TUHH
Hamburg
University of
Technology

Module Manual

Master of Science (M.Sc.)

Materials Science

Cohort: Winter Term 2020

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Program description

Content

Materials - both classic as well as novel - are the basis and the driving force for products and product innovations. The most important material-based industries in Germany, including automotive and engineering, chemical, power engineering, electrical and electronics as well as metal manufacturing and processing, generate annual sales of nearly one trillion euros and employ around five million people.

Materials scientists are developing entirely new materials concepts - for example in current key fields such as energy storage and conversion or structural lightweight construction - or they are improving existing materials and adapting them to the constantly changing requirements of global competition. With their expertise on the complex implication of structure, composition, processing steps and load and environmental influences on the performance and behavior of materials in practical use, they are also a link between design and production.

Due to the importance of material behavior for the structural design and processing of products, the study of materials has a strong engineering component. At the same time, the understanding of material behavior is based on the most recent insights in basic natural science subjects. For example, although modern high-performance steels are produced on a 1000-tonne scale, the trend is increasing towards the design of such materials and their processing steps based on model calculations based on quantum-physical principles covering the entire scale from atom to component.

Novel composite and hybrid materials that combine high strength and low weight with functional properties such as actuators or sensors are using current research results from the nanoscience. The development of biomaterials, which are increasingly important in health care, requires insights from medicine in addition to materials physical and chemical approaches. The broad interdisciplinary approach of materials science makes them a bridging discipline between the engineering and natural sciences.

The master’s program Materials Science (M.Sc.) - Multiscale Material Systems is addressed to bachelor graduates of engineering as well as physics or chemistry. With its baseline-oriented curriculum, taking into account both natural science and engineering aspects, the program provides an understanding of the fabrication, design, properties, and design principles of materials, from atomic structures and processes to component behavior.

The focus of the first year of study are the core topics: physics and chemistry of materials, methods in experiment, theory and cross-scale modeling, mechanical properties ranging from molecules to idealized monocrystalline states to real material, phase transitions and microstructure design as well as properties of functional materials. Specialization areas open up the fields of nano- and hybrid materials, technical materials, and material modeling. In the second year of study, participation in current research is the focus, with a study project on Modern Problems of Materials Science as well as the Master's Thesis.

Career prospects

Examples of task areas of materials scientists are:

- Materials expertise in construction
- process development and support in the materials producing and processing industry
- material and process development in research and development departments
- failure analysis
- quality assurance
- patents
- scientific research at universities and state research institutions

Business sectors include:

- vehicle and aircraft construction
- mechanical engineering
- chemical industry
- energy management
- electrical and electronics industry
- metal smelting and processing
- medical engineering
- civil engineering

Learning target

Knowledge

- Graduates have learned the basic principles and acquired the knowledge and skills in the field of materials science that qualifies them for professional practice in a national and international environment. Graduates are able to describe the underlying scientific principles of materials science as well as the central experimental and computational methods.
- They have an advanced knowledge in the following subject areas and can explain them:
  - metals, ceramics, polymers and their composites
  - the mutual interplay between materials behavior, microstructure, and processing
  - mechanical properties, functional properties, phase transitions and microstructure evolution
  - characterization techniques in materials science
  - modeling approaches in materials science.
- Graduates can apply their knowledge in the above-mentioned subject areas as well as their methodological skills to scientific as well as technical materials-related tasks.
- They can identify and link the relevant fundamental methods and insights in order to solve scientific as well as technical problems in the area of materials science and specifically in subject areas of their specialization.

Graduates with the specialization **"Construction Materials"**

- can evaluate metals, ceramics, polymers and composite materials for specific tasks in a technology-oriented environment.
- can develop and supervise sequences of processing steps.
- can make decisions on material selection, industrial production, quality assurance and failure analysis.

Graduates with the specialization **"Modeling"**

- can identify the appropriate modeling approaches for different phenomena on different length and time scales, adapt them to the respective problem and use them specifically for problem solving.
- can select and implement appropriate modeling approaches for given materials problems in science and technology. They can assess the

significance and reliability of modeling results in relation to the real world observations.

Graduates with the specialization **"Nano and Hybrid Materials"**

- are familiar with the phenomena and physical or physico-chemical principles that link the properties of nanoscale bodies or of materials with a nanoscale microstructure to the characteristic length scales and to the presence and properties of interfaces. In particular, they can explain the relationships mentioned.
- can implement this knowledge for setting up or for optimizing and for implementing materials design strategies that modify the material's behavior through the following approaches: tailoring nanoscale microstructure geometry; tailoring the interfacial behavior; combining hard and soft matter at the nanoscale into hybrid materials.

Social competence

- Graduates can work in teams and can organize their workflow in a problem-based approach, as a preparation for a research-oriented occupatio
- Graduates are able to present their results and insights in writing and orally and to match their presentation to its target audience
- Graduates should be able to critically and reflectively shape social processes, as well as play a decisive role in them with a sense of responsibility and a democratic sense of community.

Independence

- Graduates are able to develop branches of their subject in an effectively self-organized manner using scientific methodology.
- They are able to present their acquired knowledge in an independent manner using appropriate presentation techniques or to present it in a written document of appropriate scope.
- Graduates are able to identify additional information needs and develop a strategy to expand their knowledge independently.

