements, sets and functions</li> <li>• natural and real numbers</li> <li>• convergence of sequences and series</li> <li>• continuous and differentiable functions</li> <li>• mean value theorems</li> <li>• Taylor series</li> <li>• calculus</li> <li>• error analysis</li> <li>• fixpoint iteration</li> </ul> |
| <b>Literature</b>        | <ul style="list-style-type: none"> <li>• <a href="http://www.math.uni-hamburg.de/teaching/export/tuhh/index.html">http://www.math.uni-hamburg.de/teaching/export/tuhh/index.html</a></li> </ul>   |

| Course L1012: Analysis I |   |
|--------------------------|---|
| <b>Typ</b>               | Recitation Section (small)                          |
| <b>Hrs/wk</b>            | 1   |
| <b>CP</b>                | 1   |
| <b>Workload in Hours</b> | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>          | Dozenten des Fachbereiches Mathematik der UHH       |
| <b>Language</b>          | DE  |
| <b>Cycle</b>             | WiSe  |
| <b>Content</b>           | See interlocking course                             |
| <b>Literature</b>        | See interlocking course                             |

| Course L1013: Analysis I |   |
|--------------------------|---|
| <b>Typ</b>               | Recitation Section (large)                          |
| <b>Hrs/wk</b>            | 1   |
| <b>CP</b>                | 1   |
| <b>Workload in Hours</b> | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>          | Dozenten des Fachbereiches Mathematik der UHH       |
| <b>Language</b>          | DE  |
| <b>Cycle</b>             | WiSe  |
| <b>Content</b>           | See interlocking course                             |
| <b>Literature</b>        | See interlocking course                             |

| Course L0912: Linear Algebra I |  |
|--------------------------------|--|
| <b>Typ</b>                     | Lecture  |
| <b>Hrs/wk</b>                  | 2  |
| <b>CP</b>                      | 2  |
| <b>Workload in Hours</b>       | Independent Study Time 32, Study Time in Lecture 28  |
| <b>Lecturer</b>                | Prof. Anusch Taraz, Prof. Marko Lindner, Dr. Dennis Clemens  |
| <b>Language</b>                | DE   |
| <b>Cycle</b>                   | WiSe   |
| <b>Content</b>                 | <ul style="list-style-type: none"> <li>• vectors: intuition, rules, inner and cross product, lines and planes</li> <li>• systems of linear equations: Gauß elimination, matrix product, inverse matrices, transformations, block matrices, determinants</li> <li>• orthogonal projection in <math>\mathbb{R}^n</math>, Gram-Schmidt-Orthonormalization</li> </ul>  |
| <b>Literature</b>              | <ul style="list-style-type: none"> <li>• T. Arens u.a. : Mathematik, Spektrum Akademischer Verlag, Heidelberg 2009</li> <li>• W. Mackens, H. Voß: Mathematik I für Studierende der Ingenieurwissenschaften, HECO-Verlag, Alsdorf 1994</li> <li>• W. Mackens, H. Voß: Aufgaben und Lösungen zur Mathematik I für Studierende der Ingenieurwissenschaften, HECO-Verlag, Alsdorf 1994</li> <li>• G. Strang: Lineare Algebra, Springer-Verlag, 2003</li> <li>• G. und S. Teschl: Mathematik für Informatiker, Band 1, Springer-Verlag, 2013</li> </ul> |

| Course L0913: Linear Algebra I |   |
|--------------------------------|---|
| <b>Typ</b>                     | Recitation Section (small)  |
| <b>Hrs/wk</b>                  | 1   |
| <b>CP</b>                      | 1   |
| <b>Workload in Hours</b>       | Independent Study Time 16, Study Time in Lecture 14   |
| <b>Lecturer</b>                | Prof. Anusch Taraz, Prof. Marko Lindner, Dr. Dennis Clemens   |
| <b>Language</b>                | DE  |
| <b>Cycle</b>                   | WiSe  |
| <b>Content</b>                 | <ul style="list-style-type: none"> <li>vectors: intuition, rules, inner and cross product, lines and planes</li> <li>general vector spaces: subspaces, Euclidean vector spaces</li> <li>systems of linear equations: Gauß-elimination, matrix product, inverse matrices, transformations, LR-decomposition, block matrices, determinants</li> </ul>                                     |
| <b>Literature</b>              | <ul style="list-style-type: none"> <li>T. Arens u.a. : Mathematik, Spektrum Akademischer Verlag, Heidelberg 2009</li> <li>W. Mackens, H. Voß: Mathematik I für Studierende der Ingenieurwissenschaften, HECO-Verlag, Alsdorf 1994</li> <li>W. Mackens, H. Voß: Aufgaben und Lösungen zur Mathematik I für Studierende der Ingenieurwissenschaften, HECO-Verlag, Alsdorf 1994</li> </ul> |

| Course L0914: Linear Algebra I |   |
|--------------------------------|---|
| <b>Typ</b>                     | Recitation Section (large)                          |
| <b>Hrs/wk</b>                  | 1   |
| <b>CP</b>                      | 1   |
| <b>Workload in Hours</b>       | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>                | Dr. Christian Seifert, Dr. Dennis Clemens           |
| <b>Language</b>                | DE  |
| <b>Cycle</b>                   | WiSe  |
| <b>Content</b>                 | See interlocking course                             |
| <b>Literature</b>              | See interlocking course                             |

| Module M0889: Mechanics I (Statics)           |  |                            |                         |
|---|--|----------------------------|-------------------------|
| <b>Courses</b>                                |  |                            |                         |
| <b>Title</b>                                  |  | <b>Typ</b>                 | <b>Hrs/wk</b> <b>CP</b> |
| Mechanics I (Statics) (L1001)                 |  | Lecture                    | 2                  3    |
| Mechanics I (Statics) (L1002)                 |  | Recitation Section (small) | 2                  2    |
| Mechanics I (Statics) (L1003)                 |  | Recitation Section (large) | 1                  1    |
| <b>Module Responsible</b>                     | Prof. Robert Seifried  |                            |                         |
| <b>Admission Requirements</b>                 | None   |                            |                         |
| <b>Recommended Previous Knowledge</b>         | Solid school knowledge in mathematics and physics.   |                            |                         |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results   |                            |                         |
| <b>Professional Competence</b>                |  |                            |                         |
| <i>Knowledge</i>                              | The students can <ul style="list-style-type: none"> <li>• describe the axiomatic procedure used in mechanical contexts;</li> <li>• explain important steps in model design;</li> <li>• present technical knowledge in stereostatics.</li> </ul>  |                            |                         |
| <i>Skills</i>                                 | The students can <ul style="list-style-type: none"> <li>• explain the important elements of mathematical / mechanical analysis and model formation, and apply it to the context of their own problems;</li> <li>• apply basic statical methods to engineering problems;</li> <li>• estimate the reach and boundaries of statical methods and extend them to be applicable to wider problem sets.</li> </ul>  |                            |                         |
| <b>Personal Competence</b>                    |  |                            |                         |
| <i>Social Competence</i>                      | The students can work in groups and support each other to overcome difficulties.   |                            |                         |
| <i>Autonomy</i>                               | Students are capable of determining their own strengths and weaknesses and to organize their time and learning based on those.   |                            |                         |
| <b>Workload in Hours</b>                      | Independent Study Time 110, Study Time in Lecture 70   |                            |                         |
| <b>Credit points</b>                          | 6  |                            |                         |
| <b>Course achievement</b>                     | None   |                            |                         |
| <b>Examination</b>                            | Written exam   |                            |                         |
| <b>Examination duration and scale</b>         | 90 min   |                            |                         |
| <b>Assignment for the Following Curricula</b> | General Engineering Science (German program, 7 semester): Core qualification: Compulsory<br>Civil- and Environmental Engineering: Core qualification: Compulsory<br>Bioprocess Engineering: Core qualification: Compulsory<br>Data Science: Specialisation Mechanics: Compulsory<br>Digital Mechanical Engineering: Core qualification: Compulsory<br>Electrical Engineering: Core qualification: Elective Compulsory<br>Green Technologies: Energy, Water, Climate: Core qualification: Compulsory<br>Computational Science and Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory<br>Logistics and Mobility: Core qualification: Compulsory<br>Mechanical Engineering: Core qualification: Compulsory<br>Mechatronics: Core qualification: Compulsory<br>Orientation Studies: Core qualification: Elective Compulsory<br>Naval Architecture: Core qualification: Compulsory<br>Process Engineering: Core qualification: Compulsory<br>Engineering and Management - Major in Logistics and Mobility: Core qualification: Compulsory |                            |                         |

| Course L1001: Mechanics I (Statics) |  |
|-------------------------------------|--|
| <b>Typ</b>                          | Lecture  |
| <b>Hrs/wk</b>                       | 2  |
| <b>CP</b>                           | 3  |
| <b>Workload in Hours</b>            | Independent Study Time 62, Study Time in Lecture 28  |
| <b>Lecturer</b>                     | Prof. Robert Seifried  |
| <b>Language</b>                     | DE   |
| <b>Cycle</b>                        | WiSe   |
| <b>Content</b>                      | <ul style="list-style-type: none"> <li>• Tasks in Mechanics</li> <li>• Modelling and model elements</li> <li>• Vector calculus for forces and torques</li> <li>• Forces and equilibrium in space</li> <li>• Constraints and reactions, characterization of constraint systems</li> <li>• Planar and spatial truss structures</li> <li>• Internal forces and moments for beams and frames</li> <li>• Center of mass, volumn, area and line</li> <li>• Computation of center of mass by intergals, joint bodies</li> <li>• Friction (sliding and sticking)</li> <li>• Friction of ropes</li> </ul> |
| <b>Literature</b>                   | <b>K. Magnus, H.H. Müller-Slany: Grundlagen der Technischen Mechanik. 7. Auflage, Teubner (2009).</b><br><b>D. Gross, W. Hauger, J. Schröder, W. Wall: Technische Mechanik 1. 11. Auflage, Springer (2011).</b>  |

| Course L1002: Mechanics I (Statics) |   |
|-------------------------------------|---|
| <b>Typ</b>                          | Recitation Section (small)  |
| <b>Hrs/wk</b>                       | 2   |
| <b>CP</b>                           | 2   |
| <b>Workload in Hours</b>            | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>                     | Prof. Robert Seifried   |
| <b>Language</b>                     | DE  |
| <b>Cycle</b>                        | WiSe  |
| <b>Content</b>                      | Forces and equilibrium<br>Constraints and reactions<br>Frames<br>Center of mass<br>Friction<br>Internal forces and moments for beams  |
| <b>Literature</b>                   | K. Magnus, H.H. Müller-Slany: Grundlagen der Technischen Mechanik. 7. Auflage, Teubner (2009).<br>D. Gross, W. Hauger, J. Schröder, W. Wall: Technische Mechanik 1. 11. Auflage, Springer (2011). |

| Course L1003: Mechanics I (Statics) |   |
|-------------------------------------|---|
| <b>Typ</b>                          | Recitation Section (large)  |
| <b>Hrs/wk</b>                       | 1   |
| <b>CP</b>                           | 1   |
| <b>Workload in Hours</b>            | Independent Study Time 16, Study Time in Lecture 14   |
| <b>Lecturer</b>                     | Prof. Robert Seifried   |
| <b>Language</b>                     | DE  |
| <b>Cycle</b>                        | WiSe  |
| <b>Content</b>                      | Forces and equilibrium<br>Constraints and reactions<br>Frames<br>Center of mass<br>Friction<br>Internal forces and moments for beams  |
| <b>Literature</b>                   | K. Magnus, H.H. Müller-Slany: Grundlagen der Technischen Mechanik. 7. Auflage, Teubner (2009).<br>D. Gross, W. Hauger, J. Schröder, W. Wall: Technische Mechanik 1. 11. Auflage, Springer (2011). |

| Module M0883: General and Inorganic Chemistry |  |                            |               |                                |
|---|--|----------------------------|---------------|--------------------------------|
| <b>Courses</b>                                |  |                            |               |                                |
| <b>Title</b>                                  |  | <b>Typ</b>                 | <b>Hrs/wk</b> | <b>CP</b>                      |
| General and Inorganic Chemistry (L0824)       |  | Lecture                    | 3             | 3                              |
| Fundamentals in Inorganic Chemistry (L0996)   |  | Practical Course           | 3             | 2                              |
| Fundamentals in Inorganic Chemistry (L1941)   |  | Recitation Section (small) | 1             | 1                              |
| <b>Module Responsible</b>                     | Prof. Gerrit A. Luinstra   |                            |               |                                |
| <b>Admission Requirements</b>                 | None   |                            |               |                                |
| <b>Recommended Previous Knowledge</b>         | High school Chemistry  |                            |               |                                |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results   |                            |               |                                |
| <b>Professional Competence</b>                |  |                            |               |                                |
| <i>Knowledge</i>                              | Sstudents are able to handle molecular orbital theory including the octahedral ligand field, qualitatively describe the resulting electron density distribution and structures of molecules (VSEPR); they have developed an idea of molecular interactions in the gas, liquid and solid phases. They are able to describe chemical reactions in the sense of retention of mass and energy, enthalpy and entropy as well as the chemical equilibrium. They can explain the concept of activation energy in conjuncture with particle kinetic energy. They have increased knowledge of acid-base concepts, acid-base reactions in water, can perform pH calculations, understand titration as a quantitative analysis. They can recognize redox processes, correlate redox potentials to Gibbs energy, handle Nernst theory in describing the concentration dependence of redox potentials, known the concept of overpotential and understand corrosion as a redox reaction (local element). |                            |               |                                |
| <i>Skills</i>                                 | Students are able to use general and inorganic chemistry for the design of technical processes. Especially they are able to formulate mass and energy balances and by this to optimise technical processes. They are able to perform simple calculations of pH values in regard to an application of acids and bases, and evaluate the course of redox processes (calculation of redoxpotentials). They are able to transform a verbal formulated message into an abstract formal procedure. Students are able to present and discuss their scientific results in plenum. The students are able to document the results of their experiments scientifically. They are able to use scientific citation methods in their reports.  |                            |               |                                |
| <b>Personal Competence</b>                    |  |                            |               |                                |
| <i>Social Competence</i>                      | The students are able to discuss given tasks in small groups and to develop an approach.<br><br>Students are able to carry out experiments in small groups in lab scale and to distribute tasks in the group independently.  |                            |               |                                |
| <i>Autonomy</i>                               | Students are able to define independently tasks, to get new knowledge from existing knowledge as well as to find ways to use the knowledge in practice.<br><br>Students are able to apply their knowledge to plan, prepare and conduct experiments. Students are able to independently judge their own knowledge and to acquire missing knowledge that is required to fulfill their tasks.   |                            |               |                                |
| <b>Workload in Hours</b>                      | Independent Study Time 82, Study Time in Lecture 98  |                            |               |                                |
| <b>Credit points</b>                          | 6  |                            |               |                                |
| <b>Course achievement</b>                     | <b>Compulsory</b>  | <b>Bonus</b>               | <b>Form</b>   | <b>Description</b>             |
|   | Yes  | None                       | Subject       | theoretical and practical work |
| <b>Examination</b>                            | Written exam   |                            |               |                                |
| <b>Examination duration and scale</b>         | 120 minutes  |                            |               |                                |
| <b>Assignment for the Following Curricula</b> | Bioprocess Engineering: Core qualification: Compulsory<br>Energy and Environmental Engineering: Core qualification: Compulsory<br>Green Technologies: Energy, Water, Climate: Core qualification: Compulsory<br>Process Engineering: Core qualification: Compulsory  |                            |               |                                |

| Course L0824: General and Inorganic Chemistry |  |
|---|--|
| <b>Typ</b>                                    | Lecture  |
| <b>Hrs/wk</b>                                 | 3  |
| <b>CP</b>                                     | 3  |
| <b>Workload in Hours</b>                      | Independent Study Time 48, Study Time in Lecture 42  |
| <b>Lecturer</b>                               | Prof. Gerrit A. Luinstra   |
| <b>Language</b>                               | DE   |
| <b>Cycle</b>                                  | WiSe   |
| <b>Content</b>                                | This elementary course in chemistry comprises the following four topics, i) molecular orbital theory applied to compounds with bonds between s-, p- and d-block elements (octahedral field only), Description of molecular interactions in the gas, liquid and solid phase, (semi) conductivity on account of the formation of band structures, ii) describing chemical reactions in the sense of retention of mass and energy, enthalpy and entropy, chemical equilibrium, concepts of activation energy in conjuncture with particle kinetic energy iii) acid-base concepts, acid-base reactions in water, pH calculation, quantitative analysis (titration) iv), redox processes in water, redox potential, Nernst theory describing the concentration dependence of redox potentials, overpotential, corrosion (local elements). |
| <b>Literature</b>                             | Chemie für Ingenieure, Guido Kickelbick, ISBN 978-3-8273-7267-3<br>Chemie, Charles Mortimer (Deutsch und Englisch verfügbar)<br><a href="http://www.chemgapedia.de">http://www.chemgapedia.de</a>  |

| Course L0996: Fundamentals in Inorganic Chemistry |   |
|---|---|
| <b>Typ</b>  | Practical Course  |
| <b>Hrs/wk</b>                                     | 3   |
| <b>CP</b>   | 2   |
| <b>Workload in Hours</b>                          | Independent Study Time 18, Study Time in Lecture 42   |
| <b>Lecturer</b>                                   | Prof. Gerrit A. Luinstra  |
| <b>Language</b>                                   | DE  |
| <b>Cycle</b>                                      | WiSe  |
| <b>Content</b>                                    | This laboratory course comprises the following four topics, i) atomic structure and application of spectroscopic methods, introduction of analytic methods ii) chemical reactions (qualitative analysis), bonding types, reaction types, reaction equations iii) acid-base concepts, acid-base reactions in water, buffer solution, quantitative analysis (titration) iv), redox processes in water, redox potential, Nernst theory describing the concentration dependence of redox potentials, galvanic elements and electrolysis.<br><br>Prior to every experiment, a seminar takes place in small groups (12-15 students). The students participate orally. Team work and cooperation are forwarded because the experiments in the lab and the writing of the reports is conducted in groups of three or four students. Additionally, academic writing conveyed (documentation of experiment results in lab journals, literature citations in reports). |
| <b>Literature</b>                                 | Chemie für Ingenieure, Guido Kickelbick, ISBN 978-3-8273-7267-3<br>Chemie, Charles Mortimer (Deutsch und Englisch verfügbar)<br>Analytische und anorganische Chemie, Jander/Blasius<br>Maßanalyse, Jander/Jahr  |

| Course L1941: Fundamentals in Inorganic Chemistry |   |
|---|---|
| <b>Typ</b>  | Recitation Section (small)                          |
| <b>Hrs/wk</b>                                     | 1   |
| <b>CP</b>   | 1   |
| <b>Workload in Hours</b>                          | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>                                   | Prof. Gerrit A. Luinstra                            |
| <b>Language</b>                                   | DE  |
| <b>Cycle</b>                                      | WiSe  |
| <b>Content</b>                                    |   |
| <b>Literature</b>                                 |   |

| Module M1497: Measurement Technology for VT/ BVT        |  |                  |               |                                    |
|---|--|------------------|---------------|------------------------------------|
| <b>Courses</b>  |  |                  |               |                                    |
| <b>Title</b>  |  | <b>Typ</b>       | <b>Hrs/wk</b> | <b>CP</b>                          |
| Practical Course Measurement Technology (L2270)         |  | Practical Course | 2             | 2                                  |
| Measurement Technology (L2268)                          |  | Lecture          | 2             | 2                                  |
| Physical Fundamentals of Measurement Technology (L2269) |  | Lecture          | 2             | 2                                  |
| <b>Module Responsible</b>                               | Prof. Alexander Penn   |                  |               |                                    |
| <b>Admission Requirements</b>                           | None   |                  |               |                                    |
| <b>Recommended Previous Knowledge</b>                   | Technical interest, logical skills, integral- and differential calculus, basic physical concepts such as temperature, mass, velocity, etc..  |                  |               |                                    |
| <b>Educational Objectives</b>                           | After taking part successfully, students have reached the following learning results   |                  |               |                                    |
| <b>Professional Competence</b>                          |  |                  |               |                                    |
| <i>Knowledge</i>  | Physical basics: kinematics and dynamics (theory of motion), rotation of rigid bodies, energy and momentum, electricity, magnetism, basics of hydrodynamics, temperature and heat, ideal gas.<br><br>Metrology: SI units, measurement and measurement uncertainty, basics of sensor technology, physical principles, temperature measurement, pressure measurement, level measurement, flow measurement. Usage of Matlab scripts.<br><br>Practical course: Pressure drop in piping, calorimetry, image data acquisition, flow measurement, concentration measurement and mass transfer, capacitive measurements of solid concentrations, spectroscopy, error calculation, chromatography   |                  |               |                                    |
| <i>Skills</i>   | Literature research, categorisation of thematical topics, analysis of an experimental test stand, preparation of test protocol, first programming with Matlab, use of relevant laboratory measurement technology, preparation of a test protocol, execution of calculations.   |                  |               |                                    |
| <b>Personal Competence</b>                              |  |                  |               |                                    |
| <i>Social Competence</i>                                | Arrangement and division of work in practical training and learning groups, assessment of own level of knowledge, work on the experimental stand in groups, consultation with persons responsible for teaching, presentation of the preparation of the experiment, tolerance of frustration  |                  |               |                                    |
| <i>Autonomy</i>   | Time management of the workload, independent development of the thematic basics, personal responsibility for the provision of protective equipment and work clothing, practice of presentation in front of a group, active participation in the lectures, formulation of enquiries/detailed questions by using clicker.  |                  |               |                                    |
| <b>Workload in Hours</b>                                | Independent Study Time 96, Study Time in Lecture 84  |                  |               |                                    |
| <b>Credit points</b>                                    | 6  |                  |               |                                    |
| <b>Course achievement</b>                               | <b>Compulsory</b>  | <b>Bonus</b>     | <b>Form</b>   | <b>Description</b>                 |
|   | No   | 20 %             | Excercises    | Popup-Quizzes währen der Vorlesung |
| <b>Examination</b>                                      | Written exam   |                  |               |                                    |
| <b>Examination duration and scale</b>                   | 120 min  |                  |               |                                    |
| <b>Assignment for the Following Curricula</b>           | General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Green Technologies: Compulsory<br>Bioprocess Engineering: Core qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Process Engineering: Compulsory<br>Green Technologies: Energy, Water, Climate: Core qualification: Compulsory<br>Orientation Studies: Core qualification: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory |                  |               |                                    |

| Course L2270: Practical Course Measurement Technology |  |
|---|--|
| <b>Typ</b>  | Practical Course   |
| <b>Hrs/wk</b>   | 2  |
| <b>CP</b>   | 2  |
| <b>Workload in Hours</b>                              | Independent Study Time 32, Study Time in Lecture 28  |
| <b>Lecturer</b>                                       | Prof. Alexander Penn   |
| <b>Language</b>                                       | DE   |
| <b>Cycle</b>  | WiSe   |
| <b>Content</b>  | In the Practical Course in Measurement Technology the theory from the lectures "Physical Fundamentals of Measurement Technology" and "Measurement Technology" will be applied in practice. In small groups students learn how to handle different measurement techniques from industry and research. During the practical course, a wide range of different measurement methods will be taught, including the use of HPLC columns for qualitative mass analysis, the determination of mass transfer coefficients using optical oxygen sensors or the evaluation of image data to obtain process parameters. The practical course also teaches how measurement data are statistically evaluated and experiments are correctly documented. |
| <b>Literature</b>                                     | Hug, H.: Instrumentelle Analytik. Theorie und Praxis. Verlag Europa-Lehrmittel, Haan-Gruiten, 2015.<br><br>Kamke, W.: Der Umgang mit experimentellen Daten, insbesondere Fehleranalyse, im physikalischen Anfänger-Praktikum. Eine elementare Einführung. W. Kamke, Kirchzarten [Keltnering 197], 2010.<br><br>Strohmann, G.: Messtechnik im Chemiebetrieb. Einführung in das Messen verfahrenstechnischer Größen. Oldenbourg, München, 2004.  |

| <b>Course L2268: Measurement Technology</b> |   |
|---|---|
| <b>Typ</b>                                  | Lecture   |
| <b>Hrs/wk</b>                               | 2   |
| <b>CP</b>                                   | 2   |
| <b>Workload in Hours</b>                    | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>                             | Prof. Alexander Penn  |
| <b>Language</b>                             | DE  |
| <b>Cycle</b>                                | WiSe  |
| <b>Content</b>                              | Basic introduction to measurement technology for process engineers. Includes error calculation, measurement units, calibration, measurement data analysis, measurement techniques and sensors. Particular attention is paid to the measurement of temperature, pressure, flow and level. The lecture provides insights into the latest developments in sensor technology in measurement technology and process engineering.   |
| <b>Literature</b>                           | <p>Fraden, Jacob (2016): Handbook of Modern Sensors. Physics, Designs, and Applications. 5th ed. 2016. Cham, New York: Springer. Online verfügbar unter <a href="http://search.ebscohost.com/login.aspx?direct=true&amp;scope=site&amp;db=nlebk&amp;AN=1081958">http://search.ebscohost.com/login.aspx?direct=true&amp;scope=site&amp;db=nlebk&amp;AN=1081958</a>.</p> <p>Hering, Ekbert; Schönfelder, Gert (2018): Sensoren in Wissenschaft und Technik. Funktionsweise und Einsatzgebiete. 2. Aufl. 2018. Online verfügbar unter <a href="http://dx.doi.org/10.1007/978-3-658-12562-2">http://dx.doi.org/10.1007/978-3-658-12562-2</a>.</p> <p>Strohmann, Günther (2004): Messtechnik im Chemiebetrieb. Einführung in das Messen verfahrenstechnischer Größen. 10., durchges. Aufl. München: Oldenbourg.</p> <p>Tränkler, Hans-Rolf; Reindl, Leonhard M. (2014): Sensortechnik. Handbuch für Praxis und Wissenschaft. 2., völlig neu bearb. Aufl. Berlin: Springer Vieweg (VDI-Buch). Online verfügbar unter <a href="http://dx.doi.org/10.1007/978-3-642-29942-1">http://dx.doi.org/10.1007/978-3-642-29942-1</a>.</p> <p>Webster, John G.; Eren, Halit B. (2014): Measurement, Instrumentation, and Sensors Handbook, Second Edition. Electromagnetic, Optical, Radiation, Chemical, and Biomedical Measurement. 2nd ed. Hoboken: Taylor and Francis. Online verfügbar unter <a href="http://gbv.eblib.com/patron/FullRecord.aspx?p=1407945">http://gbv.eblib.com/patron/FullRecord.aspx?p=1407945</a>.</p> |

| <b>Course L2269: Physical Fundamentals of Measurement Technology</b> |   |
|--|---|
| <b>Typ</b>   | Lecture   |
| <b>Hrs/wk</b>  | 2   |
| <b>CP</b>  | 2   |
| <b>Workload in Hours</b>   | Independent Study Time 32, Study Time in Lecture 28 |
| <b>Lecturer</b>  | Prof. Christian Schroer                             |
| <b>Language</b>  | DE  |
| <b>Cycle</b>   | WiSe  |
| <b>Content</b>   |   |
| <b>Literature</b>  |   |