Program structure

The curriculum of the master's program "Materials Science" is structured as follows:

Core qualification: 1.-3. Semester, a total of 66 credit points. In the core qualification, the modules "Non-technical supplementary courses in the Master" and "Operation & Management" are also anchored with six credit points each.

Specialization: The students choose one of the three topics listed below, with the respective specializations during the 1st-3rd. Semesters 24 credits are earned:

- Specialization construction materials
- Specialization modeling
- Specialization nano and hybrid materials

Master thesis in the 4th semester: 30 credit points

Core Qualification

Module M0523: Business & Management

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

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

Module M0524: Non-technical Courses for Master

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

Personal Competence	
Social Competence	**Personal Competences (Social Skills)** Students will be able • to learn to collaborate in different manner, • to present and analyze problems in the abovementioned fields in a partner or group situation in a manner appropriate to the addressees, • to express themselves competently, in a culturally appropriate and gender-sensitive manner in the language of the country (as far as this study-focus would be chosen), • to explain nontechnical items to auditorium with technical background knowledge.
Autonomy	**Personal Competences (Self-reliance)** Students are able in selected areas • to reflect on their own profession and professionalism in the context of real-life fields of application • to organize themselves and their own learning processes • to reflect and decide questions in front of a broad education background • to communicate a nontechnical item in a competent way in writen form or verbaly • to organize themselves as an entrepreneurial subject country (as far as this study-focus would be chosen)
Workload in Hours	Depends on choice of courses
Credit points	6

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

Module M1197: Multiphase Materials

Courses

Title	Typ	Hrs/wk	CP
Polymer Composites (L1891)	Lecture	2	3
Lecture: Multiscale Materials (L1659)	Lecture	6	3

Module Responsible	Prof. Robert Meißner
Admission Requirements	None
Recommended Previous Knowledge	Knowledge in basics of polymers, physics and mechanics/micromechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can - explain the complex relationships of the mechanics of composite materials, the failure mechanisms and physical properties. - assess the interactions of microstructure and properties of the matrix and reinforcing materials. - explain e.g. different fiber types, including relative contexts (e.g. sustainability, environmental protection). They know different methods of modeling multiphase materials and can apply them.
Skills	Students are capable of - using standardized methods of calculation and modeling using the finite element method in a specified context to use discretization, solver, Programming with Python, Automated control and evaluation of parameter studies and examples to calculate of elastic mechanics like tensile, bending, four point bend, crack propagation, J -Integral, Cohesive zone models, Contact. - determining the material properties (elasticity, plasticity, small and large deformations, modeling of multiphase materials). - to calculate and evaluate the mechanical properties (modulus, strength) of different materials. - Approximate sizing using the network theory of the structural elements implement and evaluate. - selecting appropriate solutions for mechanical material problems: Solution of inverse problems (neural networks, optimization methods).
Personal Competence	
Social Competence	Students can - arrive at funded work results in heterogenius groups and document them. - provide appropriate feedback and handle feedback on their own performance constructively.
Autonomy	Students are able to, - assess their own strengths and weaknesses - assess their own state of learning in specific terms and to define further work steps on this basis They are able to fill gaps in as well as extent their knowledge using the literature and other sources provided by the supervisor. Furthermore, they can meaningfully extend given problems and pragmatically solve them by means of corresponding solutions and concepts.
Workload in Hours	Independent Study Time 68, Study Time in Lecture 112
Credit points	6
Course achievement	**Compulsory** Yes, **Bonus** 0 %, **Form** Written elaboration, **Description**
Examination	Written exam
Examination duration and scale	1,5 h written exam in Polymermatrix Composites
Assignment for the Following Curricula	Materials Science: Core Qualification: Compulsory

Course L1891: Polymer Composites	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Robert Meißner
Language	DE
Cycle	SoSe
Content	Manufacturing and Properties of CNTs and Graphen Manufacturing and Properties of 3-dimensional Graphenstruktures Polymer Composites with carbon nanoparticles
Literature	Aktuelle Veröffentlichungen