| Module M0671: Technical Thermodynamics I      |   |               |           |
|---|---|---------------|-----------|
| <b>Courses</b>                                |   |               |           |
| <b>Title</b>                                  | <b>Typ</b>  | <b>Hrs/wk</b> | <b>CP</b> |
| Technical Thermodynamics I (L0437)            | Lecture   | 2             | 4         |
| Technical Thermodynamics I (L0439)            | Recitation Section (large)  | 1             | 1         |
| Technical Thermodynamics I (L0441)            | Recitation Section (small)  | 1             | 1         |
| <b>Module Responsible</b>                     | NN  |               |           |
| <b>Admission Requirements</b>                 | None  |               |           |
| <b>Recommended Previous Knowledge</b>         | Elementary knowledge in Mathematics and Mechanics   |               |           |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results  |               |           |
| <b>Professional Competence</b>                | <p><i>Knowledge</i> Students are familiar with the laws of Thermodynamics. They know the relation of the kinds of energy according to 1<sup>st</sup> law of Thermodynamics and are aware about the limits of energy conversions according to 2<sup>nd</sup> law of Thermodynamics. They are able to distinguish between state variables and process variables and know the meaning of different state variables like temperature, enthalpy, entropy and also the meaning of exergy and energy. They are able to draw the Carnot cycle in a Thermodynamics related diagram. They know the physical difference between an ideal and a real gas and are able to use the related equations of state. They know the meaning of a fundamental state of equation and know the basics of two phase Thermodynamics.</p> <p><i>Skills</i> Students are able to calculate the internal energy, the enthalpy, the kinetic and the potential energy as well as work and heat for simple change of states and to use this calculations for the Carnot cycle. They are able to calculate state variables for an ideal and for a real gas from measured thermal state variables.</p> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> The students are able to discuss in small groups and develop an approach.</p> <p><i>Autonomy</i> Students are able to define independently tasks, to get new knowledge from existing knowledge as well as to find ways to use the knowledge in practice.</p> |               |           |
| <b>Workload in Hours</b>                      | Independent Study Time 124, Study Time in Lecture 56  |               |           |
| <b>Credit points</b>                          | 6   |               |           |
| <b>Course achievement</b>                     | None  |               |           |
| <b>Examination</b>                            | Written exam  |               |           |
| <b>Examination duration and scale</b>         | 90 min  |               |           |
| <b>Assignment for the Following Curricula</b> | General Engineering Science (German program, 7 semester): Core qualification: Compulsory<br>Bioprocess Engineering: Core qualification: Compulsory<br>Digital Mechanical Engineering: Core qualification: Compulsory<br>Energy and Environmental Engineering: Core qualification: Compulsory<br>Green Technologies: Energy, Water, Climate: Core qualification: Compulsory<br>Logistics and Mobility: Specialisation Traffic Planning and Systems: Elective Compulsory<br>Mechanical Engineering: Core qualification: Compulsory<br>Mechatronics: Core qualification: Compulsory<br>Orientation Studies: Core qualification: Elective Compulsory<br>Naval Architecture: Core qualification: Compulsory<br>Technomathematics: Specialisation III. Engineering Science: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory<br>Engineering and Management - Major in Logistics and Mobility: Specialisation Traffic Planning and Systems: Elective Compulsory  |               |           |

| Course L0437: Technical Thermodynamics I |   |
|--|---|
| <b>Typ</b>                               | Lecture   |
| <b>Hrs/wk</b>                            | 2   |
| <b>CP</b>                                | 4   |
| <b>Workload in Hours</b>                 | Independent Study Time 92, Study Time in Lecture 28   |
| <b>Lecturer</b>                          | NN  |
| <b>Language</b>                          | DE  |
| <b>Cycle</b>                             | SoSe  |
| <b>Content</b>                           | <ol style="list-style-type: none"> <li>1. Introduction</li> <li>2. Fundamental terms</li> <li>3. Thermal Equilibrium and temperature                             <ol style="list-style-type: none"> <li>3.1 Thermal equation of state</li> </ol> </li> <li>4. First law                             <ol style="list-style-type: none"> <li>4.1 Heat and work</li> <li>4.2 First law for closed systems</li> <li>4.3 First law for open systems</li> <li>4.4 Examples</li> </ol> </li> <li>5. Equations of state and changes of state                             <ol style="list-style-type: none"> <li>5.1 Changes of state</li> <li>5.2 Cycle processes</li> </ol> </li> <li>6. Second law                             <ol style="list-style-type: none"> <li>6.1 Carnot process</li> <li>6.2 Entropy</li> <li>6.3 Examples</li> <li>6.4 Exergy</li> </ol> </li> <li>7. Thermodynamic properties of pure fluids                             <ol style="list-style-type: none"> <li>7.1 Fundamental equations of Thermodynamics</li> <li>7.2 Thermodynamic potentials</li> <li>7.3 Calorific state variables for arbitrary fluids</li> <li>7.4 state equations (van der Waals u.a.)</li> </ol> </li> </ol> |
| <b>Literature</b>                        | <ul style="list-style-type: none"> <li>• Schmitz, G.: Technische Thermodynamik, TuTech Verlag, Hamburg, 2009</li> <li>• Baehr, H.D.; Kabelac, S.: Thermodynamik, 15. Auflage, Springer Verlag, Berlin 2012</li> <li>• Potter, M.; Somerton, C.: Thermodynamics for Engineers, Mc GrawHill, 1993</li> </ul>  |

| Course L0439: Technical Thermodynamics I |   |
|--|---|
| <b>Typ</b>                               | Recitation Section (large)                          |
| <b>Hrs/wk</b>                            | 1   |
| <b>CP</b>                                | 1   |
| <b>Workload in Hours</b>                 | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>                          | NN  |
| <b>Language</b>                          | DE  |
| <b>Cycle</b>                             | SoSe  |
| <b>Content</b>                           | See interlocking course                             |
| <b>Literature</b>                        | See interlocking course                             |

| Course L0441: Technical Thermodynamics I |   |
|--|---|
| <b>Typ</b>                               | Recitation Section (small)                          |
| <b>Hrs/wk</b>                            | 1   |
| <b>CP</b>                                | 1   |
| <b>Workload in Hours</b>                 | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>                          | NN  |
| <b>Language</b>                          | DE  |
| <b>Cycle</b>                             | SoSe  |
| <b>Content</b>                           | See interlocking course                             |
| <b>Literature</b>                        | See interlocking course                             |

| Module M0888: Organic Chemistry               |   |                  |  |
|---|---|------------------|--|
| <b>Courses</b>                                |   |                  |  |
| <b>Title</b>                                  |   | <b>Typ</b>       | <b>Hrs/wk</b> <b>CP</b>                |
| Organic Chemistry (L0831)                     |   | Lecture          | 4              4                       |
| Organic Chemistry (L0832)                     |   | Practical Course | 3              2                       |
| <b>Module Responsible</b>                     | Prof. Ralph Holl  |                  |  |
| <b>Admission Requirements</b>                 | None  |                  |  |
| <b>Recommended Previous Knowledge</b>         | High School Chemistry and/or lecture "general and inorganic chemistry"  |                  |  |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results  |                  |  |
| <b>Professional Competence</b>                |   |                  |  |
| <i>Knowledge</i>                              | Students are familiar with basic concepts of organic chemistry. They are able to classify organic molecules and to identify functional groups and to describe the respective synthesis routes. Fundamental reaction mechanisms like nucleophilic substitution, eliminations, additions and aromatic substitution can be described. Students are capable to describe in general modern reaction mechanisms.  |                  |  |
| <i>Skills</i>                                 | Students are able to use basics of organic chemistry for the design of technical processes. Especially they are able to formulate basic routes to synthesize small organic molecules and by this to optimise technical processes in Process Engineering. They are able to transform a verbally formulated message into an abstract formal procedure.<br><br>The students are able to document and interpret their working process and results scientifically. |                  |  |
| <b>Personal Competence</b>                    |   |                  |  |
| <i>Social Competence</i>                      | The students are able to discuss in small groups and develop an approach for given tasks.   |                  |  |
| <i>Autonomy</i>                               | Students are able to get new knowledge from existing knowledge as well as to find ways to use the knowledge in practice.  |                  |  |
| <b>Workload in Hours</b>                      | Independent Study Time 82, Study Time in Lecture 98   |                  |  |
| <b>Credit points</b>                          | 6   |                  |  |
| <b>Course achievement</b>                     | <b>Compulsory</b>   | <b>Bonus</b>     | <b>Form</b> <b>Description</b>         |
|   | Yes   | None             | Subject theoretical and practical work |
| <b>Examination</b>                            | Written exam  |                  |  |
| <b>Examination duration and scale</b>         | 90 minutes  |                  |  |
| <b>Assignment for the Following Curricula</b> | Bioprocess Engineering: Core qualification: Compulsory<br>Energy and Environmental Engineering: Core qualification: Compulsory<br>Green Technologies: Energy, Water, Climate: Core qualification: Compulsory<br>Process Engineering: Core qualification: Compulsory   |                  |  |

| Course L0831: Organic Chemistry |  |
|---------------------------------|--|
| <b>Typ</b>                      | Lecture  |
| <b>Hrs/wk</b>                   | 4  |
| <b>CP</b>                       | 4  |
| <b>Workload in Hours</b>        | Independent Study Time 64, Study Time in Lecture 56  |
| <b>Lecturer</b>                 | Prof. Ralph Holl, Prof. Pierre Stallforth  |
| <b>Language</b>                 | DE   |
| <b>Cycle</b>                    | SoSe   |
| <b>Content</b>                  | The lecture covers basic concepts of organic chemistry. This includes simple carbon compounds, alkanes, alkenes, aromatic compounds, alcohols, phenols, ethers, aldehydes, ketones, carboxylic acids, esters, amines, amides and amino acids. Further, fundamentals of reaction mechanisms will be described. This includes nucleophilic substitution, eliminations, additions and aromatic substitution. Also modern reaction mechanisms will be described. |
| <b>Literature</b>               | gängige einführende Werke zur Organischen Chemie. Z.B. „Organische Chemie“ von K.P.C.Vollhart & N.E.Schore, Wiley VCH  |

| Course L0832: Organic Chemistry |  |
|---------------------------------|--|
| <b>Typ</b>                      | Practical Course   |
| <b>Hrs/wk</b>                   | 3  |
| <b>CP</b>                       | 2  |
| <b>Workload in Hours</b>        | Independent Study Time 18, Study Time in Lecture 42  |
| <b>Lecturer</b>                 | Prof. Ralph Holl, Prof. Pierre Stallforth  |
| <b>Language</b>                 | DE   |
| <b>Cycle</b>                    | SoSe   |
| <b>Content</b>                  | <p>The lecture covers basic concepts of organic chemistry. This includes simple carbon compounds, alkanes, alkenes, aromatic compounds, alcohols, phenols, ethers, aldehydes, ketones, carboxylic acids, esters, amines, amides and amino acids. Further, fundamentals of reaction mechanisms will be described. This includes nucleophilic substitution, eliminations, additions and aromatic substitution. Also modern reaction mechanisms will be described.</p> <p>Prior to each experiment, an oral colloquium takes place in small groups. In the colloquium are security aspects of the experiments are discussed, as well as the topics of the experiments. Solutions to previously provided questions are answered. In the colloquia the students acquire the skill to express scientific matters orally in a scientifically correct language and to describe theoretical basics.</p> <p>The students write up a report for every experiment. They receive feedback to their level of scientific writing (citation methods, labeling of graphs, etc.), so that they can improve their competence in this field over the course of the practical course.</p> |
| <b>Literature</b>               | gängige einführende Werke zur Organischen Chemie. Z.B. „Organische Chemie“ von K.P.C.Vollhart & N.E.Schore, Wiley VCH  |

| Module M1276: Fundamentals of technical drawing |  |               |             |
|---|--|---------------|-------------|
| <b>Courses</b>                                  |  |               |             |
| <b>Title</b>                                    | <b>Typ</b>   | <b>Hrs/wk</b> | <b>CP</b>   |
| Fundamentals of Technical Drawing (L1741)       | Lecture  | 1             | 1           |
| Fundamentals of Technical Drawing (L1742)       | Recitation Section (large)   | 1             | 2           |
| <b>Module Responsible</b>                       | Dr. Marko Hoffmann   |               |             |
| <b>Admission Requirements</b>                   | None   |               |             |
| <b>Recommended Previous Knowledge</b>           | <ul style="list-style-type: none"> <li>Basic internship</li> </ul>   |               |             |
| <b>Educational Objectives</b>                   | After taking part successfully, students have reached the following learning results   |               |             |
| <b>Professional Competence</b>                  | <ul style="list-style-type: none"> <li>Students will learn how to generate technical drawing/create technical drawings according to norms</li> <li>Students will become acquainted with the various types of views in drawings (projection methods, views, sectional representations)</li> <li>Students will learn how to insert the dimensions in technical drawings</li> <li>Students will acquire the skills to render data in detailed drawings according to norms (e.g. tolerance dimensioning, fits and surface specifications)</li> </ul> |               |             |
| <i>Knowledge</i>                                |  |               |             |
| <i>Skills</i>                                   | <ul style="list-style-type: none"> <li>Students are capable to construct simple technical drawings, considering tolerances and fits.</li> <li>Students are capable to strengthen the spatial sense.</li> </ul>   |               |             |
| <b>Personal Competence</b>                      | <ul style="list-style-type: none"> <li>Students are able to work together in basic groups on subject related tasks and small design studies and present their results.</li> </ul>  |               |             |
| <i>Social Competence</i>                        |  |               |             |
| <i>Autonomy</i>                                 | <ul style="list-style-type: none"> <li>Students are capable to self-reliantly gather information from subject related, professional publications and relate that information to the context of the lecture, e.g. preparing of technical drawings or choosing of a construction material for a process equipment.</li> <li>They work on their homework by their own and get feedback in their particular basis group to evaluate their actual knowledge.</li> </ul>   |               |             |
| <b>Workload in Hours</b>                        | Independent Study Time 62, Study Time in Lecture 28  |               |             |
| <b>Credit points</b>                            | 3  |               |             |
| <b>Course achievement</b>                       | <b>Compulsory</b>  | <b>Bonus</b>  | <b>Form</b> |
|   | No   | 5 %           | Exercises   |
| <b>Examination</b>                              | Written exam   |               |             |
| <b>Examination duration and scale</b>           | 90 min   |               |             |
| <b>Assignment for the Following Curricula</b>   | Bioprocess Engineering: Core qualification: Elective Compulsory<br>Orientation Studies: Core qualification: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory   |               |             |

| Course L1741: Fundamentals of Technical Drawing |   |
|---|---|
| <b>Typ</b>                                      | Lecture   |
| <b>Hrs/wk</b>                                   | 1   |
| <b>CP</b>                                       | 1   |
| <b>Workload in Hours</b>                        | Independent Study Time 16, Study Time in Lecture 14   |
| <b>Lecturer</b>                                 | Dr. Marko Hoffmann  |
| <b>Language</b>                                 | DE  |
| <b>Cycle</b>                                    | SoSe  |
| <b>Content</b>                                  | <ul style="list-style-type: none"> <li>Technical drawing basics (contents, kinds of drawings and generation of drawings according to relevant standards)</li> <li>Projective geometry (basics, orthographic projections, isometric projections, cuts, developed views, penetration views)</li> </ul>  |
| <b>Literature</b>                               | <ul style="list-style-type: none"> <li>Hoischen, Hans; Fritz, Andreas (Hrsg.): "Hoischen/Technisches Zeichnen: Grundlagen, Normen, Beispiele, Darstellende Geometrie", 35. überarbeitete und aktualisierte Auflage, Cornelsen Verlag, Berlin, 2016.</li> <li>Fritz, Andreas; Hoischen, Hans; Rund, Wolfgang (Hrsg.): "Praxis des Technischen Zeichnens Metall / Erklärungen, Übungen, Tests", 17. überarbeitete Auflage; Cornelsen Verlag, Berlin, 2016.</li> <li>Labisch, Susanna; Weber, Christian: "Technisches Zeichnen : Selbstständig lernen und effektiv üben", 4. überarbeitete und erweiterte Auflage, Springer Vieweg Verlag, Wiesbaden, 2013.</li> <li>Kurz, Ulrich; Wittel, Herbert: "Böttcher/Forberg Technisches Zeichnen : Grundlagen, Normung, Übungen und Projektaufgaben", 26. überarbeitete und erweiterte Auflage, Springer Vieweg Verlag, Wiesbaden, 2014.</li> <li>Klein, Martin; Alex, Dieter u.a.; DIN: Deutsches Institut für Normung e.V. (Hrsg.): "Einführung in die DIN-Normen"; 14. neubearbeitete Auflage, Teubner u.a., Stuttgart u.a., 2008.</li> </ul> |

| <b>Course L1742: Fundamentals of Technical Drawing</b> |   |
|--|---|
| <b>Typ</b>   | Recitation Section (large)                          |
| <b>Hrs/wk</b>  | 1   |
| <b>CP</b>  | 2   |
| <b>Workload in Hours</b>                               | Independent Study Time 46, Study Time in Lecture 14 |
| <b>Lecturer</b>  | Dr. Marko Hoffmann                                  |
| <b>Language</b>  | DE  |
| <b>Cycle</b>   | SoSe  |
| <b>Content</b>   | See interlocking course                             |
| <b>Literature</b>                                      | See interlocking course                             |

| Module M0851: Mathematics II                  |  |        |    |  |
|---|--|--------|----|--|
| Courses                                       |  |        |    |  |
| Title   | Typ  | Hrs/wk | CP |  |
| Analysis II (L1025)                           | Lecture  | 2      | 2  |  |
| Analysis II (L1026)                           | Recitation Section (large)   | 1      | 1  |  |
| Analysis II (L1027)                           | Recitation Section (small)   | 1      | 1  |  |
| Linear Algebra II (L0915)                     | Lecture  | 2      | 2  |  |
| Linear Algebra II (L0916)                     | Recitation Section (small)   | 1      | 1  |  |
| Linear Algebra II (L0917)                     | Recitation Section (large)   | 1      | 1  |  |
| <b>Module Responsible</b>                     | Prof. Anusch Taraz   |        |    |  |
| <b>Admission Requirements</b>                 | None   |        |    |  |
| <b>Recommended Previous Knowledge</b>         | Mathematics I  |        |    |  |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results   |        |    |  |
| <b>Professional Competence</b>                | <ul style="list-style-type: none"> <li>• Students can name further concepts in analysis and linear algebra. They are able to explain them using appropriate examples.</li> <li>• Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples.</li> <li>• They know proof strategies and can reproduce them.</li> </ul>   |        |    |  |
| <i>Knowledge</i>                              |  |        |    |  |
| <i>Skills</i>                                 |  |        |    |  |
| <b>Personal Competence</b>                    |  |        |    |  |
| <i>Social Competence</i>                      | <ul style="list-style-type: none"> <li>• Students can model problems in analysis and linear algebra with the help of the concepts studied in this course. Moreover, they are capable of solving them by applying established methods.</li> <li>• Students are able to discover and verify further logical connections between the concepts studied in the course.</li> <li>• For a given problem, the students can develop and execute a suitable approach, and are able to critically evaluate the results.</li> </ul>  |        |    |  |
| <i>Autonomy</i>                               | <ul style="list-style-type: none"> <li>• Students are able to work together in teams. They are capable to use mathematics as a common language.</li> <li>• In doing so, they can communicate new concepts according to the needs of their cooperating partners. Moreover, they can design examples to check and deepen the understanding of their peers.</li> </ul>  |        |    |  |
| <i>Autonomy</i>                               | <ul style="list-style-type: none"> <li>• 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.</li> <li>• Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.</li> </ul>   |        |    |  |
| <b>Workload in Hours</b>                      | Independent Study Time 128, Study Time in Lecture 112  |        |    |  |
| <b>Credit points</b>                          | 8  |        |    |  |
| <b>Course achievement</b>                     | None   |        |    |  |
| <b>Examination</b>                            | Written exam   |        |    |  |
| <b>Examination duration and scale</b>         | 60 min (Analysis II) + 60 min (Linear Algebra II)  |        |    |  |
| <b>Assignment for the Following Curricula</b> | General Engineering Science (German program, 7 semester): Core qualification: Compulsory<br>Civil- and Environmental Engineering: Core qualification: Compulsory<br>Bioprocess Engineering: Core qualification: Compulsory<br>Digital Mechanical Engineering: Core qualification: Compulsory<br>Electrical Engineering: Core qualification: Compulsory<br>Energy and Environmental Engineering: Core qualification: Compulsory<br>Green Technologies: Energy, Water, Climate: Core qualification: Compulsory<br>Computational Science and Engineering: Core qualification: Compulsory<br>Logistics and Mobility: Core qualification: Compulsory<br>Mechanical Engineering: Core qualification: Compulsory<br>Mechatronics: Core qualification: Compulsory<br>Orientation Studies: Core qualification: Elective Compulsory<br>Naval Architecture: Core qualification: Compulsory<br>Process Engineering: Core qualification: Compulsory<br>Engineering and Management - Major in Logistics and Mobility: Core qualification: Compulsory |        |    |  |

| Course L1025: Analysis II |   |
|---------------------------|---|
| <b>Typ</b>                | Lecture   |
| <b>Hrs/wk</b>             | 2   |
| <b>CP</b>                 | 2   |
| <b>Workload in Hours</b>  | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>           | Dozenten des Fachbereiches Mathematik der UHH   |
| <b>Language</b>           | DE  |
| <b>Cycle</b>              | SoSe  |
| <b>Content</b>            | <ul style="list-style-type: none"> <li>• power series and elementary functions</li> <li>• interpolation</li> <li>• integration (proper integrals, fundamental theorem, integration rules, improper integrals, parameter dependent integrals)</li> <li>• applications of integration (volume and surface of bodies of revolution, lines and arc length, line integrals)</li> <li>• numerical quadrature</li> <li>• periodic functions</li> </ul> |
| <b>Literature</b>         | <ul style="list-style-type: none"> <li>• <a href="http://www.math.uni-hamburg.de/teaching/export/tuhh/index.html">http://www.math.uni-hamburg.de/teaching/export/tuhh/index.html</a></li> </ul>   |

| Course L1026: Analysis II |   |
|---------------------------|---|
| <b>Typ</b>                | Recitation Section (large)                          |
| <b>Hrs/wk</b>             | 1   |
| <b>CP</b>                 | 1   |
| <b>Workload in Hours</b>  | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>           | Dozenten des Fachbereiches Mathematik der UHH       |
| <b>Language</b>           | DE  |
| <b>Cycle</b>              | SoSe  |
| <b>Content</b>            | See interlocking course                             |
| <b>Literature</b>         | See interlocking course                             |

| Course L1027: Analysis II |   |
|---------------------------|---|
| <b>Typ</b>                | Recitation Section (small)                          |
| <b>Hrs/wk</b>             | 1   |
| <b>CP</b>                 | 1   |
| <b>Workload in Hours</b>  | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>           | Dozenten des Fachbereiches Mathematik der UHH       |
| <b>Language</b>           | DE  |
| <b>Cycle</b>              | SoSe  |
| <b>Content</b>            | See interlocking course                             |
| <b>Literature</b>         | See interlocking course                             |

| Course L0915: Linear Algebra II |   |
|---------------------------------|---|
| <b>Typ</b>                      | Lecture   |
| <b>Hrs/wk</b>                   | 2   |
| <b>CP</b>                       | 2   |
| <b>Workload in Hours</b>        | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>                 | Prof. Anusch Taraz, Prof. Marko Lindner, Dr. Dennis Clemens   |
| <b>Language</b>                 | DE  |
| <b>Cycle</b>                    | SoSe  |
| <b>Content</b>                  | <ul style="list-style-type: none"> <li>• general vector spaces: subspaces, Euclidean vector spaces</li> <li>• linear mappings: basis transformation, orthogonal projection, orthogonal matrices, householder matrices</li> <li>• linear regression: normal equations, linear discrete approximation</li> <li>• eigenvalues: diagonalising matrices, normal matrices, symmetric and Hermite matrices</li> <li>• system of linear differential equations</li> <li>• matrix factorizations: LR-decomposition, QR-decomposition, Schur decomposition, Jordan normal form, singular value decomposition</li> </ul> |
| <b>Literature</b>               | <ul style="list-style-type: none"> <li>• T. Arens u.a. : Mathematik, Spektrum Akademischer Verlag, Heidelberg 2009</li> <li>• W. Mackens, H. Voß: Mathematik I für Studierende der Ingenieurwissenschaften, HECO-Verlag, Alsdorf 1994</li> <li>• W. Mackens, H. Voß: Aufgaben und Lösungen zur Mathematik I für Studierende der Ingenieurwissenschaften, HECO-Verlag, Alsdorf 1994</li> <li>• G. Strang: Lineare Algebra, Springer-Verlag, 2003</li> <li>• G. und S. Teschl: Mathematik für Informatiker, Band 1, Springer-Verlag, 2013</li> </ul>  |



| Course L0916: Linear Algebra II |  |
|---------------------------------|--|
| <b>Typ</b>                      | Recitation Section (small)   |
| <b>Hrs/wk</b>                   | 1  |
| <b>CP</b>                       | 1  |
| <b>Workload in Hours</b>        | Independent Study Time 16, Study Time in Lecture 14  |
| <b>Lecturer</b>                 | Prof. Anusch Taraz, Prof. Marko Lindner, Dr. Dennis Clemens  |
| <b>Language</b>                 | DE   |
| <b>Cycle</b>                    | SoSe   |
| <b>Content</b>                  | <ul style="list-style-type: none"> <li>• linear mappings: basis transformation, orthogonal projection, orthogonal matrices, householder matrices</li> <li>• linear regression: QR-decomposition, normal equations, linear discrete approximation</li> <li>• eigenvalues: diagonalising matrices, normal matrices, symmetric and Hermite matrices, Jordan normal form, singular value decomposition</li> <li>• system of linear differential equations</li> </ul> |
| <b>Literature</b>               | <ul style="list-style-type: none"> <li>• W. Mackens, H. Voß: Mathematik I für Studierende der Ingenieurwissenschaften, HECO-Verlag, Alsdorf 1994</li> <li>• W. Mackens, H. Voß: Aufgaben und Lösungen zur Mathematik I für Studierende der Ingenieurwissenschaften, HECO-Verlag, Alsdorf 1994</li> </ul>   |

| Course L0917: Linear Algebra II |  |
|---------------------------------|--|
| <b>Typ</b>                      | Recitation Section (large)   |
| <b>Hrs/wk</b>                   | 1  |
| <b>CP</b>                       | 1  |
| <b>Workload in Hours</b>        | Independent Study Time 16, Study Time in Lecture 14                                |
| <b>Lecturer</b>                 | Prof. Anusch Taraz, Prof. Marko Lindner, Dr. Christian Seifert, Dr. Dennis Clemens |
| <b>Language</b>                 | DE   |
| <b>Cycle</b>                    | SoSe   |
| <b>Content</b>                  | See interlocking course  |
| <b>Literature</b>               | See interlocking course  |

| Module M0696: Mechanics II: Mechanics of Materials |  |                            |               |           |
|--|--|----------------------------|---------------|-----------|
| <b>Courses</b>                                     |  |                            |               |           |
| <b>Title</b>                                       |  | <b>Typ</b>                 | <b>Hrs/wk</b> | <b>CP</b> |
| Mechanics II (L0493)                               |  | Lecture                    | 2             | 2         |
| Mechanics II (L0494)                               |  | Recitation Section (small) | 2             | 2         |
| Mechanics II (L1691)                               |  | Recitation Section (large) | 2             | 2         |
| <b>Module Responsible</b>                          | Prof. Christian Cyron  |                            |               |           |
| <b>Admission Requirements</b>                      | None   |                            |               |           |
| <b>Recommended Previous Knowledge</b>              | Mechanics I  |                            |               |           |
| <b>Educational Objectives</b>                      | After taking part successfully, students have reached the following learning results   |                            |               |           |
| <b>Professional Competence</b>                     | <p><i>Knowledge</i> Having accomplished this module, the students know and understand the basic concepts of continuum mechanics and elastostatics, in particular stress, strain, constitutive laws, stretching, bending, torsion, failure analysis, energy methods and stability of structures.</p> <p><i>Skills</i> Having accomplished this module, the students are able to</p> <ul style="list-style-type: none"> <li>- apply the fundamental concepts of mathematical and mechanical modeling and analysis to problems of their choice</li> <li>- apply the basic methods of elastostatics to problems of engineering, in particular in the design of mechanical structures</li> <li>- to educate themselves about more advanced aspects of elastostatics</li> </ul>  |                            |               |           |
| <b>Personal Competence</b>                         | <p><i>Social Competence</i></p> <ul style="list-style-type: none"> <li>-</li> </ul> <p><i>Autonomy</i></p> <ul style="list-style-type: none"> <li>-</li> </ul>   |                            |               |           |
| <b>Workload in Hours</b>                           | Independent Study Time 96, Study Time in Lecture 84  |                            |               |           |
| <b>Credit points</b>                               | 6  |                            |               |           |
| <b>Course achievement</b>                          | None   |                            |               |           |
| <b>Examination</b>                                 | Written exam   |                            |               |           |
| <b>Examination duration and scale</b>              | 90 min   |                            |               |           |
| <b>Assignment for the Following Curricula</b>      | General Engineering Science (German program, 7 semester): Core qualification: Compulsory<br>Civil- and Environmental Engineering: Core qualification: Compulsory<br>Bioprocess Engineering: Core qualification: Compulsory<br>Data Science: Specialisation Mechanics: Compulsory<br>Digital Mechanical Engineering: Core qualification: Compulsory<br>Electrical Engineering: Core qualification: Elective Compulsory<br>Green Technologies: Energy, Water, Climate: Core qualification: Compulsory<br>Logistics and Mobility: Core qualification: Compulsory<br>Mechanical Engineering: Core qualification: Compulsory<br>Mechatronics: Core qualification: Compulsory<br>Orientation Studies: Core qualification: Elective Compulsory<br>Naval Architecture: Core qualification: Compulsory<br>Process Engineering: Core qualification: Compulsory<br>Engineering and Management - Major in Logistics and Mobility: Core qualification: Compulsory |                            |               |           |

| Course L0493: Mechanics II |   |
|----------------------------|---|
| <b>Typ</b>                 | Lecture   |
| <b>Hrs/wk</b>              | 2   |
| <b>CP</b>                  | 2   |
| <b>Workload in Hours</b>   | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>            | Prof. Christian Cyron   |
| <b>Language</b>            | DE  |
| <b>Cycle</b>               | SoSe  |
| <b>Content</b>             | stresses and strains<br>Hooke's law<br>tension and compression<br>torsion<br>bending<br>stability<br>buckling<br>energy methods   |
| <b>Literature</b>          | <ul style="list-style-type: none"> <li>• Gross, D., Hauger, W., Schröder, J., Wall, W.A.: Technische Mechanik 1, Springer</li> <li>• Gross, D., Hauger, W., Schröder, J., Wall, W.A.: Technische Mechanik 2 Elastostatik, Springer</li> </ul> |

| Course L0494: Mechanics II |   |
|----------------------------|---|
| <b>Typ</b>                 | Recitation Section (small)                          |
| <b>Hrs/wk</b>              | 2   |
| <b>CP</b>                  | 2   |
| <b>Workload in Hours</b>   | Independent Study Time 32, Study Time in Lecture 28 |
| <b>Lecturer</b>            | Prof. Christian Cyron                               |
| <b>Language</b>            | DE  |
| <b>Cycle</b>               | SoSe  |
| <b>Content</b>             | See interlocking course                             |
| <b>Literature</b>          | See interlocking course                             |

| Course L1691: Mechanics II |   |
|----------------------------|---|
| <b>Typ</b>                 | Recitation Section (large)                          |
| <b>Hrs/wk</b>              | 2   |
| <b>CP</b>                  | 2   |
| <b>Workload in Hours</b>   | Independent Study Time 32, Study Time in Lecture 28 |
| <b>Lecturer</b>            | Prof. Christian Cyron, Dr. Konrad Schneider         |
| <b>Language</b>            | DE  |
| <b>Cycle</b>               | SoSe  |
| <b>Content</b>             | See interlocking course                             |
| <b>Literature</b>          | See interlocking course                             |

| Module M0608: Basics of Electrical Engineering |   |               |           |
|--|---|---------------|-----------|
| <b>Courses</b>                                 |   |               |           |
| <b>Title</b>                                   | <b>Typ</b>  | <b>Hrs/wk</b> | <b>CP</b> |
| Basics of Electrical Engineering (L0290)       | Lecture   | 3             | 4         |
| Basics of Electrical Engineering (L0292)       | Recitation Section (small)  | 2             | 2         |
| <b>Module Responsible</b>                      | Prof. Thorsten Kern   |               |           |
| <b>Admission Requirements</b>                  | None  |               |           |
| <b>Recommended Previous Knowledge</b>          | Basics of mathematics   |               |           |
| <b>Educational Objectives</b>                  | After taking part successfully, students have reached the following learning results  |               |           |
| <b>Professional Competence</b>                 | <p><i>Knowledge</i> Students can to draw and explain circuit diagrams for electric and electronic circuits with a small number of components. They can describe the basic function of electric and electronic components and can present the corresponding equations. They can demonstrate the use of the standard methods for calculations.</p> <p><i>Skills</i> Students are able to analyse electric and electronic circuits with few components and to calculate selected quantities in the circuits. They apply the usual methods of the electrical engineering for this.</p> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> none</p> <p><i>Autonomy</i> Students are able independently to analyse electric and electronic circuits and to calculate selected quantities in the circuits.</p>  |               |           |
| <b>Workload in Hours</b>                       | Independent Study Time 110, Study Time in Lecture 70  |               |           |
| <b>Credit points</b>                           | 6   |               |           |
| <b>Course achievement</b>                      | None  |               |           |
| <b>Examination</b>                             | Written exam  |               |           |
| <b>Examination duration and scale</b>          | 135 minutes   |               |           |
| <b>Assignment for the Following Curricula</b>  | Bioprocess Engineering: Core qualification: Compulsory<br>Digital Mechanical Engineering: Core qualification: Compulsory<br>Energy and Environmental Engineering: Core qualification: Compulsory<br>Green Technologies: Energy, Water, Climate: Core qualification: Compulsory<br>Logistics and Mobility: Core qualification: Compulsory<br>Logistics and Mobility: Specialisation Production Management and Processes: Elective Compulsory<br>Logistics and Mobility: Specialisation Traffic Planning and Systems: Elective Compulsory<br>Mechanical Engineering: Core qualification: Compulsory<br>Orientation Studies: Core qualification: Elective Compulsory<br>Naval Architecture: Core qualification: Compulsory<br>Process Engineering: Core qualification: Compulsory<br>Engineering and Management - Major in Logistics and Mobility: Specialisation Production Management and Processes: Elective Compulsory<br>Engineering and Management - Major in Logistics and Mobility: Specialisation Traffic Planning and Systems: Elective Compulsory |               |           |

| Course L0290: Basics of Electrical Engineering |   |
|--|---|
| <b>Typ</b>                                     | Lecture   |
| <b>Hrs/wk</b>                                  | 3   |
| <b>CP</b>                                      | 4   |
| <b>Workload in Hours</b>                       | Independent Study Time 78, Study Time in Lecture 42   |
| <b>Lecturer</b>                                | Prof. Thorsten Kern   |
| <b>Language</b>                                | DE  |
| <b>Cycle</b>                                   | WiSe  |
| <b>Content</b>                                 | DC networks: Current, voltage, power, Kirchhoff's laws, equivalent sources, network analysis<br><br>AC: Characteristics, RMS, complex representation, phasor diagrams, power<br>Three phase AC: Characteristics, star-delta- connection, power, transformer<br><br>Electronics: Principle, operating behaviour and application of electronic devices as diode, Zener-diode, thyristor, transistor operational amplifier |
| <b>Literature</b>                              | Alexander von Weiss, Manfred Krause: "Allgemeine Elektrotechnik"; Vieweg-Verlag, Signatur der Bibliothek der TUHH: ETB 309<br>Ralf Kories, Heinz Schmitt - Walter: "Taschenbuch der Elektrotechnik"; Verlag Harri Deutsch; Signatur der Bibliothek der TUHH: ETB 122<br>"Grundlagen der Elektrotechnik" - andere Autoren  |

| <b>Course L0292: Basics of Electrical Engineering</b> |   |
|---|---|
| <b>Typ</b>  | Recitation Section (small)  |
| <b>Hrs/wk</b>   | 2   |
| <b>CP</b>   | 2   |
| <b>Workload in Hours</b>                              | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>                                       | Prof. Thorsten Kern, Weitere Mitarbeiter  |
| <b>Language</b>                                       | DE  |
| <b>Cycle</b>  | WiSe  |
| <b>Content</b>  | <p>Exercices to the analysis of circuits and the calculation of electrical quantities th the topics:</p> <p>DC networks: Current, voltage, power, Kirchhoff's laws, equivalent sources, network analysis</p> <p>AC: Characteristics, RMS, complexe representation, phasor diagrams, power</p> <p>Three phase AC: Characterisitics, star-delta- connection, power, transformer</p> <p>Elektronics: Principle, operating behaviour and application of electronic devises as diode, Zener-diode, thyristor, transistor operational amplifier</p> |
| <b>Literature</b>                                     | <p>Alexander von Weiss, Manfred Krause: "Allgemeine Elektrotechnik"; Vweg-Verlag, Signatur der Bibliothek der TUHH: ETB 309</p> <p>Ralf Kories, Heinz Schmitt - Walter: "Taschenbuch der Elektrotechnik"; Verlag Harri Deutsch; Signatur der Bibliothek der TUHH: ETB 122</p> <p>"Grundlagen der Elektrotechnik" - andere Autoren</p>   |

| Module M0688: Technical Thermodynamics II     |   |        |    |
|---|---|--------|----|
| Courses                                       |   |        |    |
| Title   | Typ   | Hrs/wk | CP |
| Technical Thermodynamics II (L0449)           | Lecture   | 2      | 4  |
| Technical Thermodynamics II (L0450)           | Recitation Section (large)  | 1      | 1  |
| Technical Thermodynamics II (L0451)           | Recitation Section (small)  | 1      | 1  |
| <b>Module Responsible</b>                     | NN  |        |    |
| <b>Admission Requirements</b>                 | None  |        |    |
| <b>Recommended Previous Knowledge</b>         | Elementary knowledge in Mathematics, Mechanics and Technical Thermodynamics I   |        |    |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results  |        |    |
| <b>Professional Competence</b>                | <p><i>Knowledge</i> Students are familiar with different cycle processes like Joule, Otto, Diesel, Stirling, Seiliger and Clausius-Rankine. They are able to derive energetic and exergetic efficiencies and know the influence different factors. They know the difference between anti clockwise and clockwise cycles (heat-power cycle, cooling cycle). They have increased knowledge of steam cycles and are able to draw the different cycles in Thermodynamics related diagrams. They know the laws of gas mixtures, especially of humid air processes and are able to perform simple combustion calculations. They are provided with basic knowledge in gas dynamics and know the definition of the speed of sound and know about a Laval nozzle.</p> <p><i>Skills</i> Students are able to use thermodynamic laws for the design of technical processes. Especially they are able to formulate energy, exergy- and entropy balances and by this to optimise technical processes. They are able to perform simple safety calculations in regard to an outflowing gas from a tank. They are able to transform a verbal formulated message into an abstract formal procedure.</p> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> The students are able to discuss in small groups and develop an approach.</p> <p><i>Autonomy</i> Students are able to define independently tasks, to get new knowledge from existing knowledge as well as to find ways to use the knowledge in practice.</p> |        |    |
| <b>Workload in Hours</b>                      | Independent Study Time 124, Study Time in Lecture 56  |        |    |
| <b>Credit points</b>                          | 6   |        |    |
| <b>Course achievement</b>                     | None  |        |    |
| <b>Examination</b>                            | Written exam  |        |    |
| <b>Examination duration and scale</b>         | 90 min  |        |    |
| <b>Assignment for the Following Curricula</b> | General Engineering Science (German program, 7 semester): Core qualification: Compulsory<br>Bioprocess Engineering: Core qualification: Compulsory<br>Energy and Environmental Engineering: Core qualification: Compulsory<br>Energy Systems: Technical Complementary Course Core Studies: Elective Compulsory<br>Engineering Science: Specialisation Mechanical Engineering: Elective Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering: Elective Compulsory<br>Green Technologies: Energy, Water, Climate: Core qualification: Compulsory<br>Mechanical Engineering: Core qualification: Compulsory<br>Mechatronics: Core qualification: Compulsory<br>Technomathematics: Specialisation III. Engineering Science: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory  |        |    |

| Course L0449: Technical Thermodynamics II |  |
|---|--|
| <b>Typ</b>                                | Lecture  |
| <b>Hrs/wk</b>                             | 2  |
| <b>CP</b>                                 | 4  |
| <b>Workload in Hours</b>                  | Independent Study Time 92, Study Time in Lecture 28  |
| <b>Lecturer</b>                           | NN   |
| <b>Language</b>                           | DE   |
| <b>Cycle</b>                              | WiSe   |
| <b>Content</b>                            | 8. Cycle processes<br>7. Gas - vapor - mixtures<br>10. Open systems with constant flow rates<br>11. Combustion processes<br>12. Special fields of Thermodynamics   |
| <b>Literature</b>                         | <ul style="list-style-type: none"> <li>• Schmitz, G.: Technische Thermodynamik, TuTech Verlag, Hamburg, 2009</li> <li>• Baehr, H.D.; Kabelac, S.: Thermodynamik, 15. Auflage, Springer Verlag, Berlin 2012</li> <li>• Potter, M.; Somerton, C.: Thermodynamics for Engineers, Mc GrawHill, 1993</li> </ul> |

| Course L0450: Technical Thermodynamics II |   |
|---|---|
| <b>Typ</b>                                | Recitation Section (large)                          |
| <b>Hrs/wk</b>                             | 1   |
| <b>CP</b>                                 | 1   |
| <b>Workload in Hours</b>                  | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>                           | NN  |
| <b>Language</b>                           | DE  |
| <b>Cycle</b>                              | WiSe  |
| <b>Content</b>                            | See interlocking course                             |
| <b>Literature</b>                         | See interlocking course                             |

| Course L0451: Technical Thermodynamics II |   |
|---|---|
| <b>Typ</b>                                | Recitation Section (small)                          |
| <b>Hrs/wk</b>                             | 1   |
| <b>CP</b>                                 | 1   |
| <b>Workload in Hours</b>                  | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>                           | NN  |
| <b>Language</b>                           | DE  |
| <b>Cycle</b>                              | WiSe  |
| <b>Content</b>                            | See interlocking course                             |
| <b>Literature</b>                         | See interlocking course                             |

| Module M0892: Chemical Reaction Engineering                     |   |                            |               |                                |
|---|---|----------------------------|---------------|--------------------------------|
| <b>Courses</b>  |   |                            |               |                                |
| <b>Title</b>  |   | <b>Typ</b>                 | <b>Hrs/wk</b> | <b>CP</b>                      |
| Chemical Reaction Engineering (Fundamentals) (L0204)            |   | Lecture                    | 2             | 2                              |
| Chemical Reaction Engineering (Fundamentals) (L0244)            |   | Recitation Section (large) | 2             | 2                              |
| Experimental Course Chemical Engineering (Fundamentals) (L0221) |   | Practical Course           | 2             | 2                              |
| <b>Module Responsible</b>                                       | Prof. Raimund Horn  |                            |               |                                |
| <b>Admission Requirements</b>                                   | None  |                            |               |                                |
| <b>Recommended Previous Knowledge</b>                           | Contents of the previous modules mathematics I-III, physical chemistry, technical thermodynamics I+II as well as computational methods for engineers.   |                            |               |                                |
| <b>Educational Objectives</b>                                   | After taking part successfully, students have reached the following learning results  |                            |               |                                |
| <b>Professional Competence</b>                                  |   |                            |               |                                |
| <i>Knowledge</i>  | The students are able to explain basic concepts of chemical reaction engineering. They are able to point out differences between thermodynamical and kinetical processes. The students have a strong ability to outline parts of isothermal and non-isothermal ideal reactors and to describe their properties.   |                            |               |                                |
| <i>Skills</i>   | After successful completion of the module, students are able to:  |                            |               |                                |
|   | - apply different computational methods to dimension isothermal and non-isothermal ideal reactors,  |                            |               |                                |
|   | - determine and compute stable operation points for these reactors ,  |                            |               |                                |
|   | - conduct experiments on a lab-scale pilot plants and document these according to scientific guidelines.  |                            |               |                                |
| <b>Personal Competence</b>                                      |   |                            |               |                                |
| <i>Social Competence</i>  | After successful completion of the lab-course the students have a strong ability to organize themselves in small groups to solve issues in chemical reaction engineering. The students can discuss their subject related knowledge among each other and with their teachers.  |                            |               |                                |
| <i>Autonomy</i>   | The students are able to obtain further information and assess their relevance autonomously. Students can apply their knowledge discretely to plan, prepare and conduct experiments.  |                            |               |                                |
| <b>Workload in Hours</b>  | Independent Study Time 96, Study Time in Lecture 84   |                            |               |                                |
| <b>Credit points</b>  | 6   |                            |               |                                |
| <b>Course achievement</b>                                       | <b>Compulsory</b>   | <b>Bonus</b>               | <b>Form</b>   | <b>Description</b>             |
|   | Yes   | None                       | Subject       | theoretical and practical work |
| <b>Examination</b>  | Written exam  |                            |               |                                |
| <b>Examination duration and scale</b>                           | 120 min   |                            |               |                                |
| <b>Assignment for the Following Curricula</b>                   | General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>Bioprocess Engineering: Core qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Process Engineering: Compulsory<br>Green Technologies: Energy, Water, Climate: Specialisation Bioresource Technology: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory |                            |               |                                |

| Course L0204: Chemical Reaction Engineering (Fundamentals) |  |
|--|--|
| <b>Typ</b>   | Lecture  |
| <b>Hrs/wk</b>  | 2  |
| <b>CP</b>  | 2  |
| <b>Workload in Hours</b>                                   | Independent Study Time 32, Study Time in Lecture 28  |
| <b>Lecturer</b>  | Prof. Raimund Horn   |
| <b>Language</b>  | DE   |
| <b>Cycle</b>   | WiSe   |
| <b>Content</b>   | <p>Fundamentals of chemical reaction engineering, definitions, calculation of species concentrations (reactor, reaction mixture, reactants, products, inerts and solvents, reaction volume, Reaktor volume, chemical reaction, mass, moles, mole fraction, volume, density, molar concentration, mass-concentration, molality, partial pressure, hydrodynamic residence time, space time, extent of reaction, reactor throughput, reactor load, conversion, selectivity, yield, concentration calculations in stationary and flowing multicomponent-mixtures)</p> <p>Stoichiometry and stoichiometric calculations (simple reactions, complex reactions, key reactions, key species, matrix of stoichiometric coefficients, linear dependent and independent reactions, element-species-matrix, row reduced form of a matrix, rank of a matrix, Gauss Jordan elimination, relation between stoichiometry and kinetics, calculating the extent of reaction from mole number changes in complex reactions)</p> <p>Thermodynamics (What is thermodynamics?, importance of thermodynamics in chemical reaction engineering, zeroth law of thermodynamics, temperature scales, temperature measurements in praxis, first law of thermodynamics, internal energy, enthalpy, calorimeter, heat of reaction, standard heat of formation, Hess law, heat capacity, Kirchhoff law, standard heat of reaction, pressure dependence of the heat of reaction, second law of thermodynamics, reversible and irreversible processes, entropy, Clausius inequality, free energy, Gibbs Energy, chemical potential, chemical equilibrium, activity, van't Hoff law, calculation of chemical equilibrium, principle of Le Chatelier and Braun, equilibrium calculations in multiple reaction systems, Lagrange Multipliers)</p> <p>Chemical kinetics (reversible and irreversible reactions, homogeneous and heterogeneous reactions, elementary step, reaction mechanism, microkinetics, macrokinetics, formal kinetics, reaction rate, rate of change of species mole number, Arrhenius-</p> |



|                   |  |
|-------------------|--|
|                   | <p>equation, activation energy and pre-exponential factor for complex reactions, reactions of 0., 1. and 2. order, analytical integration of rate laws, Damköhler-number, differential and integral method of kinetic analysis, laboratory reactors for kinetic measurements, half life, kinetics of complex reactions, parallel reactions, reversible reactions, sequence of reactions, irreversible reaction with pre-equilibrium, reduction of reaction mechanisms, quasi-stationarity principle of Bodenstein, rate limiting step, Michaelis-Menten kinetics, analytical integration of first order differential equations - integrating factor, numerical integration of complex kinetics)</p> <p>Types of chemical Reactors (chemical reactors in industry and laboratory, ideal vs. real reactors, discontinuous, half continuous and continuous reactors, single phase - biphasic- and multiphase reactors, batch-reactor, semi-batch reactor, CSTR, Plug Flow reactor, fixed bed reactor, adiabatic staged reactors, rotating furnaces, fluidized bed reactors, gas-liquid-reactors, multi-phase reactors)</p> <p>Isothermal ideal reactors (mole-balance of a chemical reactor, mole balance of a batch reactor, integration of the batch reactor mole balance for various kinetics, partial fraction decomposition, mole balance of the semi-batch reactor, mole balance of the plug flow reactor, analogy batch reactor - plug flow reactor, design of plug flow reactors for reactions with volume change and complex reactions, mole balance of a fixed bed reactor, design of a membrane reactor, mole balance of a continuously stirred tank reactor, comparison of CSTR and PFR with respect to conversion and selectivity, mole-balance of a cascade of tank reactors, numerical-iterative calculation of a cascade of tank reactors, Newton-Raphson method, graphical analysis of a cascade of tank reactors)</p> <p>non-isothermal ideal reactors (energy balance of a reactor, adiabatic reactor, adiabatic temperature rise, staged reactor for adiabatic exothermic reactions limited by chemical equilibrium, design of an adiabatic plug flow reactor, Levenspiel-plots, heat transfer through a reactor wall, heat transfer by convection, heat conduction, heat transfer through a cylindrical wall, design of a plug flow reactor in parallel and counter flow, heat balance of the cooling fluid, CSTR with heat exchange, multiple stationary states, ignition-extinction behavior, stability of a CSTR, complex reactions in non-isothermal reactors, optimum temperature profile of a reactor)</p> |
| <b>Literature</b> | <p>lecture notes Raimund Horn</p> <p>skript Frerich Keil</p> <p>Books:</p> <p>M. Baerns, A. Behr, A. Brehm, J. Gmehling, H. Hofmann, U. Onken, A. Renken, Technische Chemie, Wiley-VCH</p> <p>G. Emig, E. Klemm, Technische Chemie, Springer</p> <p>A. Behr, D. W. Agar, J. Jörissen, Einführung in die Technische Chemie</p> <p>E. Müller-Erlwein, Chemische Reaktionstechnik 2012, 2. Auflage, Teubner Verlag</p> <p>J. Hagen, Chemiereaktoren: Auslegung und Simulation, 2004, Wiley-VCH</p> <p>H. S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall B</p> <p>H. S. Fogler, Essentials of Chemical Reaction Engineering, Prentice Hall</p> <p>O. Levenspiel, Chemical Reaction Engineering, John Wiley &amp; Sons, 1998</p> <p>L. D. Schmidt, The Engineering of Chemical Reactions, Oxford Univ. Press, 2009</p> <p>J. B. Butt, Reaction Kinetics and Reactor Design, 2000, Marcel Dekker</p> <p>R. Aris, Elementary Chemical Reactor Analysis, Dover Publ. Inc., 2000</p> <p>M. E. Davis, R. J. Davis, Fundamentals of Chemical Reaction Engineering, McGraw Hill</p> <p>G. F. Froment, K. B. Bischoff, J. De Wilde, Chemical Reactor Analysis and Design, John Wiley &amp; Sons, 2010</p> <p>A. Jess, P. Wasserscheid, Chemical Technology An Integrated Textbook, WILEY-VCH</p>   |

| <b>Course L0244: Chemical Reaction Engineering (Fundamentals)</b> |   |
|---|---|
| <b>Typ</b>  | Recitation Section (large)  |
| <b>Hrs/wk</b>   | 2   |
| <b>CP</b>   | 2   |
| <b>Workload in Hours</b>  | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>   | Prof. Raimund Horn, Dr. Oliver Korup  |
| <b>Language</b>   | DE  |
| <b>Cycle</b>  | WiSe  |
| <b>Content</b>  | <p>Fundamentals of chemical reaction engineering, definitions, calculation of species concentrations (reactor, reaction mixture, reactants, products, inerts and solvents, reaction volume, Reaktor volume, chemical reaction, mass, moles, mole fraction, volume, density, molar concentration, mass-concentration, molality, partial pressure, hydrodynamic residence time, space time, extent of reaction, reactor throughput, reactor load, conversion, selectivity, yield, concentration calculations in stationary and flowing multicomponent-mixtures)</p> <p>Stoichiometry and stoichiometric calculations (simple reactions, complex reactions, key reactions, key species, matrix of stoichiometric coefficients, linear dependent and independent reactions, element-species-matrix, row reduced form of a matrix, rank of a matrix, Gauss Jordan elimination, relation between stoichiometry and kinetics, calculating the extent of reaction from mole number changes in complex reactions)</p> <p>Thermodynamics (What is thermodynamics?, importance of thermodynamics in chemical reaction engineering, zeroth law of thermodynamics, temperature scales, temperature measurements in praxis, first law of thermodynamics, internal energy,</p> |