Course L1659: Lecture: Multiscale Materials	
Typ	Lecture
Hrs/wk	6
CP	3
Workload in Hours	Independent Study Time 6, Study Time in Lecture 84
Lecturer	Prof. Gerold Schneider, Prof. Norbert Huber, Prof. Stefan Fritz Müller, Prof. Patrick Huber, Prof. Manfred Eich, Prof. Bodo Fiedler, Dr. Erica Lilleodden, Prof. Karl Schulte, Prof. Jörg Weißmüller, Prof. Christian Cyron
Language	DE
Cycle	WiSe
Content	The materials discussed in this lecture differ from „conventional“ ones due to their individual hierarchic microstructure. In conventional microstructure design, the morphology is adjusted, for instance, by thermal treatment and concurrent mechanical deformation. The material is continually and steadily optimized by small changes in structure or chemical composition, also in combination with self-organization processes (precipitation alloys, ceramic glasses, eutectic structures). The presented materials consist of functionalized elementary functional units based on polymers, ceramics, metals and carbon nanotubes (CNTs), which are used to create macroscopic hierarchical material systems, whose characteristic lengths range from the nanometer to the centimeter scale. These elementary functional units are either core-shell structures or cavities in metals created by alloy corrosion and subsequent polymer filling. Three classes of material systems will be presented: First, hierarchically structured ceramic/metal-polymer material systems similar to naturally occurring examples, namely nacre (1 hierarchical level), enamel (3 hierarchical levels) and bone (5 hierarchical levels) will be discussed. Starting with an elementary functional unit consisting of ceramic nanoparticles with a polymeric coating, a material is created in which on each hierarchical level, “hard” particles, made of the respective lower hierarchical level, are present in a soft polymer background. The resulting core-shell structure on each hierarchical level is the fundamental difference compared to a compound material made of rigid interpenetrating ceramic or metallic networks. The second material system is based on nanoporous gold, which acts as a prototypical material for new components in light weight construction with simultaneous actuator properties. Their production and resulting length-scale specific mechanical properties will be explained. Furthermore, related scale-spanning theoretical models for their mechanical behavior will be introduced. This covers the entire scale from the electronic structure on the atomic level up to centimeter-sized macroscopic samples. The third material system discussed in the lecture are novel hierarchical nanostructured materials based on thermally stable ceramics and metals for high-temperature photonics with potential use in thermophotovoltaic systems (TPVs) and thermal barrier coatings (TBCs). Direct and inverted 3D-photonic crystal structures (PhCs) as well as novel optically hyperbolic media, in particular, are worthwhile noting. Due to their periodicity and diffraction index contrast, PhCs exhibit a photonic band structure, characterized by photonic band gaps, areas of particularly high photonic densities of states and special dispersion relations. The presented properties are to be used to reflect thermal radiation in TBCs in a strong and directed manner, as well as to link radiation effectively and efficiently in TPVs.
Literature	Aktuelle Publikationen

Module M1198: Materials Physics and Atomistic Materials Modeling

Courses

Title	Typ	Hrs/wk	CP
Materials Physics (L1624)	Lecture	2	2
Quantum Mechanics and Atomistic Materials Modeling (L1672)	Lecture	2	2
Exercises in Materials Physics and Modeling (L2002)	Recitation Section (small)	2	2

Module Responsible	Prof. Patrick Huber
Admission Requirements	None
Recommended Previous Knowledge	Advanced mathematics, physics and chemistry for students in engineering or natural sciences
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to - explain the fundamentals of condensed matter physics - describe the fundamentals of the microscopic structure and mechanics, thermodynamics and optics of materials systems. - to understand concept and realization of advanced methods in atomistic modeling as well as to estimate their potential and limitations.
Skills	After attending this lecture the students • can perform calculations regarding the thermodynamics, mechanics, electrical and optical properties of condensed matter systems • are able to transfer their knowledge to related technological and scientific fields, e.g. materials design problems. • can select appropriate model descriptions for specific materials science problems and are able to further develop simple models.
Personal Competence	
Social Competence	The students are able to present solutions to specialists and to develop ideas further.
Autonomy	Students are able to assess their knowldege continuously on their own by exemplified practice. The students are able to assess their own strengths and weaknesses and define tasks independently.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Materials Science: Core Qualification: Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory

Course L1624: Materials Physics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Patrick Huber
Language	DE
Cycle	WiSe
Content	
Literature	Für den **Elektromagnetismus:** • Bergmann-Schäfer: „Lehrbuch der Experimentalphysik“, Band 2: „Elektromagnetismus“, de Gruyter Für die **Atomphysik:** • Haken, Wolf: „Atom- und Quantenphysik“, Springer Für die **Materialphysik und Elastizität:** • Hornbogen, Warlimont: „Metallkunde“, Springer

Course L1672: Quantum Mechanics and Atomistic Materials Modeling	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Robert Meißner
Language	DE
Cycle	WiSe
Content	- Why atomistic materials modeling - Newton's equations of motion and numerical approaches - Ergodicity - Atomic models - Basics of quantum mechanics - Atomic & molecular many-electron systems - Hartree-Fock and Density-Functional Theory - Monte-Carlo Methods - Molecular Dynamics Simulations - Phase Field Simulations
Literature	Begleitliteratur zur Vorlesung (sortiert nach Relevanz): 1. Daan Frenkel & Berend Smit „Understanding Molecular Simulations“ 2. Mark E. Tuckerman „Statistical Mechanics: Theory and Molecular Simulations“ 3. Andrew R. Leach „Molecular Modelling: Principles and Applications“ Zur Vorbereitung auf den quantenmechanischen Teil der Klausur empfiehlt sich folgende Literatur 1. Regine Freudenstein & Wilhelm Kulisch "Wiley Schnellkurs Quantenmechanik"

Course L2002: Exercises in Materials Physics and Modeling	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Robert Meißner, Prof. Patrick Huber
Language	DE
Cycle	WiSe
Content	
Literature	- Daan Frenkel & Berend Smit: Understanding Molecular Simulation from Algorithms to Applications - Rudolf Gross und Achim Marx: Festkörperphysik - Neil Ashcroft and David Mermin: Solid State Physics

Module M1170: Phenomena and Methods in Materials Science

Courses

Title	Typ	Hrs/wk	CP
Experimental Methods for the Characterization of Materials (L1580)	Lecture	2	3
Phase equilibria and transformations (L1579)	Lecture	2	3

Module Responsible	Prof. Jörg Weißmüller
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in Materials Science, e.g. Werkstoffwissenschaft I/II
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students will be able to explain the properties of advanced materials along with their applications in technology, in particular metallic, ceramic, polymeric, semiconductor, modern composite materials (biomaterials) and nanomaterials.
Skills	The students will be able to select material configurations according to the technical needs and, if necessary, to design new materials considering architectural principles from the micro- to the macroscale. The students will also gain an overview on modern materials science, which enables them to select optimum materials combinations depending on the technical applications.
Personal Competence	
Social Competence	The students are able to present solutions to specialists and to develop ideas further.
Autonomy	The students are able to ... • assess their own strengths and weaknesses. • gather new necessary expertise by their own.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Materials Science: Core Qualification: Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory

Course L1580: Experimental Methods for the Characterization of Materials

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Jürgen Markmann, Prof. Patrick Huber
Language	DE
Cycle	WiSe
Content	• Structural characterization by photons, neutrons and electrons (in particular X-ray and neutron scattering, electron microscopy, tomography) • Mechanical and thermodynamical characterization methods (indenter measurements, mechanical compression and tension tests, specific heat measurements) • Characterization of optical, electrical and magnetic properties (spectroscopy, electrical conductivity and magnetometry)
Literature	William D. Callister und David G. Rethwisch, Materialwissenschaften und Werkstofftechnik, Wiley&Sons, Asia (2011). William D. Callister, Materials Science and Technology, Wiley& Sons, Inc. (2007).

Course L1579: Phase equilibria and transformations	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Jörg Weißmüller
Language	DE
Cycle	WiSe
Content	Fundamentals of statistical physics, formal structure of phenomenological thermodynamics, simple atomistic models and free-energy functions of solid solutions and compounds. Corrections due to nonlocal interaction (elasticity, gradient terms). Phase equilibria and alloy phase diagrams as consequence thereof. Simple atomistic considerations for interaction energies in metallic solid solutions. Diffusion in real systems. Kinetics of phase transformations for real-life boundary conditions. Partitioning, stability and morphology at solidification fronts. Order of phase transformations; glass transition. Phase transitions in nano- and microscale systems.
Literature	D.A. Porter, K.E. Easterling, “Phase transformations in metals and alloys”, New York, CRC Press, Taylor & Francis, 2009, 3. Auflage Peter Haasen, „Physikalische Metallkunde“ , Springer 1994 Herbert B. Callen, “Thermodynamics and an introduction to thermostatistics”, New York, NY: Wiley, 1985, 2. Auflage. Robert W. Cahn und Peter Haasen, "Physical Metallurgy", Elsevier 1996 H. Ibach, “Physics of Surfaces and Interfaces” 2006, Berlin: Springer.

Module M1569: Applied Computational Methods for Material Science

Courses

Title	Typ	Hrs/wk	CP
Applied Computational Methods for Material Science (L1626)	Project-/problem-based Learning	3	6

Module Responsible	Prof. Norbert Huber
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of technical mechanics (statics, strength of materials, beam bending), fundamentals of mechanical properties of materials (elasticity, plasticity), materials science (tensile testing, hardness testing, bending strength), programming (Python)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to model a specimen/part using an FEM preprocessor, to mesh it and to apply boundary conditions and materials. They are able to establish 2D models (plain strain, axisymmetric) as well as 3D models and to solve these with ABAQUS. Further, they will learn how to implement contact, as e.g. needed for the simulation of nanoindentation or four point bending with rollers. With the help of Python the reading of the results and their processing will be automized. The students will be able to submit and analyze jobs in an automized way for building a data base. They can analyze such data bases with respect to underlying relationships using machine learning and test hypotheses in relation to uniqueness and completeness.
Skills	The students are able to address a given problem in a scientific approach by splitting it into subproblems and by gaining the required knowledge needed for solving each sub problem. They learn based on examples, how hypotheses are developed and how these can be verified or falsified using computer methods. In addition, the students learn how the results of the individual sub problems can be tested with regard to their correctness and how to discuss them scientificially, at one hand, and how the sum of all subresults are to be discussed in the context of the given problem and formulated hypotheses, on the other hand. A significant part of this work is the documentation in a written report, which is in style and structure comparable in all relevant elements to a scientific report.
Personal Competence	
Social Competence	As the module is based on Problem Based Learning, the students will be able to work in small groups. This includes to discuss the content of the problem, to brainstorm, to work out hypotheses, prioritize them and to agree on those hypotheses and subproblems which shall be worked out in an organized way. Due to this, a significant part of the module relies on communication skills, organizational skills and time management. Finally, the ability to split a problem into the right subproblems and to put to gether the results from the subproblems for getting the answer of the big picture is an asset for efficient and effective problem solving in general.
Autonomy	The acquisition of the necessary know-how and the solution of the subproblems is carried out individually. Due to this, the students are in the position to adopt new computer methods (here in particular Python programming, FE modeling, machine learning) and to expand those as far as necessary to solve the given task. Furthermore, the students learn to document their methods and results in a comprehensible manner and via the corrections to absorb feedback for continuously furthering the existing skills.
Workload in Hours	Independent Study Time 138, Study Time in Lecture 42
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	In total 3 problems, duration 3-4 weeks each, completed by submission of a written report. Assessment group/individal performance 50/50.
Assignment for the Following Curricula	Materials Science: Core Qualification: Compulsory