|                          |   |
|--------------------------|---|
|                          | <p>enthalpy, calorimeter, heat of reaction, standard heat of formation, Hess law, heat capacity, Kirchoff law, standard heat of reaction, pressure dependence of the heat of reaction, second law of thermodynamics, reversible and irreversible processes, entropy, Clausius inequality, free energy, Gibbs Energy, chemical potential, chemical equilibrium, activity, van't Hoff law, calculation of chemical equilibrium, principle of Le Chatelier and Braun, equilibrium calculations in multiple reaction systems, Lagrange Multipliers)</p> <p>Chemical kinetics (reversible and irreversible reactions, homogeneous and heterogeneous reactions, elementary step, reaction mechanism, microkinetics, macrokinetics, formal kinetics, reaction rate, rate of change of species mole number, Arrhenius-equation, activation energy and pre-exponential factor for complex reactions, reactions of 0., 1. and 2. order, analytical integration of rate laws, Damköhler-number, differential and integral method of kinetic analysis, laboratory reactors for kinetic measurements, half life, kinetics of complex reactions, parallel reactions, reversible reactions, sequence of reactions, irreversible reaction with pre-equilibrium, reduction of reaction mechanisms, quasi-stationarity principle of Bodenstein, rate limiting step, Michaelis-Menten kinetics, analytical integration of first order differential equations - integrating factor, numerical integration of complex kinetics)</p> <p>Types of chemical Reactors (chemical reactors in industry and laboratory, ideal vs. real reactors, discontinuous, half continuous and continuous reactors, single phase - biphasic- and multiphase reactors, batch-reactor, semi-batch reactor, CSTR, Plug Flow reactor, fixed bed reactor, adiabatic staged reactors, rotating furnaces, fluidized bed reactors, gas-liquid-reactors, multi-phase reactors)</p> <p>Isothermal ideal reactors (mole-balance of a chemical reactor, mole balance of a batch reactor, integration of the batch reactor mole balance for various kinetics, partial fraction decomposition, mole balance of the semi-batch reactor, mole balance of the plug flow reactor, analogy batch reactor - plug flow reactor, design of plug flow reactors for reactions with volume change and complex reactions, mole balance of a fixed bed reactor, design of a membrane reactor, mole balance of a continuously stirred tank reactor, comparison of CSTR and PFR with respect to conversion and selectivity, mole-balance of a cascade of tank reactors, numerical-iterative calculation of a cascade of tank reactors, Newton-Raphson method, graphical analysis of a cascade of tank reactors)</p> <p>non-isothermal ideal reactors (energy balance of a reactor, adiabatic reactor, adiabatic temperature rise, staged reactor for adiabatic exothermic reactions limited by chemical equilibrium, design of an adiabatic plug flow reactor, Levenspiel-plots, heat transfer through a reactor wall, heat transfer by convection, heat conduction, heat transfer through a cylindrical wall, design of a plug flow reactor in parallel and counter flow, heat balance of the cooling fluid, CSTR with heat exchange, multiple stationary states, ignition-extinction behavior, stability of a CSTR, complex reactions in non-isothermal reactors, optimum temperature profile of a reactor)</p> |
| <p><b>Literature</b></p> | <p>lecture notes Raimund Horn</p> <p>skript Frerich Keil</p> <p>Books:</p> <p>M. Baerns, A. Behr, A. Brehm, J. Gmehling, H. Hofmann, U. Onken, A. Renken, Technische Chemie, Wiley-VCH</p> <p>G. Emig, E. Klemm, Technische Chemie, Springer</p> <p>A. Behr, D. W. Agar, J. Jörissen, Einführung in die Technische Chemie</p> <p>E. Müller-Erlwein, Chemische Reaktionstechnik 2012, 2. Auflage, Teubner Verlag</p> <p>J. Hagen, Chemiereaktoren: Auslegung und Simulation, 2004, Wiley-VCH</p> <p>H. S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall B</p> <p>H. S. Fogler, Essentials of Chemical Reaction Engineering, Prentice Hall</p> <p>O. Levenspiel, Chemical Reaction Engineering, John Wiley &amp; Sons, 1998</p> <p>L. D. Schmidt, The Engineering of Chemical Reactions, Oxford Univ. Press, 2009</p> <p>J. B. Butt, Reaction Kinetics and Reactor Design, 2000, Marcel Dekker</p> <p>R. Aris, Elementary Chemical Reactor Analysis, Dover Publ. Inc., 2000</p> <p>M. E. Davis, R. J. Davis, Fundamentals of Chemical Reaction Engineering, McGraw Hill</p> <p>G. F. Froment, K. B. Bischoff, J. De Wilde, Chemical Reactor Analysis and Design, John Wiley &amp; Sons, 2010</p> <p>A. Jess, P. Wasserscheid, Chemical Technology An Integrated Textbook, WILEY-VCH</p>  |

| <b>Course L0221: Experimental Course Chemical Engineering (Fundamentals)</b> |   |
|--|---|
| <b>Typ</b>   | Practical Course  |
| <b>Hrs/wk</b>  | 2   |
| <b>CP</b>  | 2   |
| <b>Workload in Hours</b>   | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>  | Prof. Raimund Horn  |
| <b>Language</b>  | DE/EN   |
| <b>Cycle</b>   | SoSe  |
| <b>Content</b>   | <p>Performing and evaluation of experiments concerning chemical reaction engineering with emphasis on ideal reactors:</p> <ul style="list-style-type: none"> <li>* Batch reactor - Estimation of kinetic parameters for the saponification of ethylacetate</li> <li>*CSTR - Residence time distribution, reaction</li> <li>*CSTR in Series - Residence time distribution, reaction</li> <li>* Plug Flow Reactor - Residence time distribution, reaction</li> </ul> <p>Before the practical conduct of the experiments a colloquium takes place in which the students explain, reflect and discuss the theoretical basics and their translation into practice.</p> <p>The students write up a report for every experiment. They receive feedback to their level of scientific writing (citation methods, labeling of graphs, etc.), so that they can improve their competence in this field over the course of the practical course.</p> |
| <b>Literature</b>  | <p>Levenspiel, O.: Chemical reaction engineering; John Wiley &amp; Sons, New York, 3. Ed., 1999 VTM 309(LB)</p> <p>Praktikumsskript</p> <p>Skript Chemische Verfahrenstechnik 1 (F.Keil)</p>  |

| Module M0853: Mathematics III                                      |  |        |    |  |
|--|--|--------|----|--|
| Courses  |  |        |    |  |
| Title  | Typ  | Hrs/wk | CP |  |
| Analysis III (L1028)   | Lecture  | 2      | 2  |  |
| Analysis III (L1029)   | Recitation Section (small)   | 1      | 1  |  |
| Analysis III (L1030)   | Recitation Section (large)   | 1      | 1  |  |
| Differential Equations 1 (Ordinary Differential Equations) (L1031) | Lecture  | 2      | 2  |  |
| Differential Equations 1 (Ordinary Differential Equations) (L1032) | Recitation Section (small)   | 1      | 1  |  |
| Differential Equations 1 (Ordinary Differential Equations) (L1033) | Recitation Section (large)   | 1      | 1  |  |
| <b>Module Responsible</b>  | Prof. Anusch Taraz   |        |    |  |
| <b>Admission Requirements</b>                                      | None   |        |    |  |
| <b>Recommended Previous Knowledge</b>                              | Mathematics I + II   |        |    |  |
| <b>Educational Objectives</b>                                      | After taking part successfully, students have reached the following learning results   |        |    |  |
| <b>Professional Competence</b>                                     |  |        |    |  |
| <i>Knowledge</i>   | <ul style="list-style-type: none"> <li>Students can name the basic concepts in the area of analysis and differential equations. They are able to explain them using appropriate examples.</li> <li>Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples.</li> <li>They know proof strategies and can reproduce them.</li> </ul>   |        |    |  |
| <i>Skills</i>  | <ul style="list-style-type: none"> <li>Students can model problems in the area of analysis and differential equations with the help of the concepts studied in this course. Moreover, they are capable of solving them by applying established methods.</li> <li>Students are able to discover and verify further logical connections between the concepts studied in the course.</li> <li>For a given problem, the students can develop and execute a suitable approach, and are able to critically evaluate the results.</li> </ul>  |        |    |  |
| <b>Personal Competence</b>   |  |        |    |  |
| <i>Social Competence</i>   | <ul style="list-style-type: none"> <li>Students are able to work together in teams. They are capable to use mathematics as a common language.</li> <li>In doing so, they can communicate new concepts according to the needs of their cooperating partners. Moreover, they can design examples to check and deepen the understanding of their peers.</li> </ul>  |        |    |  |
| <i>Autonomy</i>  | <ul style="list-style-type: none"> <li>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.</li> <li>Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.</li> </ul>   |        |    |  |
| <b>Workload in Hours</b>   | Independent Study Time 128, Study Time in Lecture 112  |        |    |  |
| <b>Credit points</b>   | 8  |        |    |  |
| <b>Course achievement</b>  | None   |        |    |  |
| <b>Examination</b>   | Written exam   |        |    |  |
| <b>Examination duration and scale</b>                              | 60 min (Analysis III) + 60 min (Differential Equations 1)  |        |    |  |
| <b>Assignment for the Following Curricula</b>                      | General Engineering Science (German program, 7 semester): Core qualification: Compulsory<br>Civil- and Environmental Engineering: Core qualification: Compulsory<br>Bioprocess Engineering: Core qualification: Compulsory<br>Digital Mechanical Engineering: Core qualification: Compulsory<br>Electrical Engineering: Core qualification: Compulsory<br>Energy and Environmental Engineering: Core qualification: Compulsory<br>Green Technologies: Energy, Water, Climate: Core qualification: Compulsory<br>Computational Science and Engineering: Core qualification: Compulsory<br>Logistics and Mobility: Specialisation Traffic Planning and Systems: Elective Compulsory<br>Logistics and Mobility: Specialisation Production Management and Processes: Elective Compulsory<br>Logistics and Mobility: Specialisation Information Technology: Compulsory<br>Mechanical Engineering: Core qualification: Compulsory<br>Mechatronics: Core qualification: Compulsory<br>Naval Architecture: Core qualification: Compulsory<br>Process Engineering: Core qualification: Compulsory<br>Engineering and Management - Major in Logistics and Mobility: Specialisation Traffic Planning and Systems: Elective Compulsory<br>Engineering and Management - Major in Logistics and Mobility: Specialisation Production Management and Processes: Elective Compulsory<br>Engineering and Management - Major in Logistics and Mobility: Specialisation Information Technology: Compulsory |        |    |  |

| Course L1028: Analysis III |   |
|----------------------------|---|
| <b>Typ</b>                 | Lecture   |
| <b>Hrs/wk</b>              | 2   |
| <b>CP</b>                  | 2   |
| <b>Workload in Hours</b>   | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>            | Dozenten des Fachbereiches Mathematik der UHH   |
| <b>Language</b>            | DE  |
| <b>Cycle</b>               | WiSe  |
| <b>Content</b>             | <p>Main features of differential and integrational calculus of several variables</p> <ul style="list-style-type: none"> <li>• Differential calculus for several variables</li> <li>• Mean value theorems and Taylor's theorem</li> <li>• Maximum and minimum values</li> <li>• Implicit functions</li> <li>• Minimization under equality constraints</li> <li>• Newton's method for multiple variables</li> <li>• Double integrals over general regions</li> <li>• Line and surface integrals</li> <li>• Theorems of Gauß and Stokes</li> </ul> |
| <b>Literature</b>          | <ul style="list-style-type: none"> <li>• <a href="http://www.math.uni-hamburg.de/teaching/export/tuhh/index.html">http://www.math.uni-hamburg.de/teaching/export/tuhh/index.html</a></li> </ul>   |

| Course L1029: Analysis III |   |
|----------------------------|---|
| <b>Typ</b>                 | Recitation Section (small)                          |
| <b>Hrs/wk</b>              | 1   |
| <b>CP</b>                  | 1   |
| <b>Workload in Hours</b>   | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>            | Dozenten des Fachbereiches Mathematik der UHH       |
| <b>Language</b>            | DE  |
| <b>Cycle</b>               | WiSe  |
| <b>Content</b>             | See interlocking course                             |
| <b>Literature</b>          | See interlocking course                             |

| Course L1030: Analysis III |   |
|----------------------------|---|
| <b>Typ</b>                 | Recitation Section (large)                          |
| <b>Hrs/wk</b>              | 1   |
| <b>CP</b>                  | 1   |
| <b>Workload in Hours</b>   | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>            | Dozenten des Fachbereiches Mathematik der UHH       |
| <b>Language</b>            | DE  |
| <b>Cycle</b>               | WiSe  |
| <b>Content</b>             | See interlocking course                             |
| <b>Literature</b>          | See interlocking course                             |

| Course L1031: Differential Equations 1 (Ordinary Differential Equations) |  |
|--|--|
| <b>Typ</b>   | Lecture  |
| <b>Hrs/wk</b>  | 2  |
| <b>CP</b>  | 2  |
| <b>Workload in Hours</b>   | Independent Study Time 32, Study Time in Lecture 28  |
| <b>Lecturer</b>  | Dozenten des Fachbereiches Mathematik der UHH  |
| <b>Language</b>  | DE   |
| <b>Cycle</b>   | WiSe   |
| <b>Content</b>   | <p>Main features of the theory and numerical treatment of ordinary differential equations</p> <ul style="list-style-type: none"> <li>• Introduction and elementary methods</li> <li>• Existence and uniqueness of initial value problems</li> <li>• Linear differential equations</li> <li>• Stability and qualitative behaviour of the solution</li> <li>• Boundary value problems and basic concepts of calculus of variations</li> <li>• Eigenvalue problems</li> <li>• Numerical methods for the integration of initial and boundary value problems</li> <li>• Classification of partial differential equations</li> </ul> |
| <b>Literature</b>  | <ul style="list-style-type: none"> <li>• <a href="http://www.math.uni-hamburg.de/teaching/export/tuhh/index.html">http://www.math.uni-hamburg.de/teaching/export/tuhh/index.html</a></li> </ul>  |

| <b>Course L1032: Differential Equations 1 (Ordinary Differential Equations)</b> |   |
|---|---|
| <b>Typ</b>  | Recitation Section (small)                          |
| <b>Hrs/wk</b>   | 1   |
| <b>CP</b>   | 1   |
| <b>Workload in Hours</b>  | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>   | Dozenten des Fachbereiches Mathematik der UHH       |
| <b>Language</b>   | DE  |
| <b>Cycle</b>  | WiSe  |
| <b>Content</b>  | See interlocking course                             |
| <b>Literature</b>   | See interlocking course                             |

| <b>Course L1033: Differential Equations 1 (Ordinary Differential Equations)</b> |   |
|---|---|
| <b>Typ</b>  | Recitation Section (large)                          |
| <b>Hrs/wk</b>   | 1   |
| <b>CP</b>   | 1   |
| <b>Workload in Hours</b>  | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>   | Dozenten des Fachbereiches Mathematik der UHH       |
| <b>Language</b>   | DE  |
| <b>Cycle</b>  | WiSe  |
| <b>Content</b>  | See interlocking course                             |
| <b>Literature</b>   | See interlocking course                             |

| <b>Module M0729: Construction and Apparatus Engineering</b> |  |        |    |
|---|--|--------|----|
| <b>Courses</b>  |  |        |    |
| Title   | Typ  | Hrs/wk | CP |
| Construction and Apparatus Engineering (L0617)              | Lecture  | 2      | 3  |
| Construction and Apparatus Engineering (L0619)              | Recitation Section (small)   | 2      | 3  |
| <b>Module Responsible</b>                                   | Dr. Marko Hoffmann   |        |    |
| <b>Admission Requirements</b>                               | None   |        |    |
| <b>Recommended Previous Knowledge</b>                       | <ul style="list-style-type: none"> <li>Fundamentals of Technical Drawing</li> <li>Fundamentals of material engineering</li> <li>Technical Mechanics 1</li> <li>Physics for VT/BVT/EUT-Engineers</li> <li>Basic internship</li> </ul>   |        |    |
| <b>Educational Objectives</b>                               | After taking part successfully, students have reached the following learning results   |        |    |
| <b>Professional Competence</b><br><i>Knowledge</i>          | <ul style="list-style-type: none"> <li>Students can reproduce an overview of the important basic materials in engineering applications with priority on apparatus and plant engineering.</li> <li>Students can reproduce fundamentals of design, strength of material calculation and material selection for elements of process equipment.</li> <li>Students can reproduce basic principles of connecting and combining elements of apparatuses.</li> <li>Students have basic knowledge in the following areas: haft-hub connections, bearings, screwed connections, welded connections and sealings</li> </ul> |        |    |
| <i>Skills</i>   | <ul style="list-style-type: none"> <li>Students are capable to read and interpret complex technical drawings.</li> <li>Students are capable to calculate wall thickness of simple elements.</li> <li>Students are capable to design bolted flange connections.</li> <li>Students are capable to roughly design shell-and-tube heat exchangers.</li> </ul>  |        |    |
| <b>Personal Competence</b><br><i>Social Competence</i>      | <ul style="list-style-type: none"> <li>Students are able to work together in basic groups on subject related tasks and small design studies and present their results.</li> </ul>  |        |    |
| <i>Autonomy</i>   | <ul style="list-style-type: none"> <li>Students are capable to self-reliantly gather information from subject related, professional publications and relate that information to the context of the lecture, e.g. preparing of technical drawings or choosing of a construction material for a process equipment.</li> <li>They work on their homework by their own and get feedback in their particular basis group to evaluate their actual knowledge.</li> </ul>   |        |    |

|   |   |              |             |
|---|---|--------------|-------------|
| <b>Workload in Hours</b>                      | Independent Study Time 124, Study Time in Lecture 56  |              |             |
| <b>Credit points</b>                          | 6   |              |             |
| <b>Course achievement</b>                     | <b>Compulsory</b>   | <b>Bonus</b> | <b>Form</b> |
|   | No  | 5 %          | Excercises  |
| <b>Examination</b>                            | Written exam  |              |             |
| <b>Examination duration and scale</b>         | 120 min   |              |             |
| <b>Assignment for the Following Curricula</b> | Orientation Studies: Core qualification: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory |              |             |

| <b>Course L0617: Construction and Apparatus Engineering</b> |   |
|---|---|
| <b>Typ</b>  | Lecture   |
| <b>Hrs/wk</b>   | 2   |
| <b>CP</b>   | 3   |
| <b>Workload in Hours</b>                                    | Independent Study Time 62, Study Time in Lecture 28   |
| <b>Lecturer</b>   | Dr. Marko Hoffmann  |
| <b>Language</b>   | DE  |
| <b>Cycle</b>  | WiSe  |
| <b>Content</b>  | <ul style="list-style-type: none"> <li>• Introduction and terminology</li> <li>• Basic materials for process engineering</li> <li>• Examples of apparatuses and their elements</li> <li>• Construction conforming to standards of technical drawings and flow diagram</li> <li>• Perspective illustration of pipe systems and apparatus elements</li> <li>• Boiler formula</li> <li>• Stresses and strains of thick-walled cylindrical shells</li> <li>• Wall thickness calculations of thin-walled cylindrical shells applying mechanical strength criterion and equivalent stresses</li> <li>• System flange-bolt-gasket, sealings</li> <li>• Shaft-hub connections</li> <li>• Bearings</li> <li>• Screwed connections</li> <li>• Welded connections</li> <li>• Heat exchangers</li> </ul>  |
| <b>Literature</b>   | <ul style="list-style-type: none"> <li>• Bargel, H.-J.; Schulze, G. (Hrsg.): Werkstoffkunde. Berlin u.a., Springer Vieweg, 2012.</li> <li>• Bergmann, W.: Werkstofftechnik 1. München u.a., Hanser, 2009.</li> <li>• Bergmann, W.: Werkstofftechnik 2. München u.a., Hanser, 2008.</li> <li>• Callister, W. D.; Rethwisch, D. G.: Materialwissenschaften und Werkstofftechnik: eine Einführung, Übersetzungshrsg.: Scheffler, M., 1. Auflage, Weinheim, Wiley-VCH, 2013.</li> <li>• Klapp, E.: Apparate- und Anlagentechnik, Springer, Berlin, 2002.</li> <li>• Tietze, W.: Taschenbuch Dichtungstechnik, Vulkan, Essen, 2005.</li> <li>• Titzte, H., Wilke, H.-P.: Elemente des Apparatebaus, Springer, Berlin, 1992.</li> <li>• Schwaigerer, S., Mühlenbeck, G.: Festigkeitsberechnung im Dampfkessel-, Behälter- und Rohrleitungsbau, Springer, Berlin, 1997.</li> <li>• Seidel, W. W., Hahn, F.: Werkstofftechnik. München u.a., Hanser, 2012.</li> <li>• Wagner, W.: Festigkeitsberechnungen im Apparate- und Rohrleitungsbau, Würzburg, Vogel, 2007.</li> <li>• Wittel, H., Muhs, D., Jannasch, D.; Vošiek, J.: Roloff/Matek Maschinenelemente, Wiesbaden, Springer Vieweg, 22. Auflage, 2015.</li> </ul> |



| <b>Course L0619: Construction and Apparatus Engineering</b> |  |
|---|--|
| <b>Typ</b>  | Recitation Section (small)   |
| <b>Hrs/wk</b>   | 2  |
| <b>CP</b>   | 3  |
| <b>Workload in Hours</b>                                    | Independent Study Time 62, Study Time in Lecture 28  |
| <b>Lecturer</b>   | Dr. Marko Hoffmann   |
| <b>Language</b>   | DE   |
| <b>Cycle</b>  | WiSe   |
| <b>Content</b>  | <ul style="list-style-type: none"> <li>• Introduction and terminology</li> <li>• Basic materials for process engineering</li> <li>• Examples of apparatuses and their elements</li> <li>• Construction conforming to standards of technical drawings and flow diagram</li> <li>• Perspective illustration of pipe systems and apparatus elements</li> <li>• Boiler formula</li> <li>• Stresses and strains of thick-walled cylindrical shells</li> <li>• Wall thickness calculations of thin-walled cylindrical shells applying mechanical strength criterion and equivalent stresses</li> <li>• System flange-bolt-gasket, sealings</li> <li>• Shaft-hub connections</li> <li>• Bearings</li> <li>• Screwed connections</li> <li>• Welded connections</li> <li>• Heat exchangers</li> </ul>   |
| <b>Literature</b>   | <ul style="list-style-type: none"> <li>• Bargel, H.-J.; Schulze, G. (Hrsg.): Werkstoffkunde. Berlin u.a., Springer Vieweg, 2012.</li> <li>• Bergmann, W.: Werkstofftechnik 1. München u.a., Hanser, 2009.</li> <li>• Bergmann, W.: Werkstofftechnik 2. München u.a., Hanser, 2008.</li> <li>• Callister, W. D.; Rethwisch, D. G.: Materialwissenschaften und Werkstofftechnik: eine Einführung, Übersetzungshrsg.: Scheffler, M., 1. Auflage, Weinheim, Wiley-VCH, 2013.</li> <li>• Klapp, E.: Apparate- und Anlagentechnik, Springer, Berlin, 2002.</li> <li>• Tietze, W.: Taschenbuch Dichtungstechnik, Vulkan, Essen, 2005.</li> <li>• Titze, H., Wilke, H.-P.: Elemente des Apparatebaus, Springer, Berlin, 1992.</li> <li>• Schwaigerer, S., Mühlenbeck, G.: Festigkeitsberechnung im Dampfkessel-, Behälter- und Rohrleitungsbau, Springer, Berlin, 1997.</li> <li>• Seidel, W. W., Hahn, F.: Werkstofftechnik. München u.a., Hanser, 2012.</li> <li>• Wagner, W.: Festigkeitsberechnungen im Apparate- und Rohrleitungsbau, Würzburg, Vogel, 2007.</li> <li>• Wittel, H., Muhs, D., Jannasch, D.; Vošiek, J.: Roloff/Matek Maschinenelemente, Wiesbaden, Springer Vieweg, 22. Auflage, 2015.</li> </ul> |

| Module M0536: Fundamentals of Fluid Mechanics   |   |               |                    |
|---|---|---------------|--------------------|
| <b>Courses</b>                                  |   |               |                    |
| <b>Title</b>                                    | <b>Typ</b>  | <b>Hrs/wk</b> | <b>CP</b>          |
| Fundamentals of Fluid Mechanics (L0091)         | Lecture   | 2             | 4                  |
| Fluid Mechanics for Process Engineering (L0092) | Recitation Section (large)  | 2             | 2                  |
| <b>Module Responsible</b>                       | Prof. Michael Schlüter  |               |                    |
| <b>Admission Requirements</b>                   | None  |               |                    |
| <b>Recommended Previous Knowledge</b>           | <ul style="list-style-type: none"> <li>• Mathematics I+II+III</li> <li>• Technical Mechanics I+II</li> <li>• Technical Thermodynamics I+II</li> <li>• Working with force balances</li> <li>• Simplification and solving of partial differential equations</li> <li>• Integration</li> </ul>   |               |                    |
| <b>Educational Objectives</b>                   | After taking part successfully, students have reached the following learning results  |               |                    |
| <b>Professional Competence</b>                  | <p><i>Knowledge</i> Students are able to:</p> <ul style="list-style-type: none"> <li>• explain the difference between different types of flow</li> <li>• give an overview for different applications of the Reynolds Transport-Theorem in process engineering</li> <li>• explain simplifications of the Continuity- and Navier-Stokes-Equation by using physical boundary conditions</li> </ul> <p><i>Skills</i> The students are able to</p> <ul style="list-style-type: none"> <li>• describe and model incompressible flows mathematically</li> <li>• reduce the governing equations of fluid mechanics by simplifications to archive quantitative solutions e.g. by integration</li> <li>• notice the dependency between theory and technical applications</li> <li>• use the learned basics for fluid dynamical applications in fields of process engineering</li> </ul>   |               |                    |
| <b>Personal Competence</b>                      | <p><i>Social Competence</i> The students</p> <ul style="list-style-type: none"> <li>• are capable to gather information from subject related, professional publications and relate that information to the context of the lecture and</li> <li>• able to work together on subject related tasks in small groups. They are able to present their results effectively in English (e.g. during small group exercises)</li> <li>• are able to work out solutions for exercises by themselves, to discuss the solutions orally and to present the results.</li> </ul> <p><i>Autonomy</i> The students are able to</p> <ul style="list-style-type: none"> <li>• search further literature for each topic and to expand their knowledge with this literature,</li> <li>• work on their exercises by their own and to evaluate their actual knowledge with the feedback.</li> </ul>   |               |                    |
| <b>Workload in Hours</b>                        | Independent Study Time 124, Study Time in Lecture 56  |               |                    |
| <b>Credit points</b>                            | 6   |               |                    |
| <b>Course achievement</b>                       | <b>Compulsory</b>   | <b>Bonus</b>  | <b>Description</b> |
|   | Yes   | 5 %           | Midterm            |
| <b>Examination</b>                              | Written exam  |               |                    |
| <b>Examination duration and scale</b>           | 3 hours   |               |                    |
| <b>Assignment for the Following Curricula</b>   | General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Green Technologies: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Energy and Environmental Engineering: Compulsory<br>Bioprocess Engineering: Core qualification: Compulsory<br>Energy and Environmental Engineering: Core qualification: Compulsory<br>Green Technologies: Energy, Water, Climate: Core qualification: Compulsory<br>Logistics and Mobility: Specialisation Traffic Planning and Systems: Elective Compulsory<br>Technomathematics: Specialisation III. Engineering Science: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory<br>Engineering and Management - Major in Logistics and Mobility: Specialisation Traffic Planning and Systems: Elective Compulsory |               |                    |