Course L1626: Applied Computational Methods for Material Science	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	6
Workload in Hours	Independent Study Time 138, Study Time in Lecture 42
Lecturer	Prof. Norbert Huber
Language	DE/EN
Cycle	WiSe
Content	Finite Element Method (discretisation, solver, programming with Python, automatized control and analysis of parametric studies) Examples of elastomechanics (tension, bending, four-point-bending, contact) Material behaviour (elasticity, plasticity, small and finite deformations, nonlinearities) Solution of inverse problems (machining of data, artificial neural networks, direct and inverse solutions, existence and uniqueness)
Literature	Alle Vorlesungsmaterialien und Beispiellösungen (Input-Dateien, Python Scirpte) werden auf Stud.IP zur Verfügung gestellt. All lecture material and example solutions (input files, python scripts) will be made available in Stud.IP.

Module M1219: Advanced Laboratory Materials Sciences

Courses

Title	Typ	Hrs/wk	CP
Advanced Laboratory Materials Sciences (L1653)	Practical Course	6	6

Module Responsible	Prof. Jörg Weißmüller
Admission Requirements	None
Recommended Previous Knowledge	knowledge of Materials Science fundamentals
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know about selected experimental approaches in materials science. They are familiar with the sequence of representative experiments, typically including sample preparation and conditioning, characterization, data reduction, data analysis, error analysis and interpretation of the results.
Skills	The students are able to • independently execute material science relevant experiments • analyze experimental data • critically assess the results and recognized implications in the relevant material science context
Personal Competence	
Social Competence	The students are able to • perform experiments and protocol them through team work • discuss scientific results in a format matched to an expert target audience
Autonomy	The students are able to • gain access so the contents of the lab classes through on essentially self-organized approach • independently write up a comprehensible protocol of the experimental procedures and results • recognize the need for additional information and develop a strategy to independently advancing the knowledge and understanding
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	ca. 25 pages
Assignment for the Following Curricula	Materials Science: Core Qualification: Compulsory

Course L1653: Advanced Laboratory Materials Sciences

Typ	Practical Course
Hrs/wk	6
CP	6
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Lecturer	Prof. Jörg Weißmüller, Prof. Stefan Fritz Müller, Prof. Patrick Huber, Prof. Bodo Fiedler, Prof. Gerold Schneider
Language	DE/EN
Cycle	SoSe
Content	• Actuators for modern fuel injection systems - synthesis and properties of a model lead-free actuator • Actuation with porous metals
Literature	• siehe Versuchsbeschreibungen sowie die dort angegebenen Literaturverweise auf StudIP

Module M1226: Mechanical Properties

Courses

Title	Typ	Hrs/wk	CP
Mechanical Behaviour of Brittle Materials (L1661)	Lecture	2	3
Dislocation Theory of Plasticity (L1662)	Lecture	2	3

Module Responsible	Dr. Erica Lilleodden
Admission Requirements	None
Recommended Previous Knowledge	Basics in Materials Science I/II
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain basic principles of crystallography, statics (free body diagrams, tractions) and thermodynamics (energy minimization, energy barriers, entropy)
Skills	Students are capable of using standardized calculation methods: tensor calculations, derivatives, integrals, tensor transformations
Personal Competence	
Social Competence	Students can provide appropriate feedback and handle feedback on their own performance constructively.
Autonomy	Students are able to - assess their own strengths and weaknesses - assess their own state of learning in specific terms and to define further work steps on this basis guided by teachers. - work independently based on lectures and notes to solve problems, and to ask for help or clarifications when needed
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Materials Science: Core Qualification: Compulsory Mechanical Engineering and Management: Specialisation Materials: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Compulsory Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1661: Mechanical Behaviour of Brittle Materials	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Gerold Schneider
Language	DE/EN
Cycle	SoSe
Content	**Theoretical Strength** Of a perfect crystalline material, theoretical critical shear stress **Real strength of brittle materials** Energy release reate, stress intensity factor, fracture criterion **Scattering of strength of brittle materials** Defect distribution, strength distribution, Weibull distribution **Heterogeneous materials I** Internal stresses, micro cracks, weight function, **Heterogeneous materials II** Toughening mechanisms: crack bridging, fibres **Heterogeneous materials III** Toughening mechanisms. Process zone **Testing methods to determine the fracture toughness of brittle materials** **R-curve, stable/unstable crack growth, fractography** **Thermal shock** **Subcritical crack growth)** v-K-curve, life time prediction **Kriechen** **Mechanical properties of biological materials** **Examples of use for a mechanically reliable design of ceramic components**
Literature	D R H Jones, Michael F. Ashby, Engineering Materials 1, An Introduction to Properties, Applications and Design, Elesevier D.J. Green, An introduction to the mechanical properties of ceramics”, Cambridge University Press, 1998 B.R. Lawn, Fracture of Brittle Solids“, Cambridge University Press, 1993 D. Munz, T. Fett, Ceramics, Springer, 2001 D.W. Richerson, Modern Ceramic Engineering, Marcel Decker, New York, 1992