| Course L0091: Fundamentals of Fluid Mechanics |  |
|---|--|
| <b>Typ</b>                                    | Lecture  |
| <b>Hrs/wk</b>                                 | 2  |
| <b>CP</b>                                     | 4  |
| <b>Workload in Hours</b>                      | Independent Study Time 92, Study Time in Lecture 28  |
| <b>Lecturer</b>                               | Prof. Michael Schlüter   |
| <b>Language</b>                               | DE   |
| <b>Cycle</b>                                  | SoSe   |
| <b>Content</b>                                | <ul style="list-style-type: none"> <li>• fluid properties</li> <li>• hydrostatic</li> <li>• overall balances - theory of streamline</li> <li>• overall balances- conservation equations</li> <li>• differential balances - Navier Stokes equations</li> <li>• irrotational flows - Potenzialströmungen</li> <li>• flow around bodies - theory of physical similarity</li> <li>• turbulent flows</li> <li>• compressible flows</li> </ul>   |
| <b>Literature</b>                             | <ol style="list-style-type: none"> <li>1. Crowe, C. T.: Engineering fluid mechanics. Wiley, New York, 2009.</li> <li>2. Durst, F.: Strömungsmechanik: Einführung in die Theorie der Strömungen von Fluiden. Springer-Verlag, Berlin, Heidelberg, 2006.</li> <li>3. Fox, R.W.; et al.: Introduction to Fluid Mechanics. J. Wiley &amp; Sons, 1994</li> <li>4. Herwig, H.: Strömungsmechanik: Eine Einführung in die Physik und die mathematische Modellierung von Strömungen. Springer Verlag, Berlin, Heidelberg, New York, 2006</li> <li>5. Herwig, H.: Strömungsmechanik: Einführung in die Physik von technischen Strömungen: Vieweg+Teubner Verlag / GWV Fachverlage GmbH, Wiesbaden, 2008</li> <li>6. Kuhlmann, H.C.: Strömungsmechanik. München, Pearson Studium, 2007</li> <li>7. Oertl, H.: Strömungsmechanik: Grundlagen, Grundgleichungen, Lösungsmethoden, Softwarebeispiele. Vieweg+ Teubner Verlag / GWV Fachverlage GmbH, Wiesbaden, 2009</li> <li>8. Schade, H.; Kunz, E.: Strömungslehre. Verlag de Gruyter, Berlin, New York, 2007</li> <li>9. Truckenbrodt, E.: Fluidmechanik 1: Grundlagen und elementare Strömungsvorgänge dichtebeständiger Fluide. Springer-Verlag, Berlin, Heidelberg, 2008</li> <li>10. Schlichting, H. : Grenzschicht-Theorie. Springer-Verlag, Berlin, 2006</li> <li>11. van Dyke, M.: An Album of Fluid Motion. The Parabolic Press, Stanford California, 1882.</li> <li>12. White, F.: Fluid Mechanics, Mcgraw-Hill, ISBN-10: 0071311211, ISBN-13: 978-0071311212, 2011</li> </ol> |

| Course L0092: Fluid Mechanics for Process Engineering |  |
|---|--|
| <b>Typ</b>  | Recitation Section (large)   |
| <b>Hrs/wk</b>   | 2  |
| <b>CP</b>   | 2  |
| <b>Workload in Hours</b>                              | Independent Study Time 32, Study Time in Lecture 28  |
| <b>Lecturer</b>                                       | Prof. Michael Schlüter   |
| <b>Language</b>                                       | DE   |
| <b>Cycle</b>  | SoSe   |
| <b>Content</b>  | In the exercise-lecture the topics from the main lecture are discussed intensively and transferred into application. For that, the students receive example tasks for download. The students solve these problems based on the lecture material either independently or in small groups. The solution is discussed with the students under scientific supervision and parts of the solutions are presented on the chalk board. At the end of each exercise-lecture, the correct solution is presented on the chalk board. Parallel to the exercise-lecture tutorials are held where the student solve exam questions under a set time-frame in small groups and discuss the solutions afterwards.  |
| <b>Literature</b>                                     | <ol style="list-style-type: none"> <li>1. Crowe, C. T.: Engineering fluid mechanics. Wiley, New York, 2009.</li> <li>2. Durst, F.: Strömungsmechanik: Einführung in die Theorie der Strömungen von Fluiden. Springer-Verlag, Berlin, Heidelberg, 2006.</li> <li>3. Fox, R.W.; et al.: Introduction to Fluid Mechanics. J. Wiley &amp; Sons, 1994</li> <li>4. Herwig, H.: Strömungsmechanik: Eine Einführung in die Physik und die mathematische Modellierung von Strömungen. Springer Verlag, Berlin, Heidelberg, New York, 2006</li> <li>5. Herwig, H.: Strömungsmechanik: Einführung in die Physik von technischen Strömungen: Vieweg+Teubner Verlag / GWV Fachverlage GmbH, Wiesbaden, 2008</li> <li>6. Kuhlmann, H.C.: Strömungsmechanik. München, Pearson Studium, 2007</li> <li>7. Oertl, H.: Strömungsmechanik: Grundlagen, Grundgleichungen, Lösungsmethoden, Softwarebeispiele. Vieweg+ Teubner Verlag / GWV Fachverlage GmbH, Wiesbaden, 2009</li> <li>8. Schade, H.; Kunz, E.: Strömungslehre. Verlag de Gruyter, Berlin, New York, 2007</li> <li>9. Truckenbrodt, E.: Fluidmechanik 1: Grundlagen und elementare Strömungsvorgänge dichtebeständiger Fluide. Springer-Verlag, Berlin, Heidelberg, 2008</li> <li>10. Schlichting, H. : Grenzschicht-Theorie. Springer-Verlag, Berlin, 2006</li> <li>11. van Dyke, M.: An Album of Fluid Motion. The Parabolic Press, Stanford California, 1882.</li> <li>12. White, F.: Fluid Mechanics, Mcgraw-Hill, ISBN-10: 0071311211, ISBN-13: 978-0071311212, 2011</li> </ol> |

| Module M0544: Phase Equilibria Thermodynamics |   |               |           |
|---|---|---------------|-----------|
| <b>Courses</b>                                |   |               |           |
| <b>Title</b>                                  | <b>Typ</b>  | <b>Hrs/wk</b> | <b>CP</b> |
| Phase Equilibria Thermodynamics (L0114)       | Lecture   | 2             | 2         |
| Phase Equilibria Thermodynamics (L0140)       | Recitation Section (small)  | 1             | 2         |
| Phase Equilibria Thermodynamics (L0142)       | Recitation Section (large)  | 1             | 2         |
| <b>Module Responsible</b>                     | Prof. Irina Smirnova  |               |           |
| <b>Admission Requirements</b>                 | None  |               |           |
| <b>Recommended Previous Knowledge</b>         | Mathematics, Physical Chemistry, Thermodynamics I and II  |               |           |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results  |               |           |
| <b>Professional Competence</b>                |   |               |           |
| <i>Knowledge</i>                              | <ul style="list-style-type: none"> <li>Starting from the very basics of thermodynamics, the students learn the mathematical tools to describe thermodynamic equilibria.</li> <li>They learn how state variables are influenced by the mixing of compounds and learn concepts to quantitatively describe these properties.</li> <li>Moreover, the students learn how phase equilibria can be described mathematically and which phenomena may occur if different phases (vapor, liquid, solid) coexist in equilibrium. Furthermore the fundamentals of reaction equilibria are taught.</li> <li>For different phase equilibria, several examples relevant for different kinds of processes are shown and the necessary knowledge for plotting and interpreting the equilibria are taught.</li> </ul>   |               |           |
| <i>Skills</i>                                 | <ul style="list-style-type: none"> <li>Applying their knowledge, the students are able to identify the correct equation for the determination of the equilibrium state and know how to simplify these equations meaningfully.</li> <li>The students know models which can be used to determine the properties of the system in the equilibrium state and they are able to solve the resulting mathematical relations.</li> <li>For specific applications, they are able to self-reliantly find necessary physico-chemical properties of compounds as well as model parameters in literature sources.</li> <li>Beside pure compound properties the students are capable of describing the properties of mixtures.</li> <li>The students know how to visualize phase equilibria graphically and they know how to interpret the occurring phenomena.</li> <li>Based on their knowledge, the students are able to understand fundamental concepts that are the basis for many separation and reaction processes in chemical engineering.</li> </ul> |               |           |
| <b>Personal Competence</b>                    |   |               |           |
| <i>Social Competence</i>                      | The students are able to work in small groups, to solve the corresponding problems and to present them orally to the tutors and other students  |               |           |
| <i>Autonomy</i>                               | <ul style="list-style-type: none"> <li>The students are able to find necessary information self-reliantly in literature sources and to judge their quality.</li> <li>During the semester the students are able to check their learning progress continuously in exercises. Based on this knowledge the students can adapt their learning process.</li> </ul>  |               |           |
| <b>Workload in Hours</b>                      | Independent Study Time 124, Study Time in Lecture 56  |               |           |
| <b>Credit points</b>                          | 6   |               |           |
| <b>Course achievement</b>                     | None  |               |           |
| <b>Examination</b>                            | Written exam  |               |           |
| <b>Examination duration and scale</b>         | 120 minutes; theoretical questions and calculations   |               |           |
| <b>Assignment for the Following Curricula</b> | General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Green Technologies, Focus Renewable Energy: Elective Compulsory<br>Bioprocess Engineering: Core qualification: Compulsory<br>Green Technologies: Energy, Water, Climate: Specialisation Bioresource Technology: Elective Compulsory<br>Green Technologies: Energy, Water, Climate: Specialisation Energy Systems: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory  |               |           |

| Course L0114: Phase Equilibria Thermodynamics |  |
|---|--|
| <b>Typ</b>                                    | Lecture  |
| <b>Hrs/wk</b>                                 | 2  |
| <b>CP</b>                                     | 2  |
| <b>Workload in Hours</b>                      | Independent Study Time 32, Study Time in Lecture 28  |
| <b>Lecturer</b>                               | Prof. Irina Smirnova   |
| <b>Language</b>                               | DE   |
| <b>Cycle</b>                                  | SoSe   |
| <b>Content</b>                                | <ol style="list-style-type: none"> <li>1. Introduction: Applications of thermodynamics of mixtures</li> <li>2. Thermodynamic equations in multi-component systems: Fundamental equations, chemical potential, fugacity</li> <li>3. Phase equilibria of pure substances: thermodynamic equilibrium, vapor pressure, Gibbs' phase rule</li> <li>4. Equations of state: virial equations, van-der-Waals equation, generalized equations of state</li> <li>5. Mixing properties: ideal and real mixtures, excess properties, partial molar properties</li> <li>6. Vapor-liquid-equilibria: binary systems, azeotropes, equilibrium condition</li> <li>7. Gas-liquid-equilibria: equilibrium condition, Henry-coefficient</li> <li>8. <math>G^E</math>-Models: Hildebrand-model, Flory-Huggins-model, Wilson-model, UNIQUAC, UNIFAC</li> <li>9. Liquid-liquid-equilibria: equilibrium condition, phase equilibria in binary and ternary systems</li> <li>10. Solid-liquid-equilibria: equilibrium condition, binary systems</li> <li>11. Chemical reactions: reaction coordinate, mass action law, influence of pressure and temperature</li> <li>12. Osmotic pressure</li> </ol> |
| <b>Literature</b>                             | <ul style="list-style-type: none"> <li>• Jürgen Gmehling, Bärbel Kolbe: Thermodynamik. VCH 1992</li> <li>• J.M. Prausnitz, R.N. Lichtenthaler, E.G. de Azevedo: Molecular Thermodynamics of Fluid-Phase Equilibria, 3rd ed. Prentice Hall, 1999.</li> <li>• J.W. Tester, M. Modell: Thermodynamics and its Applications. 3<sup>rd</sup> ed. Prentice Hall, 1997. J.P. O'Connell, J.M. Haile: Thermodynamics. Cambridge University Press, 2005.</li> </ul>  |

| Course L0140: Phase Equilibria Thermodynamics |  |
|---|--|
| <b>Typ</b>                                    | Recitation Section (small)   |
| <b>Hrs/wk</b>                                 | 1  |
| <b>CP</b>                                     | 2  |
| <b>Workload in Hours</b>                      | Independent Study Time 46, Study Time in Lecture 14  |
| <b>Lecturer</b>                               | Prof. Irina Smirnova   |
| <b>Language</b>                               | DE   |
| <b>Cycle</b>                                  | SoSe   |
| <b>Content</b>                                | <ol style="list-style-type: none"> <li>1. Introduction: Applications of thermodynamics of mixtures</li> <li>2. Thermodynamic equations in multi-component systems: Fundamental equations, chemical potential, fugacity</li> <li>3. Phase equilibria of pure substances: thermodynamic equilibrium, vapor pressure, Gibbs' phase rule</li> <li>4. Equations of state: virial equations, van-der-Waals equation, generalized equations of state</li> <li>5. Mixing properties: ideal and real mixtures, excess properties, partial molar properties</li> <li>6. Vapor-liquid-equilibria: binary systems, azeotropes, equilibrium condition</li> <li>7. Gas-liquid-equilibria: equilibrium condition, Henry-coefficient</li> <li>8. <math>G^E</math>-Models: Hildebrand-model, Flory-Huggins-model, Wilson-model, UNIQUAC, UNIFAC</li> <li>9. Liquid-liquid-equilibria: equilibrium condition, phase equilibria in binary and ternary systems</li> <li>10. Solid-liquid-equilibria: equilibrium condition, binary systems</li> <li>11. Chemical reactions: reaction coordinate, mass action law, influence of pressure and temperature</li> <li>12. Osmotic pressure</li> </ol> <p>The students work on tasks in small groups and present their results in front of all students.</p> |
| <b>Literature</b>                             | <ul style="list-style-type: none"> <li>• Jürgen Gmehling, Bärbel Kolbe: Thermodynamik. VCH 1992</li> <li>• J.M. Prausnitz, R.N. Lichtenthaler, E.G. de Azevedo: Molecular Thermodynamics of Fluid-Phase Equilibria, 3rd ed. Prentice Hall, 1999.</li> <li>• J.W. Tester, M. Modell: Thermodynamics and its Applications. 3<sup>rd</sup> ed. Prentice Hall, 1997. J.P. O'Connell, J.M. Haile: Thermodynamics. Cambridge University Press, 2005.</li> </ul>  |

| Course L0142: Phase Equilibria Thermodynamics |  |
|---|--|
| <b>Typ</b>                                    | Recitation Section (large)   |
| <b>Hrs/wk</b>                                 | 1  |
| <b>CP</b>                                     | 2  |
| <b>Workload in Hours</b>                      | Independent Study Time 46, Study Time in Lecture 14  |
| <b>Lecturer</b>                               | Prof. Irina Smirnova   |
| <b>Language</b>                               | DE   |
| <b>Cycle</b>                                  | SoSe   |
| <b>Content</b>                                | <ol style="list-style-type: none"> <li>1. Introduction: Applications of thermodynamics of mixtures</li> <li>2. Thermodynamic equations in multi-component systems: Fundamental equations, chemical potential, fugacity</li> <li>3. Phase equilibria of pure substances: thermodynamic equilibrium, vapor pressure, Gibbs' phase rule</li> <li>4. Equations of state: virial equations, van-der-Waals equation, generalized equations of state</li> <li>5. Mixing properties: ideal and real mixtures, excess properties, partial molar properties</li> <li>6. Vapor-liquid-equilibria: binary systems, azeotropes, equilibrium condition</li> <li>7. Gas-liquid-equilibria: equilibrium condition, Henry-coefficient</li> <li>8. <math>G^E</math>-Models: Hildebrand-model, Flory-Huggins-model, Wilson-model, UNIQUAC, UNIFAC</li> <li>9. Liquid-liquid-equilibria: equilibrium condition, phase equilibria in binary and ternary systems</li> <li>10. Solid-liquid-equilibria: equilibrium condition, binary systems</li> <li>11. Chemical reactions: reaction coordinate, mass action law, influence of pressure and temperature</li> <li>12. Osmotic pressure</li> </ol> |
| <b>Literature</b>                             | <ul style="list-style-type: none"> <li>• Jürgen Gmehling, Bärbel Kolbe: Thermodynamik. VCH 1992</li> <li>• J.M. Prausnitz, R.N. Lichtenthaler, E.G. de Azevedo: Molecular Thermodynamics of Fluid-Phase Equilibria, 3rd ed. Prentice Hall, 1999.</li> <li>• J.W. Tester, M. Modell: Thermodynamics and its Applications. 3<sup>rd</sup> ed. Prentice Hall, 1997. J.P. O'Connell, J.M. Haile: Thermodynamics. Cambridge University Press, 2005.</li> </ul>  |

| Module M0938: Bioprocess Engineering - Fundamentals           |   |                            |               |                                |
|---|---|----------------------------|---------------|--------------------------------|
| <b>Courses</b>  |   |                            |               |                                |
| <b>Title</b>  |   | <b>Typ</b>                 | <b>Hrs/wk</b> | <b>CP</b>                      |
| Bioprocess Engineering - Fundamentals (L0841)                 |   | Lecture                    | 2             | 3                              |
| Bioprocess Engineering- Fundamentals (L0842)                  |   | Recitation Section (large) | 2             | 1                              |
| Bioprocess Engineering - Fundamental Practical Course (L0843) |   | Practical Course           | 2             | 2                              |
| <b>Module Responsible</b>                                     | Prof. Andreas Liese   |                            |               |                                |
| <b>Admission Requirements</b>                                 | None  |                            |               |                                |
| <b>Recommended Previous Knowledge</b>                         | none, module "organic chemistry", module "fundamentals for process engineering"   |                            |               |                                |
| <b>Educational Objectives</b>                                 | After taking part successfully, students have reached the following learning results  |                            |               |                                |
| <b>Professional Competence</b>                                |   |                            |               |                                |
| <i>Knowledge</i>  | Students are able to describe the basic concepts of bioprocess engineering. They are able to classify different types of kinetics for enzymes and microorganisms, as well as to differentiate different types of inhibition. The parameters of stoichiometry and rheology can be named and mass transport processes in bioreactors can be explained. The students are capable to explain fundamental bioprocess management, sterilization technology and downstream processing in detail.   |                            |               |                                |
| <i>Skills</i>   | After successful completion of this module, students should be able to <ul style="list-style-type: none"> <li>• describe different kinetic approaches for growth and substrate-uptake and to calculate the corresponding parameters</li> <li>• predict qualitatively the influence of energy generation, regeneration of redox equivalents and growth inhibition on the fermentation process</li> <li>• analyze bioprocesses on basis of stoichiometry and to set up / solve metabolic flux equations</li> <li>• distinguish between scale-up criteria for different bioreactors and bioprocesses (anaerobic, aerobic as well as microaerobic) to compare them as well as to apply them to current biotechnical problem</li> <li>• propose solutions to complicated biotechnological problems and to deduce the corresponding models</li> <li>• to explore new knowledge resources and to apply the newly gained contents</li> <li>• identify scientific problems with concrete industrial use and to formulate solutions.</li> <li>• to document and discuss their procedures as well as results in a scientific manner</li> </ul> |                            |               |                                |
| <b>Personal Competence</b>                                    |   |                            |               |                                |
| <i>Social Competence</i>                                      | After completion of this module participants should 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 in engineering and scientific environments.   |                            |               |                                |
| <i>Autonomy</i>   | After completion of this module participants will be able to solve a technical problem in a team independently by organizing their workflow and to present their results in a plenum.   |                            |               |                                |
| <b>Workload in Hours</b>                                      | Independent Study Time 96, Study Time in Lecture 84   |                            |               |                                |
| <b>Credit points</b>  | 6   |                            |               |                                |
| <b>Course achievement</b>                                     | <b>Compulsory</b>   | <b>Bonus</b>               | <b>Form</b>   | <b>Description</b>             |
|   | Yes   | 5 %                        | Subject       | theoretical and practical work |
| <b>Examination</b>  | Written exam  |                            |               |                                |
| <b>Examination duration and scale</b>                         | 90 min  |                            |               |                                |
| <b>Assignment for the Following Curricula</b>                 | General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>Bioprocess Engineering: Core qualification: Compulsory<br>Green Technologies: Energy, Water, Climate: Specialisation Bioresource Technology: Elective Compulsory<br>Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Compulsory<br>Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory<br>Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory<br>Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory<br>Technomathematics: Specialisation III. Engineering Science: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory   |                            |               |                                |

| Course L0841: Bioprocess Engineering - Fundamentals |  |
|---|--|
| <b>Typ</b>  | Lecture  |
| <b>Hrs/wk</b>                                       | 2  |
| <b>CP</b>   | 3  |
| <b>Workload in Hours</b>                            | Independent Study Time 62, Study Time in Lecture 28  |
| <b>Lecturer</b>                                     | Prof. Andreas Liese  |
| <b>Language</b>                                     | DE   |
| <b>Cycle</b>  | SoSe   |
| <b>Content</b>                                      | <ul style="list-style-type: none"> <li>• Introduction: state-of-the-art and development trends in the biotechnology, introduction to the lecture</li> <li>• Enzyme kinetics: Michaelis-Menten, different types of enzyme inhibition, linearization, conversion, yield, selectivity (Prof. Liese)</li> <li>• Stoichiometry: coefficient of respiration, electron balance, degree of reduction, coefficient of yield, theoretical oxygen demand (Prof. Liese)</li> <li>• Microbial growth kinetic: batch- and chemostat culture (Prof. Zeng)</li> <li>• Kinetic of substrate consumption and product formation (Prof. Zeng)</li> <li>• Rheology: non-newtonian fluids, viscosity, agitators, energy input (Prof. Liese)</li> <li>• Transport process in a bioreactor (Prof. Zeng)</li> <li>• Technology of sterilization (Prof. Zeng)</li> <li>• Fundamentals of bioprocess management: bioreactors and calculation of batch, fed-batch and continuous bioprocesses (Prof. Zeng/Prof. Liese)</li> <li>• Downstream technology in biotechnology: cell breakdown, centrifugation, filtration, aqueous two phase systems (Prof. Liese)</li> </ul> |
| <b>Literature</b>                                   | <p>K. Buchholz, V. Kasche, U. Bornscheuer: Biocatalysts and Enzyme Technology, 2. Aufl. Wiley-VCH, 2012</p> <p>H. Chmiel: Bioprozeßtechnik, Elsevier, 2006</p> <p>R.H. Balz et al.: Manual of Industrial Microbiology and Biotechnology, 3. edition, ASM Press, 2010</p> <p>H.W. Blanch, D. Clark: Biochemical Engineering, Taylor &amp; Francis, 1997</p> <p>P. M. Doran: Bioprocess Engineering Principles, 2. edition, Academic Press, 2013</p>   |

| Course L0842: Bioprocess Engineering- Fundamentals |   |
|--|---|
| <b>Typ</b>   | Recitation Section (large)  |
| <b>Hrs/wk</b>                                      | 2   |
| <b>CP</b>  | 1   |
| <b>Workload in Hours</b>                           | Independent Study Time 2, Study Time in Lecture 28  |
| <b>Lecturer</b>                                    | Prof. Andreas Liese   |
| <b>Language</b>                                    | DE  |
| <b>Cycle</b>                                       | SoSe  |
| <b>Content</b>                                     | <ol style="list-style-type: none"> <li>1. Introduction (Prof. Liese, Prof. Zeng)</li> <li>2. Enzymatic kinetics (Prof. Liese)</li> <li>3. Stoichiometry I + II (Prof. Liese)</li> <li>4. Microbial Kinetics I+II (Prof. Zeng)</li> <li>5. Rheology (Prof. Liese)</li> <li>6. Mass transfer in bioprocess (Prof. Zeng)</li> <li>7. Continuous culture (Chemostat) (Prof. Zeng)</li> <li>8. Sterilisation (Prof. Zeng)</li> <li>9. Downstream processing (Prof. Liese)</li> <li>10. Repetition (Reserve) (Prof. Liese, Prof. Zeng)</li> </ol> |
| <b>Literature</b>                                  | siehe Vorlesung   |



| <b>Course L0843: Bioprocess Engineering - Fundamental Practical Course</b> |   |
|--|---|
| <b>Typ</b>   | Practical Course  |
| <b>Hrs/wk</b>  | 2   |
| <b>CP</b>  | 2   |
| <b>Workload in Hours</b>   | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>  | Prof. Andreas Liese, Prof. An-Ping Zeng   |
| <b>Language</b>  | DE  |
| <b>Cycle</b>   | SoSe  |
| <b>Content</b>   | <p>In this course fermentation and downstream technologies on the example of the production of an enzyme by means of a recombinant microorganism is learned. Detailed characterization and simulation of enzyme kinetics as well as application of the enzyme in a bioreactor is carried out.</p> <p>The students document their experiments and results in a protocol.</p> |
| <b>Literature</b>  | Skript  |

| Module M1693: Computer Science for Engineers - Programming Concepts, Data Handling & Communication |  |                            |               |  |
|--|--|----------------------------|---------------|--|
| <b>Courses</b>   |  |                            |               |  |
| <b>Title</b>   |  | <b>Typ</b>                 | <b>Hrs/wk</b> | <b>CP</b>                                |
| Computer Science for Engineers - Programming Concepts, Data Handling & Communication (L2689)       |  | Lecture                    | 3             | 3  |
| Computer Science for Engineers - Programming Concepts, Data Handling & Communication (L2690)       |  | Recitation Section (small) | 2             | 3  |
| <b>Module Responsible</b>  | Prof. Sibylle Fröschle   |                            |               |  |
| <b>Admission Requirements</b>  | None   |                            |               |  |
| <b>Recommended Previous Knowledge</b>  |  |                            |               |  |
| <b>Educational Objectives</b>  | After taking part successfully, students have reached the following learning results   |                            |               |  |
| <b>Professional Competence</b><br><i>Knowledge</i><br><i>Skills</i>                                |  |                            |               |  |
| <b>Personal Competence</b><br><i>Social Competence</i><br><i>Autonomy</i>                          |  |                            |               |  |
| <b>Workload in Hours</b>   | Independent Study Time 110, Study Time in Lecture 70   |                            |               |  |
| <b>Credit points</b>   | 6  |                            |               |  |
| <b>Course achievement</b>  | <b>Compulsory</b>  | <b>Bonus</b>               | <b>Form</b>   | <b>Description</b>                       |
|  | No   | 10 %                       | Attestation   | Testate finden semesterbegleitend statt. |
| <b>Examination</b>   | Written exam   |                            |               |  |
| <b>Examination duration and scale</b>  | 120 min  |                            |               |  |
| <b>Assignment for the Following Curricula</b>  | General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Biomedical Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Green Technologies, Focus Renewable Energy: Elective Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Energy Systems: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Aircraft Systems Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Product Development and Production: Elective Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Electrical Engineering: Elective Compulsory<br>Bioprocess Engineering: Core qualification: Compulsory<br>Electrical Engineering: Core qualification: Compulsory<br>Energy and Environmental Engineering: Core qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Process Engineering: Elective Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Energy and Environmental Engineering: Elective Compulsory<br>Green Technologies: Energy, Water, Climate: Specialisation Energy Systems: Elective Compulsory<br>Logistics and Mobility: Core qualification: Compulsory<br>Logistics and Mobility: Specialisation Information Technology: Compulsory<br>Mechatronics: Core qualification: Compulsory<br>Process Engineering: Core qualification: Compulsory<br>Engineering and Management - Major in Logistics and Mobility: Specialisation Information Technology: Compulsory |                            |               |  |

| Course L2689: Computer Science for Engineers - Programming Concepts, Data Handling & Communication |   |
|--|---|
| <b>Typ</b>   | Lecture   |
| <b>Hrs/wk</b>  | 3   |
| <b>CP</b>  | 3   |
| <b>Workload in Hours</b>   | Independent Study Time 48, Study Time in Lecture 42   |
| <b>Lecturer</b>  | Prof. Sibylle Fröschle  |
| <b>Language</b>  | DE  |
| <b>Cycle</b>   | SoSe  |
| <b>Content</b>   |   |
| <b>Literature</b>  | John V. Guttag: Introduction to Computation and Programming Using Python. With Application to Understanding Data. 2nd Edition. The MIT Press, 2016. |

| <b>Course L2690: Computer Science for Engineers - Programming Concepts, Data Handling &amp; Communication</b> |   |
|---|---|
| <b>Typ</b>  | Recitation Section (small)                          |
| <b>Hrs/wk</b>   | 2   |
| <b>CP</b>   | 3   |
| <b>Workload in Hours</b>  | Independent Study Time 62, Study Time in Lecture 28 |
| <b>Lecturer</b>   | Prof. Sibylle Fröschle                              |
| <b>Language</b>   | DE  |
| <b>Cycle</b>  | SoSe  |
| <b>Content</b>  | See interlocking course                             |
| <b>Literature</b>   | See interlocking course                             |

| Module M0618: Renewables Energy Systems       |   |               |           |
|---|---|---------------|-----------|
| <b>Courses</b>                                |   |               |           |
| <b>Title</b>                                  | <b>Typ</b>  | <b>Hrs/wk</b> | <b>CP</b> |
| Power Industry (L0316)                        | Lecture   | 1             | 1         |
| Energy Systems and Energy Industry (L0315)    | Lecture   | 2             | 2         |
| Renewable Energy (L0313)                      | Lecture   | 2             | 2         |
| Renewable Energy (L1434)                      | Recitation Section (small)  | 1             | 1         |
| <b>Module Responsible</b>                     | Prof. Martin Kaltschmitt  |               |           |
| <b>Admission Requirements</b>                 | None  |               |           |
| <b>Recommended Previous Knowledge</b>         | none  |               |           |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results  |               |           |
| <b>Professional Competence</b>                | <p><i>Knowledge</i> With completion of this module, the students can provide an overview of characteristics of energy systems and their economic efficiency. They can explain the issues occurring in this context. Furthermore, they can explain details of power generation, power distribution and power trading with regard to subject-related contexts. The students can explain these aspects, which are applicable to many energy systems in general, especially for renewable energy systems and critically discuss them. Furthermore, the students can explain the environmental benefits from the use of such systems.</p> <p><i>Skills</i> Students are able to apply methodologies for detailed determination of energy demand or energy production for various types of energy systems. Furthermore, they can evaluate energy systems technically, environmentally and economically and design them under certain given conditions. Therefore, they can choose the necessary subject-specific calculation rules, also for not standardized solutions of a problem.</p> <p>The students are able to explain questions and possible approaches to its processing from the field of renewable energies orally and to put them into the right context.</p> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> The students are able to analyze suitable technical alternatives and to assess them with technical, economical and ecological criteria under sustainability aspects. This allows them to make an effective contribution to a more sustainable power supply.</p> <p><i>Autonomy</i> Students can independently exploit sources, acquire the particular knowledge about the subject area and transform it to new questions.</p> |               |           |
| <b>Workload in Hours</b>                      | Independent Study Time 96, Study Time in Lecture 84   |               |           |
| <b>Credit points</b>                          | 6   |               |           |
| <b>Course achievement</b>                     | None  |               |           |
| <b>Examination</b>                            | Written exam  |               |           |
| <b>Examination duration and scale</b>         | 3 hours written exam  |               |           |
| <b>Assignment for the Following Curricula</b> | General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Energy and Environmental Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Energy Systems: Elective Compulsory<br>Civil- and Environmental Engineering: Specialisation Civil Engineering: Elective Compulsory<br>Civil- and Environmental Engineering: Specialisation Traffic and Mobility: Elective Compulsory<br>Civil- and Environmental Engineering: Specialisation Water and Environment: Elective Compulsory<br>Energy and Environmental Engineering: Core qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Energy Systems: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory   |               |           |

| Course L0316: Power Industry |  |
|------------------------------|--|
| <b>Typ</b>                   | Lecture  |
| <b>Hrs/wk</b>                | 1  |
| <b>CP</b>                    | 1  |
| <b>Workload in Hours</b>     | Independent Study Time 16, Study Time in Lecture 14  |
| <b>Lecturer</b>              | Prof. Martin Kaltschmitt, Prof. Andreas Wiese  |
| <b>Language</b>              | DE   |
| <b>Cycle</b>                 | SoSe   |
| <b>Content</b>               | <ul style="list-style-type: none"> <li>• Electrical energy in the energy system</li> <li>• Demand and use of electrical energy (households, industry, "new" buyers (including e-mobility))</li> <li>• Electricity generation                             <ul style="list-style-type: none"> <li>◦ electricity generation technologies using fossil fuels and their characteristics</li> <li>◦ combined heat and power technologies and their production characteristics</li> <li>◦ electricity generation from renewable energy technologies and their characteristics</li> </ul> </li> <li>• Power distribution                             <ul style="list-style-type: none"> <li>◦ "classic" distribution of electrical energy</li> <li>◦ challenges of fluctuating electricity generation by distributed systems (electricity market, electricity stock exchange, emissions trading)</li> </ul> </li> <li>• District heating industry</li> <li>• Legal and administrative aspects                             <ul style="list-style-type: none"> <li>◦ Energy Act</li> <li>◦ support instruments for renewable energy</li> <li>◦ CHP Act</li> </ul> </li> <li>• Cost and efficiency calculation</li> </ul> |
| <b>Literature</b>            | Folien der Vorlesung   |

| Course L0315: Energy Systems and Energy Industry |  |
|--|--|
| <b>Typ</b>                                       | Lecture  |
| <b>Hrs/wk</b>                                    | 2  |
| <b>CP</b>  | 2  |
| <b>Workload in Hours</b>                         | Independent Study Time 32, Study Time in Lecture 28  |
| <b>Lecturer</b>                                  | Prof. Martin Kaltschmitt   |
| <b>Language</b>                                  | DE   |
| <b>Cycle</b>                                     | SoSe   |
| <b>Content</b>                                   | <ul style="list-style-type: none"> <li>• Energy: development and significance</li> <li>• Fundamentals and basic concepts</li> <li>• Energy demand and future trends (heat, electricity, fuels)</li> <li>• Energy reserve and sources</li> <li>• Cost and efficiency calculation</li> <li>• Final and effective energy from petroleum, natural gas, coal, uranium and other</li> <li>• Legal, administrative and organizational aspects of energy systems</li> <li>• Energy systems as a permanent optimization task</li> </ul> |
| <b>Literature</b>                                | <ul style="list-style-type: none"> <li>• Kopien der Folien</li> </ul>  |

| Course L0313: Renewable Energy |   |
|--------------------------------|---|
| <b>Typ</b>                     | Lecture   |
| <b>Hrs/wk</b>                  | 2   |
| <b>CP</b>                      | 2   |
| <b>Workload in Hours</b>       | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>                | Prof. Martin Kaltschmitt  |
| <b>Language</b>                | DE/EN   |
| <b>Cycle</b>                   | SoSe  |
| <b>Content</b>                 | <ul style="list-style-type: none"> <li>• introduction</li> <li>• solar energy for heat and power generation</li> <li>• wind power for electricity generation</li> <li>• hydropower for electricity generation</li> <li>• ocean energy for electricity generation</li> <li>• geothermal energy for heat and electricity generation</li> </ul>  |
| <b>Literature</b>              | <ul style="list-style-type: none"> <li>• Kaltschmitt, M.; Streicher, W.; Wiese, A. (Hrsg.): Erneuerbare Energien - Systemtechnik, Wirtschaftlichkeit, Umweltaspekte; Springer, Berlin, Heidelberg, 2006, 4. Auflage</li> <li>• Kaltschmitt, M.; Streicher, W.; Wiese, A. (Hrsg.): Renewable Energy - Technology, Economics and Environment; Springer, Berlin, Heidelberg, 2007</li> </ul> |

| <b>Course L1434: Renewable Energy</b> |   |
|---------------------------------------|---|
| <b>Typ</b>                            | Recitation Section (small)  |
| <b>Hrs/wk</b>                         | 1   |
| <b>CP</b>                             | 1   |
| <b>Workload in Hours</b>              | Independent Study Time 16, Study Time in Lecture 14   |
| <b>Lecturer</b>                       | Prof. Martin Kaltschmitt  |
| <b>Language</b>                       | DE/EN   |
| <b>Cycle</b>                          | SoSe  |
| <b>Content</b>                        | <p>Students work on different tasks in the field of renewable energies. They present their solutions in the exercise lesson and discuss it with other students and the lecturer.</p> <p>Possible tasks in the field of renewable energies are:</p> <ul style="list-style-type: none"> <li>• Solar thermal heat</li> <li>• Concentrating solare power</li> <li>• Photovoltaic</li> <li>• Windenergie</li> <li>• Hydropower</li> <li>• Heat pump</li> <li>• Deep geothermal energy</li> </ul> |
| <b>Literature</b>                     | <ul style="list-style-type: none"> <li>• Kaltschmitt, M.; Streicher, W.; Wiese, A. (Hrsg.): Erneuerbare Energien - Systemtechnik, Wirtschaftlichkeit, Umweltaspekte; Springer, Berlin, Heidelberg, 2006, 4. Auflage</li> <li>• Kaltschmitt, M.; Streicher, W.; Wiese, A. (Hrsg.): Renewable Energy - Technology, Economics and Environment; Springer, Berlin, Heidelberg, 2007</li> </ul>   |

| Module M0538: Heat and Mass Transfer          |   |               |           |
|---|---|---------------|-----------|
| <b>Courses</b>                                |   |               |           |
| <b>Title</b>                                  | <b>Typ</b>  | <b>Hrs/wk</b> | <b>CP</b> |
| Heat and Mass Transfer (L0101)                | Lecture   | 2             | 2         |
| Heat and Mass Transfer (L0102)                | Recitation Section (small)  | 1             | 2         |
| Heat and Mass Transfer (L1868)                | Recitation Section (large)  | 1             | 2         |
| <b>Module Responsible</b>                     | Prof. Irina Smirnova  |               |           |
| <b>Admission Requirements</b>                 | None  |               |           |
| <b>Recommended Previous Knowledge</b>         | Basic knowledge: Technical Thermodynamics   |               |           |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results  |               |           |
| <b>Professional Competence</b>                | <ul style="list-style-type: none"> <li>• The students are capable of explaining qualitative and determining quantitative heat transfer in procedural apparatus (e. g. heat exchanger, chemical reactors).</li> <li>• They are capable of distinguish and characterize different kinds of heat transfer mechanisms namely heat conduction, heat transfer and thermal radiation.</li> <li>• The students have the ability to explain the physical basis for mass transfer in detail and to describe mass transfer qualitative and quantitative by using suitable mass transfer theories.</li> <li>• They are able to depict the analogy between heat- and mass transfer and to describe complex linked processes in detail.</li> </ul><br><ul style="list-style-type: none"> <li>• The students are able to set reasonable system boundaries for a given transport problem by using the gained knowledge and to balance the corresponding energy and mass flow, respectively.</li> <li>• They are capable to solve specific heat transfer problems (e.g. heated chemical reactors, temperature alteration in fluids) and to calculate the corresponding heat flows.</li> <li>• Using dimensionless quantities, the students can execute scaling up of technical processes or apparatus.</li> <li>• They are able to distinguish between diffusion, convective mass transition and mass transfer. They can use this knowledge for the description and design of apparatus (e.g. extraction column, rectification column).</li> <li>• In this context, the students are capable to choose and design fundamental types of heat and mass exchanger for a specific application considering their advantages and disadvantages, respectively.</li> <li>• In addition, they can calculate both, steady-state and non-steady-state processes in procedural apparatus.</li> <li>• The students are capable to connect their knowledge obtained in this course with knowlegde of other courses (In particular the courses thermodynamics, fluid mechanics and chemical process engineering) to solve concrete technical problems.</li> </ul><br><ul style="list-style-type: none"> <li>• The students are capable to work on subject-specific challenges in teams and to present the results orally in a reasonable manner to tutors and other students.</li> </ul><br><ul style="list-style-type: none"> <li>• The students are able to find and evaluate necessary information from suitable sources</li> <li>• They are able to prove their level of knowledge during the course with accompanying procedure continuously (clicker-system, exam-like assignments) and on this basis they can control their learning processes.</li> </ul> |               |           |
| <i>Knowledge</i>                              |   |               |           |
| <i>Skills</i>                                 |   |               |           |
| <b>Personal Competence</b>                    |   |               |           |
| <i>Social Competence</i>                      |   |               |           |
| <i>Autonomy</i>                               |   |               |           |
| <b>Workload in Hours</b>                      | Independent Study Time 124, Study Time in Lecture 56  |               |           |
| <b>Credit points</b>                          | 6   |               |           |
| <b>Course achievement</b>                     | None  |               |           |
| <b>Examination</b>                            | Written exam  |               |           |
| <b>Examination duration and scale</b>         | 120 minutes; theoretical questions and calculations   |               |           |
| <b>Assignment for the Following Curricula</b> | General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Green Technologies: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Energy and Enviromental Engineering: Compulsory<br>Bioprocess Engineering: Core qualification: Compulsory<br>Energy and Environmental Engineering: Core qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Energy and Enviromental Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Process Engineering: Compulsory<br>Green Technologies: Energy, Water, Climate: Core qualification: Compulsory<br>Technomathematics: Specialisation III. Engineering Science: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory  |               |           |

| Course L0101: Heat and Mass Transfer |   |
|--------------------------------------|---|
| <b>Typ</b>                           | Lecture   |
| <b>Hrs/wk</b>                        | 2   |
| <b>CP</b>                            | 2   |
| <b>Workload in Hours</b>             | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>                      | Prof. Irina Smirnova  |
| <b>Language</b>                      | DE  |
| <b>Cycle</b>                         | WiSe  |
| <b>Content</b>                       | <ol style="list-style-type: none"> <li>1. Heat transfer                             <ul style="list-style-type: none"> <li>◦ Introduction, one-dimensional heat conduction</li> <li>◦ Convective heat transfer</li> <li>◦ Multidimensional heat conduction</li> <li>◦ Non-steady heat conduction</li> <li>◦ Thermal radiation</li> </ul> </li> <li>2. Mass transfer                             <ul style="list-style-type: none"> <li>◦ one-way diffusion, equimolar countercurrent diffusion</li> <li>◦ boundary layer theory, non-steady mass transfer</li> <li>◦ Heat and mass transfer single particle/ fixed bed</li> <li>◦ Mass transfer and chemical reactions</li> </ul> </li> </ol> |
| <b>Literature</b>                    | <ol style="list-style-type: none"> <li>1. H.D. Baehr und K. Stephan: Wärme- und Stoffübertragung, Springer</li> <li>2. VDI-Wärmeatlas</li> </ol>  |

| Course L0102: Heat and Mass Transfer |   |
|--------------------------------------|---|
| <b>Typ</b>                           | Recitation Section (small)                          |
| <b>Hrs/wk</b>                        | 1   |
| <b>CP</b>                            | 2   |
| <b>Workload in Hours</b>             | Independent Study Time 46, Study Time in Lecture 14 |
| <b>Lecturer</b>                      | Prof. Irina Smirnova                                |
| <b>Language</b>                      | DE  |
| <b>Cycle</b>                         | WiSe  |
| <b>Content</b>                       | See interlocking course                             |
| <b>Literature</b>                    | See interlocking course                             |

| Course L1868: Heat and Mass Transfer |   |
|--------------------------------------|---|
| <b>Typ</b>                           | Recitation Section (large)                          |
| <b>Hrs/wk</b>                        | 1   |
| <b>CP</b>                            | 2   |
| <b>Workload in Hours</b>             | Independent Study Time 46, Study Time in Lecture 14 |
| <b>Lecturer</b>                      | Prof. Irina Smirnova                                |
| <b>Language</b>                      | DE  |
| <b>Cycle</b>                         | WiSe  |
| <b>Content</b>                       | See interlocking course                             |
| <b>Literature</b>                    | See interlocking course                             |



| Module M0546: Thermal Separation Processes    |   |               |           |
|---|---|---------------|-----------|
| <b>Courses</b>                                |   |               |           |
| <b>Title</b>                                  | <b>Typ</b>  | <b>Hrs/wk</b> | <b>CP</b> |
| Thermal Separation Processes (L0118)          | Lecture   | 2             | 2         |
| Thermal Separation Processes (L0119)          | Recitation Section (small)  | 2             | 2         |
| Thermal Separation Processes (L0141)          | Recitation Section (large)  | 1             | 1         |
| Separation Processes (L1159)                  | Practical Course  | 1             | 1         |
| <b>Module Responsible</b>                     | Prof. Irina Smirnova  |               |           |
| <b>Admission Requirements</b>                 | None  |               |           |
| <b>Recommended Previous Knowledge</b>         | Recommended requirements: Thermodynamics III  |               |           |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results  |               |           |
| <b>Professional Competence</b>                | <ul style="list-style-type: none"> <li>The students can distinguish and describe different types of separation processes such as distillation, extraction, and adsorption</li> <li>The students develop an understanding for the course of concentration during a separation process, the estimation of the energy demand of a process, the possibilities of energy saving, and the selection of separation systems</li> <li>They have good knowledge of designing methods for separation processes and devices</li> </ul>  |               |           |
| <i>Knowledge</i>                              |   |               |           |
| <i>Skills</i>                                 | <ul style="list-style-type: none"> <li>Using the gained knowledge the students can select a reasonable system boundary for a given separation process and can close the associated energy and material balances</li> <li>The students can use different graphical methods for the designing of a separation process and define the amount of theoretical stages required</li> <li>They can select and design a basic type of thermal separation process for a given case based on the advantages and disadvantages of the process</li> <li>The students are capable to obtain independently the needed material properties from appropriate sources (diagrams and tables)</li> <li>They can calculate continuous and discontinuous processes</li> <li>The students are able to prove their theoretical knowledge in the experimental lab work.</li> <li>The students are able to discuss the theoretical background and the content of the experimental work with the teachers in colloquium.</li> </ul> <p>The students are capable of linking their gained knowledge with the content of other lectures and use it together for the solution of technical problems. Other lectures such as thermodynamics, fluid mechanics and chemical engineering.</p>                |               |           |
| <b>Personal Competence</b>                    | <ul style="list-style-type: none"> <li>The students can work technical assignments in small groups and present the combined results in the tutorial</li> <li>The students are able to carry out practical lab work in small groups and organize a functional division of labor between them. They are able to discuss their results and to document them scientifically in a report.</li> </ul>   |               |           |
| <i>Social Competence</i>                      |   |               |           |
| <i>Autonomy</i>                               | <ul style="list-style-type: none"> <li>The students are capable to obtain the needed information from suitable sources by themselves and assess their quality</li> <li>The students can proof the state of their knowledge with exam resembling assignments and in this way control their learning process</li> </ul>   |               |           |
| <b>Workload in Hours</b>                      | Independent Study Time 96, Study Time in Lecture 84   |               |           |
| <b>Credit points</b>                          | 6   |               |           |
| <b>Course achievement</b>                     | None  |               |           |
| <b>Examination</b>                            | Written exam  |               |           |
| <b>Examination duration and scale</b>         | 120 minutes; theoretical questions and calculations   |               |           |
| <b>Assignment for the Following Curricula</b> | General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Green Technologies, Focus Renewable Energy: Elective Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Energy and Environmental Engineering: Compulsory<br>Bioprocess Engineering: Core qualification: Compulsory<br>Energy and Environmental Engineering: Core qualification: Elective Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Energy and Environmental Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Process Engineering: Compulsory<br>Green Technologies: Energy, Water, Climate: Specialisation Energy Systems: Elective Compulsory<br>Green Technologies: Energy, Water, Climate: Specialisation Bioresource Technology: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory |               |           |

| Course L0118: Thermal Separation Processes |   |
|--|---|
| <b>Typ</b>                                 | Lecture   |
| <b>Hrs/wk</b>                              | 2   |
| <b>CP</b>                                  | 2   |
| <b>Workload in Hours</b>                   | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>                            | Prof. Irina Smirnova  |
| <b>Language</b>                            | DE  |
| <b>Cycle</b>                               | WiSe  |
| <b>Content</b>                             | <ul style="list-style-type: none"> <li>• Introduction in the thermal process engineering and to the main features of separation processes</li> <li>• Simple equilibrium processes, several steps processes</li> <li>• Distillation of binary mixtures, enthalpy-concentration diagrams</li> <li>• Extractive and azeotrope distillation, water vapor distillation, stepwise distillation</li> <li>• Extraction: separation ternary systems, ternary diagram</li> <li>• Multiphase separation including complex mixtures</li> <li>• Designing of separation devices without discrete stages</li> <li>• Drying</li> <li>• Chromatographic separation processes</li> <li>• Membrane separation</li> <li>• Energy demand of separation processes</li> <li>• Advance overview of separation processes</li> <li>• Selection of separation processes</li> </ul>  |
| <b>Literature</b>                          | <ul style="list-style-type: none"> <li>• G. Brunner: Skriptum Thermische Verfahrenstechnik</li> <li>• J. King: Separation Processes, McGraw-Hill, 2. Aufl. 1980</li> <li>• Sattler: Thermische Trennverfahren, VCH, Weinheim 1995</li> <li>• J.D. Seader, E.J. Henley: Separation Process Principles, Wiley, New York, 1998.</li> <li>• Mersmann: Thermische Verfahrenstechnik, Springer, 1980</li> <li>• Grassmann, Widmer, Sinn: Einführung in die Thermische Verfahrenstechnik, 3. Aufl., Walter de Gruyter, Berlin 1997</li> <li>• Brunner, G.: Gas extraction. An introduction to fundamentals of supercritical fluids and the application to separation processes. Steinkopff, Darmstadt; Springer, New York; 1994. ISBN 3-7985-0944-1 ; ISBN 0-387-91477-3 .</li> <li>• R. Goedecke (Hrsg.): Fluid-Verfahrenstechnik, Wiley-VCH Verlag, Weinheim, 2006.             <ul style="list-style-type: none"> <li>◦ Perry"s Chemical Engineers" Handbook, R.H. Perry, D.W. Green, J.O. Maloney (Hrsg.), 6th ed., McGraw-Hill, New York</li> <li>1984 Ullmann"s Enzyklopädie der Technischen Chemie</li> </ul> </li> </ul> |

| <b>Course L0119: Thermal Separation Processes</b> |   |
|---|---|
| <b>Typ</b>  | Recitation Section (small)  |
| <b>Hrs/wk</b>                                     | 2   |
| <b>CP</b>   | 2   |
| <b>Workload in Hours</b>                          | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>                                   | Prof. Irina Smirnova  |
| <b>Language</b>                                   | DE  |
| <b>Cycle</b>                                      | WiSe  |
| <b>Content</b>                                    | <ul style="list-style-type: none"> <li>• Introduction in the thermal process engineering and to the main features of separation processes</li> <li>• Simple equilibrium processes, several steps processes</li> <li>• Distillation of binary mixtures, enthalpy-concentration diagrams</li> <li>• Extractive and azeotrope distillation, water vapor distillation, stepwise distillation</li> <li>• Extraction: separation ternary systems, ternary diagram</li> <li>• Multiphase separation including complex mixtures</li> <li>• Designing of separation devices without discrete stages</li> <li>• Drying</li> <li>• Chromatographic separation processes</li> <li>• Membrane separation</li> <li>• Energy demand of separation processes</li> <li>• Advance overview of separation processes</li> <li>• Selection of separation processes</li> </ul> <p>The students work on tasks in small groups and present their results in front of all students.</p>  |
| <b>Literature</b>                                 | <ul style="list-style-type: none"> <li>• G. Brunner: Skriptum Thermische Verfahrenstechnik</li> <li>• J. King: Separation Processes, McGraw-Hill, 2. Aufl. 1980</li> <li>• Sattler: Thermische Trennverfahren, VCH, Weinheim 1995</li> <li>• J.D. Seader, E.J. Henley: Separation Process Principles, Wiley, New York, 1998.</li> <li>• Mersmann: Thermische Verfahrenstechnik, Springer, 1980</li> <li>• Grassmann, Widmer, Sinn: Einführung in die Thermische Verfahrenstechnik, 3. Aufl., Walter de Gruyter, Berlin 1997</li> <li>• Brunner, G.: Gas extraction. An introduction to fundamentals of supercritical fluids and the application to separation processes. Steinkopff, Darmstadt; Springer, New York; 1994. ISBN 3-7985-0944-1 ; ISBN 0-387-91477-3 .</li> <li>• R. Goedecke (Hrsg.): Fluid-Verfahrenstechnik, Wiley-VCH Verlag, Weinheim, 2006.</li> <li>• Perry"s Chemical Engineers" Handbook, R.H. Perry, D.W. Green, J.O. Maloney (Hrsg.), 6th ed., McGraw-Hill, New York 1984</li> <li>• Ullmann"s Enzyklopädie der Technischen Chemie</li> </ul> |

| Course L0141: Thermal Separation Processes |   |
|--|---|
| <b>Typ</b>                                 | Recitation Section (large)  |
| <b>Hrs/wk</b>                              | 1   |
| <b>CP</b>                                  | 1   |
| <b>Workload in Hours</b>                   | Independent Study Time 16, Study Time in Lecture 14   |
| <b>Lecturer</b>                            | Prof. Irina Smirnova  |
| <b>Language</b>                            | DE  |
| <b>Cycle</b>                               | WiSe  |
| <b>Content</b>                             | <ul style="list-style-type: none"> <li>• Introduction in the thermal process engineering and to the main features of separation processes</li> <li>• Simple equilibrium processes, several steps processes</li> <li>• Distillation of binary mixtures, enthalpy-concentration diagrams</li> <li>• Extractive and azeotrope distillation, water vapor distillation, stepwise distillation</li> <li>• Extraction: separation ternary systems, ternary diagram</li> <li>• Multiphase separation including complex mixtures</li> <li>• Designing of separation devices without discrete stages</li> <li>• Drying</li> <li>• Chromatographic separation processes</li> <li>• Membrane separation</li> <li>• Energy demand of separation processes</li> <li>• Advance overview of separation processes</li> <li>• Selection of separation processes</li> </ul>  |
| <b>Literature</b>                          | <ul style="list-style-type: none"> <li>• G. Brunner: Skriptum Thermische Verfahrenstechnik</li> <li>• J. King: Separation Processes, McGraw-Hill, 2. Aufl. 1980</li> <li>• Sattler: Thermische Trennverfahren, VCH, Weinheim 1995</li> <li>• J.D. Seader, E.J. Henley: Separation Process Principles, Wiley, New York, 1998.</li> <li>• Mersmann: Thermische Verfahrenstechnik, Springer, 1980</li> <li>• Grassmann, Widmer, Sinn: Einführung in die Thermische Verfahrenstechnik, 3. Aufl., Walter de Gruyter, Berlin 1997</li> <li>• Brunner, G.: Gas extraction. An introduction to fundamentals of supercritical fluids and the application to separation processes. Steinkopff, Darmstadt; Springer, New York; 1994. ISBN 3-7985-0944-1 ; ISBN 0-387-91477-3 .</li> <li>• R. Goedecke (Hrsg.): Fluid-Verfahrenstechnik, Wiley-VCH Verlag, Weinheim, 2006.</li> <li>• Perry"s Chemical Engineers" Handbook, R.H. Perry, D.W. Green, J.O. Maloney (Hrsg.), 6th ed., McGraw-Hill, New York 1984</li> <li>• Ullmann"s Enzyklopädie der Technischen Chemie</li> </ul> |