Course L1662: Dislocation Theory of Plasticity	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Erica Lilleodden
Language	DE/EN
Cycle	SoSe
Content	This class will cover the principles of dislocation theory from a physical metallurgy perspective, providing a fundamental understanding of the relations between the strength and of crystalline solids and distributions of defects. We will review the concept of dislocations, defining terminology used, and providing an overview of important concepts (e.g. linear elasticity, stress-strain relations, and stress transformations) for theory development. We will develop the theory of dislocation plasticity through derived stress-strain fields, associated self-energies, and the induced forces on dislocations due to internal and externally applied stresses. Dislocation structure will be discussed, including core models, stacking faults, and dislocation arrays (including grain boundary descriptions). Mechanisms of dislocation multiplication and strengthening will be covered along with general principles of creep and strain rate sensitivity. Final topics will include non-FCC dislocations, emphasizing the differences in structure and corresponding implications on dislocation mobility and macroscopic mechanical behavior; and dislocations in finite volumes.
Literature	Vorlesungsskript Aktuelle Publikationen Bücher: Introduction to Dislocations, by D. Hull and D.J. Bacon Theory of Dislocations, by J.P. Hirth and J. Lothe Physical Metallurgy, by Peter Hassen

Module M1199: Advanced Functional Materials

Courses

Title	Typ	Hrs/wk	CP
Advanced Functional Materials (L1625)	Seminar	2	6

Module Responsible	Prof. Patrick Huber
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in Materials Science, e.g. Materials Science I/II
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students will be able to explain the properties of advanced materials along with their applications in technology, in particular metallic, ceramic, polymeric, semiconductor, modern composite materials (biomaterials) and nanomaterials.
Skills	The students will be able to select material configurations according to the technical needs and, if necessary, to design new materials considering architectural principles from the micro- to the macroscale. The students will also gain an overview on modern materials science, which enables them to select optimum materials combinations depending on the technical applications.
Personal Competence	
Social Competence	The students are able to present solutions to specialists and to develop ideas further.
Autonomy	The students are able to ... • assess their own strengths and weaknesses. • gather new necessary expertise by their own.
Workload in Hours	Independent Study Time 152, Study Time in Lecture 28
Credit points	6
Course achievement	None
Examination	Presentation
Examination duration and scale	30 min
Assignment for the Following Curricula	Materials Science: Core Qualification: Compulsory Mechanical Engineering and Management: Specialisation Materials: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory

Course L1625: Advanced Functional Materials

Typ	Seminar
Hrs/wk	2
CP	6
Workload in Hours	Independent Study Time 152, Study Time in Lecture 28
Lecturer	Prof. Patrick Huber, Prof. Stefan Fritz Müller, Prof. Bodo Fiedler, Prof. Gerold Schneider, Prof. Jörg Weißmüller, Prof. Christian Cyron
Language	DE
Cycle	WiSe
Content	1. Porous Solids - Preparation, Characterization and Functionalities 2. Fluidics with nanoporous membranes 3. Thermoplastic elastomers 4. Optimization of polymer properties by nanoparticles 5. Fiber composites in automotive 6. Modeling of materials based on quantum mechanics 7. Biomaterials
Literature	Aktuelle Publikationen aus der Fachliteratur werden während der Veranstaltung bekanntgegeben.

Module M1221: Study work on Modern Issues in the Materials Sciences

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

Module Responsible	Prof. Jörg Weißmüller
Admission Requirements	None
Recommended Previous Knowledge	knowledge of Materials Science fundamentals
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	In the field of their Research Project, the students can provide examples concerning the state-of-the-art in research, development, or application. They can critically discuss the relevant issues in the context of current problems and frameworks in science and society. In the context of the Research Project, the students know the relevant fundamentals of materials science as well as methodological approach is suitable for the problem of the project.
Skills	The students have familiarized themselves with the approaches for independently acquiring the basic knowledge for solving the material science problem of their project. They can use the relevant resources as for example search engines and databases for scientific publications of patents. The students are familiar with writing a report addressing a scientific audience, including the conventions for outline, citation and bibliography. The can design and deliver on oral presentation of the project results. The students can expose in detail and critically assess the scientific approaches that they chose for their scientific work on the project. The students are able to independently perform scientific experiment, computations or simulation relevant for the project, perform the data analysis and provide a critical scientific discussion of their results.
Personal Competence	
Social Competence	Students are able to discuss scientific results with specific target groups, to document results in a written form and to present them orally.
Autonomy	The students have familiarized themselves with the challenges and approaches involved in independently solving a new research problems in the field of material science (see also Fachkompetenz/Fertigkeiten - English).
Workload in Hours	Independent Study Time 360, Study Time in Lecture 0
Credit points	12
Course achievement	None
Examination	Study work
Examination duration and scale	according to FSPO
Assignment for the Following Curricula	Materials Science: Core Qualification: Compulsory

Specialization Engineering Materials

Students learn in the Engineering Materials specialization the evaluation of the different materials in the technology-oriented environment.