| Course L1159: Separation Processes |   |
|------------------------------------|---|
| <b>Typ</b>                         | Practical Course  |
| <b>Hrs/wk</b>                      | 1   |
| <b>CP</b>                          | 1   |
| <b>Workload in Hours</b>           | Independent Study Time 16, Study Time in Lecture 14   |
| <b>Lecturer</b>                    | Prof. Irina Smirnova  |
| <b>Language</b>                    | DE/EN   |
| <b>Cycle</b>                       | WiSe  |
| <b>Content</b>                     | <p>The students work on eight different experiments in this practical course. For every one of the eight experiments, a colloquium takes place in which the students explain and discuss the theoretical background and its translation into practice with staff and fellow students.</p> <p>The students work small groups with a high degree of division of labor. For every experiment, the students write a report. They receive instructions in terms of scientific writing as well as feedback on their own reports and level of scientific writing so they can increase their capabilities in this area.</p> <p>Topics of the practical course:</p> <ul style="list-style-type: none"> <li>• Introduction in the thermal process engineering and to the main features of separation processes</li> <li>• Simple equilibrium processes, several steps processes</li> <li>• Distillation of binary mixtures, enthalpy-concentration diagrams</li> <li>• Extractive and azeotrope distillation, water vapor distillation, stepwise distillation</li> <li>• Extraction: separation ternary systems, ternary diagram</li> <li>• Multiphase separation including complex mixtures</li> <li>• Designing of separation devices without discrete stages</li> <li>• Drying</li> <li>• Chromatographic separation processes</li> <li>• Membrane separation</li> <li>• Energy demand of separation processes</li> <li>• Advance overview of separation processes</li> <li>• Selection of separation processes</li> </ul> |
| <b>Literature</b>                  | <ul style="list-style-type: none"> <li>• G. Brunner: Skriptum Thermische Verfahrenstechnik</li> <li>• J. King: Separation Processes, McGraw-Hill, 2. Aufl. 1980</li> <li>• Sattler: Thermische Trennverfahren, VCH, Weinheim 1995</li> <li>• J.D. Seader, E.J. Henley: Separation Process Principles, Wiley, New York, 1998.</li> <li>• Mersmann: Thermische Verfahrenstechnik, Springer, 1980</li> <li>• Grassmann, Widmer, Sinn: Einführung in die Thermische Verfahrenstechnik, 3. Aufl., Walter de Gruyter, Berlin 1997</li> <li>• Brunner, G.: Gas extraction. An introduction to fundamentals of supercritical fluids and the application to separation processes. Steinkopff, Darmstadt; Springer, New York; 1994. ISBN 3-7985-0944-1 ; ISBN 0-387-91477-3 .</li> <li>• R. Goedecke (Hrsg.): Fluid-Verfahrenstechnik, Wiley-VCH Verlag, Weinheim, 2006.</li> <li>• Perry"s Chemical Engineers" Handbook, R.H. Perry, D.W. Green, J.O. Maloney (Hrsg.), 6th ed., McGraw-Hill, New York 1984</li> <li>• Ullmann"s Enzyklopädie der Technischen Chemie</li> </ul>   |

| Module M1275: Environmental Technology              |  |                  |  |
|---|--|------------------|--|
| <b>Courses</b>                                      |  |                  |  |
| <b>Title</b>  |  | <b>Typ</b>       | <b>Hrs/wk</b>                          |
| Practical Exercise Environmental Technology (L1387) |  | Practical Course | 1                                      |
| Environmental Technologie (L0326)                   |  | Lecture          | 2                                      |
| <b>Module Responsible</b>                           | Prof. Martin Kaltschmitt   |                  |  |
| <b>Admission Requirements</b>                       | None   |                  |  |
| <b>Recommended Previous Knowledge</b>               | Fundamentals of inorganic/organic chemistry and biology  |                  |  |
| <b>Educational Objectives</b>                       | After taking part successfully, students have reached the following learning results   |                  |  |
| <b>Professional Competence</b>                      | With the completion of this modul the students obtain profound knowledge of environmental technology. They are able to describe the behaviour of chemicals in the environment. Students can give an overview of scientific disciplines involved. They can explain terms and allocate them to related methods.  |                  |  |
| <i>Knowledge</i>                                    |  |                  |  |
| <i>Skills</i>                                       | Students are able to propose appropriate management and mitigation measures for environmental problems. They are able to determine geochemical parameters and to assess the potential of pollutants to migrate and transform. The students are able to work out well founded opinions on how Environmental Technology contributes to sustainable development, and they can present and defend these opinons in front of and against the group.   |                  |  |
| <b>Personal Competence</b>                          | The students are able to discuss the various technical and scientific tasks, both subject-specific and multidisciplinary. They are able to develop different approaches to the task as a group as well as to discuss their theoretical or practical implementation.  |                  |  |
| <i>Social Competence</i>                            |  |                  |  |
| <i>Autonomy</i>                                     | Students can independently exploit sources about of the subject, acquire the particular knowledge and tranfer it to new problems.  |                  |  |
| <b>Workload in Hours</b>                            | Independent Study Time 48, Study Time in Lecture 42  |                  |  |
| <b>Credit points</b>                                | 3  |                  |  |
| <b>Course achievement</b>                           | <b>Compulsory</b>  | <b>Bonus</b>     | <b>Description</b>                     |
|   | Yes  | None             | Subject theoretical and practical work |
| <b>Examination</b>                                  | Written exam   |                  |  |
| <b>Examination duration and scale</b>               | 1 hour   |                  |  |
| <b>Assignment for the Following Curricula</b>       | General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Elective Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Bioprocess Engineering: Elective Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Energy and Enviromental Engineering: Compulsory<br>Bioprocess Engineering: Core qualification: Elective Compulsory<br>Energy and Environmental Engineering: Core qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Bioprocess Engineering: Elective Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Energy and Enviromental Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Core qualification: Elective Compulsory |                  |  |

| Course L1387: Practical Exercise Environmental Technology |   |
|---|---|
| <b>Typ</b>  | Practical Course  |
| <b>Hrs/wk</b>   | 1   |
| <b>CP</b>   | 1   |
| <b>Workload in Hours</b>                                  | Independent Study Time 16, Study Time in Lecture 14   |
| <b>Lecturer</b>   | Prof. Martin Kaltschmitt, Dr. Isabel Höfer  |
| <b>Language</b>   | DE  |
| <b>Cycle</b>  | SoSe  |
| <b>Content</b>  | <p>The practical course Environmental Engineering currently consists of 6 experiments, which deal with the different focal points of environmental engineering in the areas of air, water, soil, environment, biomass and noise. The following experiments are carried out for this purpose:</p> <ul style="list-style-type: none"> <li>Determination of the calorific value of biomass,</li> <li>soil purification,</li> <li>waste water treatment,</li> <li>noise emissions,</li> <li>plastic waste,</li> <li>biowaste.</li> </ul> <p>Translated with <a href="http://www.DeepL.com/Translator">www.DeepL.com/Translator</a> (free version)</p> <p>Within the lab course students discuss the various technical and scientific tasks, both subject-specific and multidisciplinary. They discuss different approaches to the task as well as it's theoretical or practical implementation.</p> |
| <b>Literature</b>   |   |

| <b>Course L0326: Environmental Technologie</b> |  |
|--|--|
| <b>Typ</b>                                     | Lecture  |
| <b>Hrs/wk</b>                                  | 2  |
| <b>CP</b>                                      | 2  |
| <b>Workload in Hours</b>                       | Independent Study Time 32, Study Time in Lecture 28  |
| <b>Lecturer</b>                                | Prof. Martin Kaltschmitt, Dr. Isabel Höfer   |
| <b>Language</b>                                | DE   |
| <b>Cycle</b>                                   | WiSe   |
| <b>Content</b>                                 | <ol style="list-style-type: none"> <li>1. Introductory seminar on environmental science:</li> <li>2. Environmental impact and adverse effects</li> <li>3. Wastewater technology</li> <li>4. Air pollution control</li> <li>5. Noise protection</li> <li>6. Waste and recycling management</li> <li>7. Soil and ground water protection</li> <li>8. Renewable energies</li> <li>9. Resource conservation and energy efficiency</li> </ol> |
| <b>Literature</b>                              | Förster, U.: Umweltschutztechnik; 2012; Springer Berlin (Verlag) 8., Aufl. 2012; 978-3-642-22972-5 (ISBN)  |

| Module M0833: Introduction to Control Systems |  |        |    |
|---|--|--------|----|
| Courses                                       |  |        |    |
| Title   | Typ  | Hrs/wk | CP |
| Introduction to Control Systems (L0654)       | Lecture  | 2      | 4  |
| Introduction to Control Systems (L0655)       | Recitation Section (small)   | 2      | 2  |
| <b>Module Responsible</b>                     | Prof. Herbert Werner   |        |    |
| <b>Admission Requirements</b>                 | None   |        |    |
| <b>Recommended Previous Knowledge</b>         | Representation of signals and systems in time and frequency domain, Laplace transform  |        |    |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results   |        |    |
| <b>Professional Competence</b>                | <p><i>Knowledge</i></p> <ul style="list-style-type: none"> <li>• Students can represent dynamic system behavior in time and frequency domain, and can in particular explain properties of first and second order systems</li> <li>• They can explain the dynamics of simple control loops and interpret dynamic properties in terms of frequency response and root locus</li> <li>• They can explain the Nyquist stability criterion and the stability margins derived from it.</li> <li>• They can explain the role of the phase margin in analysis and synthesis of control loops</li> <li>• They can explain the way a PID controller affects a control loop in terms of its frequency response</li> <li>• They can explain issues arising when controllers designed in continuous time domain are implemented digitally</li> </ul> <p><i>Skills</i></p> <ul style="list-style-type: none"> <li>• Students can transform models of linear dynamic systems from time to frequency domain and vice versa</li> <li>• They can simulate and assess the behavior of systems and control loops</li> <li>• They can design PID controllers with the help of heuristic (Ziegler-Nichols) tuning rules</li> <li>• They can analyze and synthesize simple control loops with the help of root locus and frequency response techniques</li> <li>• They can calculate discrete-time approximations of controllers designed in continuous-time and use it for digital implementation</li> <li>• They can use standard software tools (Matlab Control Toolbox, Simulink) for carrying out these tasks</li> </ul> <p><b>Personal Competence</b></p> <p><i>Social Competence</i><br/>Students can work in small groups to jointly solve technical problems, and experimentally validate their controller designs</p> <p><i>Autonomy</i><br/>Students can obtain information from provided sources (lecture notes, software documentation, experiment guides) and use it when solving given problems.</p> <p>They can assess their knowledge in weekly on-line tests and thereby control their learning progress.</p>  |        |    |
| <b>Workload in Hours</b>                      | Independent Study Time 124, Study Time in Lecture 56   |        |    |
| <b>Credit points</b>                          | 6  |        |    |
| <b>Course achievement</b>                     | None   |        |    |
| <b>Examination</b>                            | Written exam   |        |    |
| <b>Examination duration and scale</b>         | 120 min  |        |    |
| <b>Assignment for the Following Curricula</b> | <p>General Engineering Science (German program, 7 semester): Core qualification: Compulsory</p> <p>Bioprocess Engineering: Core qualification: Compulsory</p> <p>Computer Science: Specialisation Computational Mathematics: Elective Compulsory</p> <p>Data Science: Core qualification: Elective Compulsory</p> <p>Electrical Engineering: Core qualification: Compulsory</p> <p>Energy and Environmental Engineering: Core qualification: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Electrical Engineering: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Civil Engineering: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Bioprocess Engineering: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Energy and Environmental Engineering: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Computer Science: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Energy Systems: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Aircraft Systems Engineering: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Product Development and Production: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Naval Architecture: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Process Engineering: Compulsory</p> |        |    |



|   |
|---|
| <p>General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: Compulsory<br/>                 Green Technologies: Energy, Water, Climate: Core qualification: Compulsory<br/>                 Computational Science and Engineering: Core qualification: Compulsory<br/>                 Logistics and Mobility: Specialisation Engineering Science: Elective Compulsory<br/>                 Logistics and Mobility: Specialisation Information Technology: Elective Compulsory<br/>                 Logistics and Mobility: Specialisation Traffic Planning and Systems: Elective Compulsory<br/>                 Logistics and Mobility: Specialisation Production Management and Processes: Elective Compulsory<br/>                 Mechanical Engineering: Core qualification: Compulsory<br/>                 Mechatronics: Core qualification: Compulsory<br/>                 Technomathematics: Specialisation III. Engineering Science: Elective Compulsory<br/>                 Theoretical Mechanical Engineering: Technical Complementary Course Core Studies: Elective Compulsory<br/>                 Process Engineering: Core qualification: Compulsory<br/>                 Engineering and Management - Major in Logistics and Mobility: Specialisation Information Technology: Elective Compulsory<br/>                 Engineering and Management - Major in Logistics and Mobility: Specialisation Traffic Planning and Systems: Elective Compulsory<br/>                 Engineering and Management - Major in Logistics and Mobility: Specialisation Production Management and Processes: Elective Compulsory</p> |
|---|

| Course L0654: Introduction to Control Systems |  |
|---|--|
| <b>Typ</b>                                    | Lecture  |
| <b>Hrs/wk</b>                                 | 2  |
| <b>CP</b>                                     | 4  |
| <b>Workload in Hours</b>                      | Independent Study Time 92, Study Time in Lecture 28  |
| <b>Lecturer</b>                               | Prof. Herbert Werner   |
| <b>Language</b>                               | DE   |
| <b>Cycle</b>                                  | WiSe   |
| <b>Content</b>                                | <p>Signals and systems</p> <ul style="list-style-type: none"> <li>• Linear systems, differential equations and transfer functions</li> <li>• First and second order systems, poles and zeros, impulse and step response</li> <li>• Stability</li> </ul> <p>Feedback systems</p> <ul style="list-style-type: none"> <li>• Principle of feedback, open-loop versus closed-loop control</li> <li>• Reference tracking and disturbance rejection</li> <li>• Types of feedback, PID control</li> <li>• System type and steady-state error, error constants</li> <li>• Internal model principle</li> </ul> <p>Root locus techniques</p> <ul style="list-style-type: none"> <li>• Root locus plots</li> <li>• Root locus design of PID controllers</li> </ul> <p>Frequency response techniques</p> <ul style="list-style-type: none"> <li>• Bode diagram</li> <li>• Minimum and non-minimum phase systems</li> <li>• Nyquist plot, Nyquist stability criterion, phase and gain margin</li> <li>• Loop shaping, lead lag compensation</li> <li>• Frequency response interpretation of PID control</li> </ul> <p>Time delay systems</p> <ul style="list-style-type: none"> <li>• Root locus and frequency response of time delay systems</li> <li>• Smith predictor</li> </ul> <p>Digital control</p> <ul style="list-style-type: none"> <li>• Sampled-data systems, difference equations</li> <li>• Tustin approximation, digital implementation of PID controllers</li> </ul> <p>Software tools</p> <ul style="list-style-type: none"> <li>• Introduction to Matlab, Simulink, Control toolbox</li> <li>• Computer-based exercises throughout the course</li> </ul> |
| <b>Literature</b>                             | <ul style="list-style-type: none"> <li>• Werner, H., Lecture Notes „Introduction to Control Systems“</li> <li>• G.F. Franklin, J.D. Powell and A. Emami-Naeini "Feedback Control of Dynamic Systems", Addison Wesley, Reading, MA, 2009</li> <li>• K. Ogata "Modern Control Engineering", Fourth Edition, Prentice Hall, Upper Saddle River, NJ, 2010</li> <li>• R.C. Dorf and R.H. Bishop, "Modern Control Systems", Addison Wesley, Reading, MA 2010</li> </ul>  |

| <b>Course L0655: Introduction to Control Systems</b> |   |
|--|---|
| <b>Typ</b>   | Recitation Section (small)                          |
| <b>Hrs/wk</b>  | 2   |
| <b>CP</b>  | 2   |
| <b>Workload in Hours</b>                             | Independent Study Time 32, Study Time in Lecture 28 |
| <b>Lecturer</b>                                      | Prof. Herbert Werner                                |
| <b>Language</b>                                      | DE  |
| <b>Cycle</b>   | WiSe  |
| <b>Content</b>                                       | See interlocking course                             |
| <b>Literature</b>                                    | See interlocking course                             |

| Module M1498: Practice of Process Engineering        |   |               |           |
|--|---|---------------|-----------|
| <b>Courses</b>                                       |   |               |           |
| <b>Title</b>   | <b>Typ</b>  | <b>Hrs/wk</b> | <b>CP</b> |
| Practice in Process Engineering (L2271)              | Project Seminar   | 2             | 2         |
| Lectures for Practice of Process Engineering (L2272) | Seminar   | 1             | 1         |
| <b>Module Responsible</b>                            | Prof. Irina Smirnova  |               |           |
| <b>Admission Requirements</b>                        | None  |               |           |
| <b>Recommended Previous Knowledge</b>                | none  |               |           |
| <b>Educational Objectives</b>                        | After taking part successfully, students have reached the following learning results  |               |           |
| <b>Professional Competence</b>                       | After passing this module the students have the ability to:   |               |           |
| <i>Knowledge</i>                                     | <ul style="list-style-type: none"> <li>• give an overview of a certain important field on process and bioprocess engineering,</li> <li>• explain some working methods for different fields in process engineering.</li> </ul>   |               |           |
| <i>Skills</i>  | After successfully completing this module, students are able to   |               |           |
|  | <ul style="list-style-type: none"> <li>• prepare a written summary of a process engineering topic</li> <li>• to briefly present and discuss a topic in a short presentation</li> <li>• to roughly describe independently typical process engineering and biotechnological processes by means of notes.</li> </ul> |               |           |
| <b>Personal Competence</b>                           | The students are able to  |               |           |
| <i>Social Competence</i>                             | <ul style="list-style-type: none"> <li>• work out results in groups and document them,</li> <li>• provide appropriate feedback and handle feedback on their own performance constructively.</li> </ul>  |               |           |
| <i>Autonomy</i>                                      | The students are able to estimate their progress of learning by themselves and to deliberate their lack of knowledge in Process Engineering and Bioprocess Engineering.   |               |           |
| <b>Workload in Hours</b>                             | Independent Study Time 48, Study Time in Lecture 42   |               |           |
| <b>Credit points</b>                                 | 3   |               |           |
| <b>Course achievement</b>                            | None  |               |           |
| <b>Examination</b>                                   | Subject theoretical and practical work  |               |           |
| <b>Examination duration and scale</b>                | 1 DIN A4 page report to be handed out to the person responsible for the module + presentation at the end of the semester  |               |           |
| <b>Assignment for the Following Curricula</b>        | Bioprocess Engineering: Core qualification: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory  |               |           |

| Course L2271: Practice in Process Engineering |  |
|---|--|
| <b>Typ</b>                                    | Project Seminar  |
| <b>Hrs/wk</b>                                 | 2  |
| <b>CP</b>                                     | 2  |
| <b>Workload in Hours</b>                      | Independent Study Time 32, Study Time in Lecture 28  |
| <b>Lecturer</b>                               | Dozenten des SD V  |
| <b>Language</b>                               | DE   |
| <b>Cycle</b>                                  | WiSe/SoSe  |
| <b>Content</b>                                | <p>The following activities can be credited to students:</p> <ul style="list-style-type: none"> <li>• Internships in industry (e.g. also during the semester break)</li> <li>• Completed practical projects with construction and workshop activities (basic internship) at institutes of the faculty</li> <li>• Activities on experimental plants at institutes of the faculty</li> <li>• Own project in the student workshop</li> <li>• Small projects in the FabLab</li> </ul> <p>For further information please visit: <a href="https://www.tuhh.de/verfahrenstechnik/lehre.html">https://www.tuhh.de/verfahrenstechnik/lehre.html</a></p> |
| <b>Literature</b>                             |  |

| <b>Course L2272: Lectures for Praticice of Process Engineering</b> |  |
|--|--|
| <b>Typ</b>   | Seminar  |
| <b>Hrs/wk</b>  | 1  |
| <b>CP</b>  | 1  |
| <b>Workload in Hours</b>   | Independent Study Time 16, Study Time in Lecture 14  |
| <b>Lecturer</b>  | Dozenten des SD V  |
| <b>Language</b>  | DE/EN  |
| <b>Cycle</b>   | WiSe/SoSe  |
| <b>Content</b>   | <p>The following events can be credited as lectures:</p> <ul style="list-style-type: none"> <li>• Ring-Lectures</li> <li>• VT Colloquia</li> <li>• Presentations of Master Theses</li> </ul> <p>For further information please visit <a href="https://www.tuhh.de/verfahrenstechnik/lehre.html">https://www.tuhh.de/verfahrenstechnik/lehre.html</a></p> |
| <b>Literature</b>  |  |

| <b>Module M0829: Foundations of Management</b> |  |               |           |
|--|--|---------------|-----------|
| <b>Courses</b>                                 |  |               |           |
| <b>Title</b>                                   | <b>Typ</b>   | <b>Hrs/wk</b> | <b>CP</b> |
| Management Tutorial (L0882)                    | Recitation Section (small)   | 2             | 3         |
| Introduction to Management (L0880)             | Lecture  | 3             | 3         |
| <b>Module Responsible</b>                      | Prof. Christoph Ihl  |               |           |
| <b>Admission Requirements</b>                  | None   |               |           |
| <b>Recommended Previous Knowledge</b>          | Basic Knowledge of Mathematics and Business  |               |           |
| <b>Educational Objectives</b>                  | After taking part successfully, students have reached the following learning results   |               |           |
| <b>Professional Competence</b>                 | After taking this module, students know the important basics of many different areas in Business and Management, from Planning and Organisation to Marketing and Innovation, and also to Investment and Controlling. In particular they are able to  |               |           |
| <i>Knowledge</i>                               | <ul style="list-style-type: none"> <li>• explain the differences between Economics and Management and the sub-disciplines in Management and to name important definitions from the field of Management</li> <li>• explain the most important aspects of and goals in Management and name the most important aspects of entrepreneurial projects</li> <li>• describe and explain basic business functions as production, procurement and sourcing, supply chain management, organization and human resource management, information management, innovation management and marketing</li> <li>• explain the relevance of planning and decision making in Business, esp. in situations under multiple objectives and uncertainty, and explain some basic methods from mathematical Finance</li> <li>• state basics from accounting and costing and selected controlling methods.</li> </ul>   |               |           |
| <i>Skills</i>                                  | <p>Students are able to analyse business units with respect to different criteria (organization, objectives, strategies etc.) and to carry out an Entrepreneurship project in a team. In particular, they are able to</p> <ul style="list-style-type: none"> <li>• analyse Management goals and structure them appropriately</li> <li>• analyse organisational and staff structures of companies</li> <li>• apply methods for decision making under multiple objectives, under uncertainty and under risk</li> <li>• analyse production and procurement systems and Business information systems</li> <li>• analyse and apply basic methods of marketing</li> <li>• select and apply basic methods from mathematical finance to predefined problems</li> <li>• apply basic methods from accounting, costing and controlling to predefined problems</li> </ul>  |               |           |
| <b>Personal Competence</b>                     | Students are able to   |               |           |
| <i>Social Competence</i>                       | <ul style="list-style-type: none"> <li>• work successfully in a team of students</li> <li>• to apply their knowledge from the lecture to an entrepreneurship project and write a coherent report on the project</li> <li>• to communicate appropriately and</li> <li>• to cooperate respectfully with their fellow students.</li> </ul>  |               |           |
| <i>Autonomy</i>                                | <p>Students are able to</p> <ul style="list-style-type: none"> <li>• work in a team and to organize the team themselves</li> <li>• to write a report on their project.</li> </ul>  |               |           |
| <b>Workload in Hours</b>                       | Independent Study Time 110, Study Time in Lecture 70   |               |           |
| <b>Credit points</b>                           | 6  |               |           |
| <b>Course achievement</b>                      | None   |               |           |
| <b>Examination</b>                             | Subject theoretical and practical work   |               |           |
| <b>Examination duration and scale</b>          | several written exams during the semester  |               |           |
| <b>Assignment for the Following Curricula</b>  | <p>General Engineering Science (German program, 7 semester): Core qualification: Compulsory<br/>           Civil- and Environmental Engineering: Specialisation Civil Engineering: Elective Compulsory<br/>           Civil- and Environmental Engineering: Specialisation Water and Environment: Elective Compulsory<br/>           Civil- and Environmental Engineering: Specialisation Traffic and Mobility: Elective Compulsory<br/>           Bioprocess Engineering: Core qualification: Compulsory<br/>           Computer Science: Core qualification: Compulsory<br/>           Data Science: Core qualification: Compulsory<br/>           Electrical Engineering: Core qualification: Compulsory<br/>           Energy and Environmental Engineering: Core qualification: Compulsory<br/>           General Engineering Science (English program, 7 semester): Specialisation Electrical Engineering: Compulsory<br/>           General Engineering Science (English program, 7 semester): Specialisation Civil Engineering: Compulsory<br/>           General Engineering Science (English program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br/>           General Engineering Science (English program, 7 semester): Specialisation Energy and Environmental Engineering: Compulsory<br/>           General Engineering Science (English program, 7 semester): Specialisation Computer Science: Compulsory<br/>           General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory<br/>           General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Energy Systems: Compulsory<br/>           General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Aircraft Systems Engineering: Compulsory</p> |               |           |

|  |  |
|--|--|
|  | <p>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Product Development and Production: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Naval Architecture: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Process Engineering: Compulsory</p> <p>General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: Compulsory</p> <p>Green Technologies: Energy, Water, Climate: Core qualification: Compulsory</p> <p>Computational Science and Engineering: Core qualification: Compulsory</p> <p>Logistics and Mobility: Core qualification: Compulsory</p> <p>Mechanical Engineering: Core qualification: Compulsory</p> <p>Mechatronics: Core qualification: Compulsory</p> <p>Orientation Studies: Core qualification: Elective Compulsory</p> <p>Orientation Studies: Core qualification: Elective Compulsory</p> <p>Naval Architecture: Core qualification: Compulsory</p> <p>Technomathematics: Core qualification: Compulsory</p> <p>Process Engineering: Core qualification: Compulsory</p> <p>Engineering and Management - Major in Logistics and Mobility: Core qualification: Compulsory</p> |
|--|--|

| Course L0882: Management Tutorial |  |
|-----------------------------------|--|
| <b>Typ</b>                        | Recitation Section (small)   |
| <b>Hrs/wk</b>                     | 2  |
| <b>CP</b>                         | 3  |
| <b>Workload in Hours</b>          | Independent Study Time 62, Study Time in Lecture 28  |
| <b>Lecturer</b>                   | Prof. Christoph Ihl, Katharina Roedelius   |
| <b>Language</b>                   | DE   |
| <b>Cycle</b>                      | WiSe/SoSe  |
| <b>Content</b>                    | <p>In the management tutorial, the contents of the lecture will be deepened by practical examples and the application of the discussed tools.</p> <p>If there is adequate demand, a problem-oriented tutorial will be offered in parallel, which students can choose alternatively. Here, students work in groups on selected projects that focus on the elaboration of an innovative business idea from the point of view of an established company or a startup. Again, the business knowledge from the lecture should come to practical use. The group projects are guided by a mentor.</p> |
| <b>Literature</b>                 | Relevante Literatur aus der korrespondierenden Vorlesung.  |