They gain knowledge about process planning as well as managing of projects or personnel. Students are able to evaluate and make decisions on materials, industrial production, quality assurance and failure analysis.

Module M1342: Polymers

Courses

Title	Typ	Hrs/wk	CP
Structure and Properties of Polymers (L0389)	Lecture	2	3
Processing and design with polymers (L1892)	Lecture	2	3

Module Responsible	Dr. Hans Wittich
Admission Requirements	None
Recommended Previous Knowledge	Basics: chemistry / physics / material science
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can use the knowledge of plastics and define the necessary testing and analysis. They can explain the complex relationships structure-property relationship and the interactions of chemical structure of the polymers, including to explain neighboring contexts (e.g. sustainability, environmental protection).
Skills	Students are capable of - using standardized calculation methods in a given context to mechanical properties (modulus, strength) to calculate and evaluate the different materials. - selecting appropriate solutions for mechanical recycling problems and sizing example stiffness, corrosion resistance.
Personal Competence	
Social Competence	Students can - arrive at funded work results in heterogenius groups and document them. - provide appropriate feedback and handle feedback on their own performance constructively.
Autonomy	Students are able to - assess their own strengths and weaknesses. - assess their own state of learning in specific terms and to define further work steps on this basis. - assess possible consequences of their professional activity.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	180 min
Assignment for the Following Curricula	Materials Science: Specialisation Engineering Materials: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory

Course L0389: Structure and Properties of Polymers	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Hans Wittich
Language	DE
Cycle	WiSe
Content	- Structure and properties of polymers - Structure of macromolecules Constitution, Configuration, Conformation, Bonds, Synthesis, Molecular weihght distribution - Morphology amorph, crystalline, blends - Properties Elasticity, plasticity, viscoelacity - Thermal properties - Electrical properties - Theoretical modelling - Applications
Literature	Ehrenstein: Polymer-Werkstoffe, Carl Hanser Verlag

Course L1892: Processing and design with polymers	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Bodo Fiedler, Dr. Hans Wittich
Language	DE/EN
Cycle	WiSe
Content	Manufacturing of Polymers: General Properties; Calendering; Extrusion; Injection Moulding; Thermoforming, Foaming; Joining Designing with Polymers: Materials Selection; Structural Design; Dimensioning
Literature	Osswald, Menges: Materials Science of Polymers for Engineers, Hanser Verlag Crawford: Plastics engineering, Pergamon Press Michaeli: Einführung in die Kunststoffverarbeitung, Hanser Verlag Konstruieren mit Kunststoffen, Gunter Erhard , Hanser Verlag

Module M1344: Processing of fibre-polymer-composites

Courses

Title	Typ	Hrs/wk	CP
Processing of fibre-polymer-composites (L1895)	Lecture	2	3
From Molecule to Composites Part (L1516)	Project-/problem-based Learning	2	3

Module Responsible	Prof. Bodo Fiedler
Admission Requirements	None
Recommended Previous Knowledge	Knowledge in the basics of chemistry / physics / materials science
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to give a summary of the technical details of the manufacturing processes composites and illustrate respective relationships. They are capable of describing and communicating relevant problems and questions using appropriate technical language. They can explain the typical process of solving practical problems and present related results.
Skills	Students can use the knowledge of fiber-reinforced composites (FRP) and its constituents (fiber / matrix) and define the necessary testing and analysis. They can explain the complex structure-property relationship and the interactions of chemical structure of the polymers, their processing with the different fiber types, including to explain neighboring contexts (e.g. sustainability, environmental protection).
Personal Competence	
Social Competence	Students are able to cooperate in small, mixed-subject groups in order to independently derive solutions to given problems in the context of civil engineering. They are able to effectively present and explain their results alone or in groups in front of a qualified audience. Students have the ability to develop alternative approaches to an engineering problem independently or in groups and discuss advantages as well as drawbacks.
Autonomy	Students are capable of independently solving mechanical engineering problems using provided literature. They are able to fill gaps in as well as extent their knowledge using the literature and other sources provided by the supervisor. Furthermore, they can meaningfully extend given problems and pragmatically solve them by means of corresponding solutions and concepts.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Materials Science: Specialisation Engineering Materials: Elective Compulsory Mechanical Engineering and Management: Specialisation Materials: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory

Course L1895: Processing of fibre-polymer-composites

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Bodo Fiedler
Language	DE/EN
Cycle	SoSe
Content	Manufacturing of Composites: Hand Lay-Up; Pre-Preg; GMT, BMC; SMC, RIM; Pultrusion; Filament Winding
Literature	Åström: Manufacturing of Polymer Composites, Chapman and Hall

Course L1516: From Molecule to Composites Part	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Bodo Fiedler
Language	DE/EN
Cycle	SoSe
Content	Students get the task in the form of a customer request for the development and production of a MTB handlebar made of fiber composites. In the task technical and normative requirements (standards) are given, all other required information come from the lectures and tutorials, and the respective documents (electronically and in conversation). The procedure is to specify in a milestone schedule and allows students to plan tasks and to work continuously. At project end, each group has a made handlebar with approved quality. In each project meeting the design (discussion of the requirements and risks) are discussed. The calculations are analyzed, evaluated and established manufacturing methods are selected. Materials are selected bar will be produced. The quality and the mechanical properties are checked. At the end of the final report created (compilation of the results for the "customers"). After the test during the "customer / supplier conversation" there is a mutual feedback-talk ("lessons learned") in order to ensure the continuous improvement.
Literature	Customer Request ("Handout")