| <b>Course L0880: Introduction to Management</b> |  |
|---|--|
| <b>Typ</b>                                      | Lecture  |
| <b>Hrs/wk</b>                                   | 3  |
| <b>CP</b>                                       | 3  |
| <b>Workload in Hours</b>                        | Independent Study Time 48, Study Time in Lecture 42  |
| <b>Lecturer</b>                                 | Prof. Christoph Ihl, Prof. Thorsten Blecker, Prof. Christian Lütjhe, Prof. Christian Ringle, Prof. Kathrin Fischer, Prof. Cornelius Herstatt, Prof. Wolfgang Kersten, Prof. Matthias Meyer, Prof. Thomas Wrona   |
| <b>Language</b>                                 | DE   |
| <b>Cycle</b>                                    | WiSe/SoSe  |
| <b>Content</b>                                  | <ul style="list-style-type: none"> <li>• Introduction to Business and Management, Business versus Economics, relevant areas in Business and Management</li> <li>• Important definitions from Management,</li> <li>• Developing Objectives for Business, and their relation to important Business functions</li> <li>• Business Functions: Functions of the Value Chain, e.g. Production and Procurement, Supply Chain Management, Innovation Management, Marketing and Sales</li> <li>• Cross-sectional Functions, e.g. Organisation, Human Ressource Management, Supply Chain Management, Information Management</li> <li>• Definitions as information, information systems, aspects of data security and strategic information systems</li> <li>• Definition and Relevance of innovations, e.g. innovation opportunities, risks etc.</li> <li>• Relevance of marketing, B2B vs. B2C-Marketing</li> <li>• different techniques from the field of marketing (e.g. scenario technique), pricing strategies</li> <li>• important organizational structures</li> <li>• basics of human ressource management</li> <li>• Introduction to Business Planning and the steps of a planning process</li> <li>• Decision Analysis: Elements of decision problems and methods for solving decision problems</li> <li>• Selected Planning Tasks, e.g. Investment and Financial Decisions</li> <li>• Introduction to Accounting: Accounting, Balance-Sheets, Costing</li> <li>• Relevance of Controlling and selected Controlling methods</li> <li>• Important aspects of Entrepreneurship projects</li> </ul> |
| <b>Literature</b>                               | <p>Bamberg, G., Coenenberg, A.: Betriebswirtschaftliche Entscheidungslehre, 14. Aufl., München 2008</p> <p>Eisenführ, F., Weber, M.: Rationales Entscheiden, 4. Aufl., Berlin et al. 2003</p> <p>Heinhold, M.: Buchführung in Fallbeispielen, 10. Aufl., Stuttgart 2006.</p> <p>Kruschwitz, L.: Finanzmathematik. 3. Auflage, München 2001.</p> <p>Pellens, B., Fülbier, R. U., Gassen, J., Sellhorn, T.: Internationale Rechnungslegung, 7. Aufl., Stuttgart 2008.</p> <p>Schweitzer, M.: Planung und Steuerung, in: Bea/Friedl/Schweitzer: Allgemeine Betriebswirtschaftslehre, Bd. 2: Führung, 9. Aufl., Stuttgart 2005.</p> <p>Weber, J., Schäffer, U. : Einführung in das Controlling, 12. Auflage, Stuttgart 2008.</p> <p>Weber, J./Weißenberger, B.: Einführung in das Rechnungswesen, 7. Auflage, Stuttgart 2006.</p>  |

| Module M1274: Environmental Technology        |   |        |    |
|---|---|--------|----|
| Courses                                       |   |        |    |
| Title   | Typ   | Hrs/wk | CP |
| Environmental Assessment (L0860)              | Lecture   | 2      | 2  |
| Environmental Assessment (L1054)              | Recitation Section (small)  | 1      | 1  |
| <b>Module Responsible</b>                     | Prof. Martin Kaltschmitt  |        |    |
| <b>Admission Requirements</b>                 | None  |        |    |
| <b>Recommended Previous Knowledge</b>         | Fundamentals of inorganic/organic chemistry and biology   |        |    |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results  |        |    |
| <b>Professional Competence</b>                | <p><i>Knowledge</i> With the completion of this module the students acquire in-depth knowledge of important cause-effect chains of potential environmental problems which might occur from production processes, projects or construction measures. They have knowledge about the methodological diversity and are competent in dealing with different methods and instruments to assess environmental impacts. Besides the students are able to estimate the complexity of these environmental processes as well as uncertainties and difficulties with their measurement.</p> <p><i>Skills</i> The students are able to select a suitable method for the respective case from the variety of assessment methods. Thereby they can develop suitable solutions for managing and mitigating environmental problems in a business context. They are able to carry out Life Cycle Impact Assessments independently and can apply the software programs OpenLCA and the database Ecolnvent. After finishing the course the students have the competence to critically judge research results or other publications on environmental impacts.</p> <p><b>Personal Competence</b></p> <p><i>Social Competence</i> The students are able to discuss the various technical and scientific tasks, both subject-specific and multidisciplinary. They are able to develop jointly different solutions and to discuss their theoretical or practical implementation. Due to the selected lecture topics, the students receive insights into the multi-layered issues of the environment protection and the concept of sustainability. Their sensitivity and consciousness towards these subjects are raised and which helps to raise their awareness of their future social responsibilities in their role as engineers.</p> <p><i>Autonomy</i> The students learn to research, process and present a scientific topic independently. They are able to carry out independent scientific work. They can solve an environmental problem in a business context and are able to judge results of other publications.</p> |        |    |
| <b>Workload in Hours</b>                      | Independent Study Time 48, Study Time in Lecture 42   |        |    |
| <b>Credit points</b>                          | 3   |        |    |
| <b>Course achievement</b>                     | None  |        |    |
| <b>Examination</b>                            | Written exam  |        |    |
| <b>Examination duration and scale</b>         | 1 hour written exam   |        |    |
| <b>Assignment for the Following Curricula</b> | General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Elective Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Bioprocess Engineering: Elective Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Energy and Environmental Engineering: Compulsory<br>Bioprocess Engineering: Core qualification: Elective Compulsory<br>Energy and Environmental Engineering: Core qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Bioprocess Engineering: Elective Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Process Engineering: Elective Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Energy and Environmental Engineering: Compulsory<br>Process Engineering: Core qualification: Elective Compulsory  |        |    |



| Course L0860: Environmental Assessment |  |
|--|--|
| <b>Typ</b>                             | Lecture  |
| <b>Hrs/wk</b>                          | 2  |
| <b>CP</b>                              | 2  |
| <b>Workload in Hours</b>               | Independent Study Time 32, Study Time in Lecture 28  |
| <b>Lecturer</b>                        | Dr. Anne Rödl, Dr. Christoph Hagen Balzer  |
| <b>Language</b>                        | DE/EN  |
| <b>Cycle</b>                           | WiSe   |
| <b>Content</b>                         | <p><b>Contaminants:</b> Impact- and Risk Assessment</p> <p><b>Environmental damage &amp; precautionary principle:</b> Environmental Risk Assessment (ERA)</p> <p><b>Resource and water consumption:</b> Material flow analysis</p> <p><b>Energy consumption:</b> Cumulated energy demand (CED), cost analysis</p> <p><b>Life cycle concept:</b> Life cycle assessment (LCA)</p> <p><b>Sustainability:</b> Comprehensive product system assessment , SEE-Balance</p> <p><b>Management:</b> Environmental and Sustainability management (EMAS)</p> <p><b>Complex systems:</b> MCDA and scenario method</p> |
| <b>Literature</b>                      | <p>Foliensätze der Vorlesung</p> <p>Studie: <b>Instrumente zur Nachhaltigkeitsbewertung</b> - Eine Synopse (Forschungszentrum Jülich GmbH)</p>   |

| Course L1054: Environmental Assessment |  |
|--|--|
| <b>Typ</b>                             | Recitation Section (small)   |
| <b>Hrs/wk</b>                          | 1  |
| <b>CP</b>                              | 1  |
| <b>Workload in Hours</b>               | Independent Study Time 16, Study Time in Lecture 14  |
| <b>Lecturer</b>                        | Prof. Martin Kaltschmitt, Dr. Anne Rödl  |
| <b>Language</b>                        | DE   |
| <b>Cycle</b>                           | WiSe   |
| <b>Content</b>                         | <p><b>Presentation and application of free software programs in order to understand the concepts of environmental assessment methods better.</b></p> <p>Within the group exercise students discuss the various technical and scientific tasks, both subject-specific and multidisciplinary. They discuss different approaches to the task as well as it's theoretical or practical implementation.</p> |
| <b>Literature</b>                      | Power point Präsentationen   |

| Module M0539: Process and Plant Engineering I |  |                            |               |                                |
|---|--|----------------------------|---------------|--------------------------------|
| <b>Courses</b>                                |  |                            |               |                                |
| <b>Title</b>                                  |  | <b>Typ</b>                 | <b>Hrs/wk</b> | <b>CP</b>                      |
| Process and Plant Engineering I (L0095)       |  | Lecture                    | 2             | 2                              |
| Process and Plant Engineering I (L0096)       |  | Recitation Section (large) | 1             | 2                              |
| Process and Plant Engineering I (L1214)       |  | Recitation Section (small) | 1             | 2                              |
| <b>Module Responsible</b>                     | Prof. Mirko Skiborowski  |                            |               |                                |
| <b>Admission Requirements</b>                 | None   |                            |               |                                |
| <b>Recommended Previous Knowledge</b>         | unit operation of thermal and mechanical separation processes<br>chemical reactor engineering  |                            |               |                                |
| <b>Educational Objectives</b>                 | After taking part successfully, students have reached the following learning results   |                            |               |                                |
| <b>Professional Competence</b>                | students can:  |                            |               |                                |
| <i>Knowledge</i>                              | classify and formulate global balance equations of chemical processes<br>specify linear component equations of complex chemical processes<br>explain linear regression and data reconciliation problems<br>explain pfd-diagrams  |                            |               |                                |
| <i>Skills</i>                                 | students are capable of<br>- formulation of mass and energy balance equations and estimation of product streams<br>- estimation of component streams of chemical plants using linear component balance models<br>- solution of data reconciliation tasks<br>- conduction of process synthesis<br>- economic evaluation of processes and the estimation of production costs   |                            |               |                                |
| <b>Personal Competence</b>                    |  |                            |               |                                |
| <i>Social Competence</i>                      |  |                            |               |                                |
| <i>Autonomy</i>                               |  |                            |               |                                |
| <b>Workload in Hours</b>                      | Independent Study Time 124, Study Time in Lecture 56   |                            |               |                                |
| <b>Credit points</b>                          | 6  |                            |               |                                |
| <b>Course achievement</b>                     | <b>Compulsory</b>  | <b>Bonus</b>               | <b>Form</b>   | <b>Description</b>             |
|   | Yes  | 10 %                       | Subject       | theoretical and practical work |
| <b>Examination</b>                            | Written exam   |                            |               |                                |
| <b>Examination duration and scale</b>         | 120 Min. lectures notes and books  |                            |               |                                |
| <b>Assignment for the Following Curricula</b> | General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>Bioprocess Engineering: Core qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Energy and Environmental Engineering: Elective Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Process Engineering: Compulsory<br>Green Technologies: Energy, Water, Climate: Specialisation Bioresource Technology: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory |                            |               |                                |

| Course L0095: Process and Plant Engineering I |   |
|---|---|
| <b>Typ</b>                                    | Lecture   |
| <b>Hrs/wk</b>                                 | 2   |
| <b>CP</b>                                     | 2   |
| <b>Workload in Hours</b>                      | Independent Study Time 32, Study Time in Lecture 28   |
| <b>Lecturer</b>                               | Prof. Mirko Skiborowski   |
| <b>Language</b>                               | DE  |
| <b>Cycle</b>                                  | SoSe  |
| <b>Content</b>                                | <ol style="list-style-type: none"> <li><b>Introduction</b><br/>Structure and operation of production plants<br/>Operational business process<br/>Technical process design<br/>Motivation and targets of process development<br/>Life cycle of production plants</li> <li><b>Engineering methods and tools</b><br/>Mass and energy balances<br/>Strategies of process synthesis<br/>Graphical representation of processes<br/>Multidimensional regression</li> </ol> |

|                   |  |
|-------------------|--|
|                   | <p>Data reconciliation and data validation</p> <p>3. <b>Process Synthesis</b><br/>                 Decision levels<br/>                 Experimental process development<br/>                 Reactor synthesis<br/>                 Synthesis of separation processes (process alternatives and criteria for selection)<br/>                 Integration of reaction systems/separation systems (interactions, recycle streams)</p> <p>4. <b>Process safety</b></p> <p>5. <b>Cost estimation of production plants</b><br/>                 Production costs, capital costs, economic evaluation</p>   |
| <b>Literature</b> | <p>S.D. Barnicki, J.R. Fair, Ind. End. Chem., 29(1990), S. 421, Ind. End. Chem., 31(1992), S. 1679</p> <p>H. Becker, S. Godorr, H. Kreis, Chemical Engineering, January 2001, S. 68-74</p> <p>Behr, W. Ebbers, N. Wiese, Chem. -Ing.-Tech. 72(2000)Nr. 10, S.1157</p> <p>E. Blass, Entwicklung verfahrenstechnischer Prozesse, Springer-Verlag, 2. Auflage 1997</p> <p>M. H. Bauer, J. Stichlmair, Chem.-Ing.-Tech., 68(1996), Nr. 8, 911-916</p> <p>R. Dittmeyer, W. Keim, G. Kreysa, A. Oberholz, Chemische Technik. Prozesse und Produkte, Band 2, Neue Technologien, 5. Auflage, Wiley-VCH GmbH&amp;Co.KGaA, Weinheim, 2004</p> <p>J.M. Douglas, Conceptual Design of Chemical Processes, Mc Graw-Hill, NY, 1988</p> <p>G. Fieg, Inz. Chem. Proc., 5(1979), S.15-19</p> <p>G. Fieg, G. Wozny, L. Jeromin, Chem. Eng. Technol. 17(1994),5, 301-306</p> <p>G. Fieg, Heat and Mass Transfer 32(1996), S. 205-213</p> <p>G. Fieg, Chem. Eng. Processing, Vol. 41/2(2001), S. 123-133</p> <p>U.H. Felcht, Chemie eine reife Industrie oder weiterhin Innovationsmotor, Universitätsbuchhandlung Blazek und Bergamann, Frankfurt, 2000</p> <p>J.P. van Gigh, Systems Design, Modeling and Metamodeling, Plenum Press, New York, 1991</p> <p>T.F. Edgar, D.M. Himmelblau, L.S. Lasdon, Optimization of Chemical Processes, McGraw-Hill, 2001</p> <p>G. Gruhn, Vorlesungsmanuskript „Prozess- und Anlagentechnik, TU Hamburg-Harburg</p> <p>D. Hairston, Chemical Engineering, October 2001, S. 31-37</p> <p>J.L.A. Koolen, Design of Simple and Robust Process Plants, Wiley-VCH, Weinheim, 2002</p> <p>J. Krekel, G. Siekmann, Chem. -Ing.-Tech. 57(1985)Nr. 6, S. 511</p> <p>K. Machej, G. Fieg, J. Wojcik, Inz. Chem. Proc., 2(1981), S.815-824</p> <p>S. Meier, G. Kaibel, Chem. -Ing.-Tech. 62(1990)Nr. 13, S.169</p> <p>J. Mittelstraß, Chem. -Ing.-Tech. 66(1994), S. 309</p> <p>P. Li, M. Flender, K. Löwe, G. Wozny, G. Fieg, Fett/Lipid 100(1998), Nr. 12, S. 528-534</p> <p>G. Kaibel, Dissertation, TU München, 1987</p> <p>G. Kaibel, Chem.-Ing.-Tech. 61 (1989), Nr. 2, S. 104-112</p> <p>G. Kaibel, Chem. Eng. Technol., 10(1987), Nr. 2, S. 92-98</p> <p>H.J. Lang, Chem. Eng. 54(10),117, 1947</p> <p>H.J. Lang, Chem. Eng. 55(6), 112, 1948</p> <p>F. Lestak, C. Collins, Chemical Engineering, July 1997, S. 72-76</p> |

| Course L0096: Process and Plant Engineering I |   |
|---|---|
| <b>Typ</b>                                    | Recitation Section (large)                          |
| <b>Hrs/wk</b>                                 | 1   |
| <b>CP</b>                                     | 2   |
| <b>Workload in Hours</b>                      | Independent Study Time 46, Study Time in Lecture 14 |
| <b>Lecturer</b>                               | Prof. Mirko Skiborowski, Dr. Thomas Waluga          |
| <b>Language</b>                               | DE  |
| <b>Cycle</b>                                  | SoSe  |
| <b>Content</b>                                | See interlocking course                             |
| <b>Literature</b>                             | See interlocking course                             |

| <b>Course L1214: Process and Plant Engineering I</b> |   |
|--|---|
| <b>Typ</b>   | Recitation Section (small)                          |
| <b>Hrs/wk</b>  | 1   |
| <b>CP</b>  | 2   |
| <b>Workload in Hours</b>                             | Independent Study Time 46, Study Time in Lecture 14 |
| <b>Lecturer</b>                                      | Prof. Mirko Skiborowski, Dr. Thomas Waluga          |
| <b>Language</b>                                      | DE  |
| <b>Cycle</b>   | SoSe  |
| <b>Content</b>                                       | See interlocking course                             |
| <b>Literature</b>                                    | See interlocking course                             |

| Module M0670: Particle Technology and Solids Process Engineering |   |                            |                     |  |
|--|---|----------------------------|---------------------|--|
| <b>Courses</b>   |   |                            |                     |  |
| <b>Title</b>   |   | <b>Typ</b>                 | <b>Hrs/wk</b>       | <b>CP</b>  |
| Particle Technology I (L0434)                                    |   | Lecture                    | 2                   | 3  |
| Particle Technology I (L0435)                                    |   | Recitation Section (small) | 1                   | 1  |
| Particle Technology I (L0440)                                    |   | Practical Course           | 2                   | 2  |
| <b>Module Responsible</b>  | Prof. Stefan Heinrich   |                            |                     |  |
| <b>Admission Requirements</b>                                    | None  |                            |                     |  |
| <b>Recommended Previous Knowledge</b>                            | keine   |                            |                     |  |
| <b>Educational Objectives</b>                                    | After taking part successfully, students have reached the following learning results  |                            |                     |  |
| <b>Professional Competence</b>                                   |   |                            |                     |  |
| <i>Knowledge</i>   | After successful completion of the module students are able to  |                            |                     |  |
|  | <ul style="list-style-type: none"> <li>name and explain processes and unit-operations of solids process engineering,</li> <li>characterize particles, particle distributions and to discuss their bulk properties</li> </ul>  |                            |                     |  |
| <i>Skills</i>  | Students are able to  |                            |                     |  |
|  | <ul style="list-style-type: none"> <li>choose and design apparatuses and processes for solids processing according to the desired solids properties of the product</li> <li>asses solids with respect to their behavior in solids processing steps</li> <li>document their work scientifically.</li> </ul>  |                            |                     |  |
| <b>Personal Competence</b>                                       |   |                            |                     |  |
| <i>Social Competence</i>   | The students are able to discuss scientific topics orally with other students or scientific personal and to develop solutions for technical-scientific issues in a group.   |                            |                     |  |
| <i>Autonomy</i>  | Students are able to analyze and solve questions regarding solid particles independently.   |                            |                     |  |
| <b>Workload in Hours</b>   | Independent Study Time 110, Study Time in Lecture 70  |                            |                     |  |
| <b>Credit points</b>   | 6   |                            |                     |  |
| <b>Course achievement</b>  | <b>Compulsory</b>   | <b>Bonus</b>               | <b>Form</b>         | <b>Description</b>                                     |
|  | Yes   | None                       | Written elaboration | sechs Berichte (pro Versuch ein Bericht) à 5-10 Seiten |
| <b>Examination</b>   | Written exam  |                            |                     |  |
| <b>Examination duration and scale</b>                            | 90 minutes  |                            |                     |  |
| <b>Assignment for the Following Curricula</b>                    | General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Energy and Environmental Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Green Technologies, Focus Water and Environmental Engineering: Elective Compulsory<br>Bioprocess Engineering: Core qualification: Compulsory<br>Energy and Environmental Engineering: Core qualification: Elective Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Energy and Environmental Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Process Engineering: Compulsory<br>Green Technologies: Energy, Water, Climate: Specialisation Water: Elective Compulsory<br>Process Engineering: Core qualification: Compulsory |                            |                     |  |

| Course L0434: Particle Technology I |   |
|-------------------------------------|---|
| <b>Typ</b>                          | Lecture   |
| <b>Hrs/wk</b>                       | 2   |
| <b>CP</b>                           | 3   |
| <b>Workload in Hours</b>            | Independent Study Time 62, Study Time in Lecture 28   |
| <b>Lecturer</b>                     | Prof. Stefan Heinrich   |
| <b>Language</b>                     | DE  |
| <b>Cycle</b>                        | SoSe  |
| <b>Content</b>                      | <ul style="list-style-type: none"> <li>• Description of particles and particle distributions</li> <li>• Description of a separation process</li> <li>• Description of a particle mixture</li> <li>• Particle size reduction</li> <li>• Agglomeration, particle size enlargement</li> <li>• Storage and flow of bulk solids</li> <li>• Basics of fluid/particle flows</li> <li>• classifying processes</li> <li>• Separation of particles from fluids</li> <li>• Basic fluid mechanics of fluidized beds</li> <li>• Pneumatic and hydraulic transport</li> </ul> |
| <b>Literature</b>                   | <p>Schubert, H.; Heidenreich, E.; Liepe, F.; Neeße, T.: Mechanische Verfahrenstechnik. Deutscher Verlag für die Grundstoffindustrie, Leipzig, 1990.</p> <p>Stieß, M.: Mechanische Verfahrenstechnik I und II. Springer Verlag, Berlin, 1992.</p>  |

| Course L0435: Particle Technology I |   |
|-------------------------------------|---|
| <b>Typ</b>                          | Recitation Section (small)                          |
| <b>Hrs/wk</b>                       | 1   |
| <b>CP</b>                           | 1   |
| <b>Workload in Hours</b>            | Independent Study Time 16, Study Time in Lecture 14 |
| <b>Lecturer</b>                     | Prof. Stefan Heinrich                               |
| <b>Language</b>                     | DE  |
| <b>Cycle</b>                        | SoSe  |
| <b>Content</b>                      | See interlocking course                             |
| <b>Literature</b>                   | See interlocking course                             |

| Course L0440: Particle Technology I |  |
|-------------------------------------|--|
| <b>Typ</b>                          | Practical Course   |
| <b>Hrs/wk</b>                       | 2  |
| <b>CP</b>                           | 2  |
| <b>Workload in Hours</b>            | Independent Study Time 32, Study Time in Lecture 28  |
| <b>Lecturer</b>                     | Prof. Stefan Heinrich  |
| <b>Language</b>                     | DE/EN  |
| <b>Cycle</b>                        | SoSe   |
| <b>Content</b>                      | <ul style="list-style-type: none"> <li>• Sieving</li> <li>• Bulk properties</li> <li>• Size reduction</li> <li>• Mixing</li> <li>• Gas cyclone</li> <li>• Blaine-test, filtration</li> <li>• Sedimentation</li> </ul>                            |
| <b>Literature</b>                   | <p>Schubert, H.; Heidenreich, E.; Liepe, F.; Neeße, T.: Mechanische Verfahrenstechnik. Deutscher Verlag für die Grundstoffindustrie, Leipzig, 1990.</p> <p>Stieß, M.: Mechanische Verfahrenstechnik I und II. Springer Verlag, Berlin, 1992.</p> |

**Thesis**

| Module M-001: Bachelor Thesis                          |  |        |    |
|--|--|--------|----|
| Courses  |  |        |    |
| Title  | Typ  | Hrs/wk | CP |
| <b>Module Responsible</b>                              | Professoren der TUHH   |        |    |
| <b>Admission Requirements</b>                          | <ul style="list-style-type: none"> <li>According to General Regulations §21 (1):</li> </ul> <p>At least 126 ECTS credit points have to be achieved in study programme. The examinations board decides on exceptions.</p>   |        |    |
| <b>Recommended Previous Knowledge</b>                  |  |        |    |
| <b>Educational Objectives</b>                          | After taking part successfully, students have reached the following learning results   |        |    |
| <b>Professional Competence</b><br><i>Knowledge</i>     | <ul style="list-style-type: none"> <li>The students can select, outline and, if need be, critically discuss the most important scientific fundamentals of their course of study (facts, theories, and methods).</li> <li>On the basis of their fundamental knowledge of their subject the students are capable in relation to a specific issue of opening up and establishing links with extended specialized expertise.</li> <li>The students are able to outline the state of research on a selected issue in their subject area.</li> </ul>   |        |    |
| <b>Professional Competence</b><br><i>Skills</i>        | <ul style="list-style-type: none"> <li>The students can make targeted use of the basic knowledge of their subject that they have acquired in their studies to solve subject-related problems.</li> <li>With the aid of the methods they have learnt during their studies the students can analyze problems, make decisions on technical issues, and develop solutions.</li> <li>The students can take up a critical position on the findings of their own research work from a specialized perspective.</li> </ul>   |        |    |
| <b>Personal Competence</b><br><i>Social Competence</i> | <ul style="list-style-type: none"> <li>Both in writing and orally the students can outline a scientific issue for an expert audience accurately, understandably and in a structured way.</li> <li>The students can deal with issues in an expert discussion and answer them in a manner that is appropriate to the addressees. In doing so they can uphold their own assessments and viewpoints convincingly.</li> </ul>   |        |    |
| <b>Personal Competence</b><br><i>Autonomy</i>          | <ul style="list-style-type: none"> <li>The students are capable of structuring an extensive work process in terms of time and of dealing with an issue within a specified time frame.</li> <li>The students are able to identify, open up, and connect knowledge and material necessary for working on a scientific problem.</li> <li>The students can apply the essential techniques of scientific work to research of their own.</li> </ul>  |        |    |
| <b>Workload in Hours</b>                               | Independent Study Time 360, Study Time in Lecture 0  |        |    |
| <b>Credit points</b>                                   | 12   |        |    |
| <b>Course achievement</b>                              | None   |        |    |
| <b>Examination</b>                                     | Thesis   |        |    |
| <b>Examination duration and scale</b>                  | According to General Regulations   |        |    |
| <b>Assignment for the Following Curricula</b>          | General Engineering Science (German program): Thesis: Compulsory<br>General Engineering Science (German program, 7 semester): Thesis: Compulsory<br>Civil- and Environmental Engineering: Thesis: Compulsory<br>Bioprocess Engineering: Thesis: Compulsory<br>Computer Science: Thesis: Compulsory<br>Data Science: Thesis: Compulsory<br>Digital Mechanical Engineering: Thesis: Compulsory<br>Electrical Engineering: Thesis: Compulsory<br>Energy and Environmental Engineering: Thesis: Compulsory<br>Engineering Science: Thesis: Compulsory<br>General Engineering Science (English program, 7 semester): Thesis: Compulsory<br>Green Technologies: Energy, Water, Climate: Thesis: Compulsory<br>Computational Science and Engineering: Thesis: Compulsory<br>Logistics and Mobility: Thesis: Compulsory<br>Mechanical Engineering: Thesis: Compulsory<br>Mechatronics: Thesis: Compulsory<br>Naval Architecture: Thesis: Compulsory<br>Technomathematics: Thesis: Compulsory<br>Teilstudiengang Lehramt Elektrotechnik-Informationstechnik: Thesis: Compulsory<br>Teilstudiengang Lehramt Metalltechnik: Thesis: Compulsory<br>Process Engineering: Thesis: Compulsory<br>Engineering and Management - Major in Logistics and Mobility: Thesis: Compulsory |        |    |