Module M1343: Fibre-polymer-composites

Courses

Title	Typ	Hrs/wk	CP
Structure and properties of fibre-polymer-composites (L1894)	Lecture	2	3
Design with fibre-polymer-composites (L1893)	Lecture	2	3

Module Responsible	Prof. Bodo Fiedler
Admission Requirements	None
Recommended Previous Knowledge	Basics: chemistry / physics / materials science
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can use the knowledge of fiber-reinforced composites (FRP) and its constituents to play (fiber / matrix) and define the necessary testing and analysis. They can explain the complex relationships structure-property relationship and the interactions of chemical structure of the polymers, their processing with the different fiber types, including to explain neighboring contexts (e.g. sustainability, environmental protection).
Skills	Students are capable of • using standardized calculation methods in a given context to mechanical properties (modulus, strength) to calculate and evaluate the different materials. • approximate sizing using the network theory of the structural elements implement and evaluate. • selecting appropriate solutions for mechanical recycling problems and sizing example stiffness, corrosion resistance.
Personal Competence	
Social Competence	Students can • arrive at funded work results in heterogenius groups and document them. • provide appropriate feedback and handle feedback on their own performance constructively.
Autonomy	Students are able to - assess their own strengths and weaknesses. - assess their own state of learning in specific terms and to define further work steps on this basis. - assess possible consequences of their professional activity.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	180 min
Assignment for the Following Curricula	Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Materials Science: Specialisation Engineering Materials: Elective Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1894: Structure and properties of fibre-polymer-composites	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Bodo Fiedler
Language	EN
Cycle	SoSe
Content	- Microstructure and properties of the matrix and reinforcing materials and their interaction - Development of composite materials - Mechanical and physical properties - Mechanics of Composite Materials - Laminate theory - Test methods - Non destructive testing - Failure mechanisms - Theoretical models for the prediction of properties - Application
Literature	Hall, Clyne: Introduction to Composite materials, Cambridge University Press Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press Mallick: Fibre-Reinforced Composites, Marcel Deckker, New York

Course L1893: Design with fibre-polymer-composites	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Bodo Fiedler
Language	EN
Cycle	SoSe
Content	Designing with Composites: Laminate Theory; Failure Criteria; Design of Pipes and Shafts; Sandwich Structures; Notches; Joining Techniques; Compression Loading; Examples
Literature	Konstruieren mit Kunststoffen, Gunter Erhard , Hanser Verlag

Module M1345: Metallic and Hybrid Light-weight Materials

Courses

Title	Typ	Hrs/wk	CP
Joining of Polymer-Metal Lightweight Structures (L0500)	Lecture	2	2
Joining of Polymer-Metal Lightweight Structures (L0501)	Practical Course	1	1
Metallic Light-weight Materials (L1660)	Lecture	2	3

Module Responsible	Prof. Marcus Rutner
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	
Skills	
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	45 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Materials Science: Specialisation Engineering Materials: Elective Compulsory

Course L0500: Joining of Polymer-Metal Lightweight Structures

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Marcus Rutner
Language	EN
Cycle	WiSe

Content

Contents:

The lecture and the related laboratory exercises intend to provide an insight on advanced joining technologies for polymer-metal lightweight structures used in engineering applications. A general understanding of the principles of the consolidated and new technologies and its main fields of applications is to be accomplished through theoretical and practical lectures.

Theoretical Lectures:

- Review of the relevant properties of Lightweight Alloys, Engineering Plastics and Composites in Joining Technology
- Introduction to Welding of Lightweight Alloys, Thermoplastics and Fiber Reinforced Plastics
- Mechanical Fastening of Polymer-Metal Hybrid Structures
- Adhesive Bonding of Polymer-Metal Hybrid Structures
- Fusion and Solid State Joining Processes of Polymer-Metal Hybrid Structures
- Hybrid Joining Methods and Direct Assembly of Polymer-Metal Hybrid Structures

Laboratory Exercises:

- Joining Processes: Introduction to state-of-the-art joining technologies
- Introduction to metallographic specimen preparation, optical microscopy and mechanical testing of polymer-metal joints

Course Outcomes:

After successful completion of this unit, students should be able to understand the principles of welding and joining of polymer-metal lightweight structures as well as their application fields.

Literature

- S. T. Amancio-Filho, L.-A. Blaga, Joining of Polymer-Metal Hybrid Structures, Wiley, 2018
- J.F. Shackelford, Introduction to materials science for engineers, Prentice-Hall International
- J. Rotheiser, Joining of Plastics, Handbook for designers and engineers, Hanser Publishers
- D.A. Grewell, A. Benatar, J.B. Park, Plastics and Composites Welding Handbook
- D. Lohwasser, Z. Chen, Friction Stir Welding, From basics to applications, Woodhead Publishing Limited
- J. Friedrich, Metal-Polymer Systems: Interface Design and Chemical Bonding, Wiley, 2017

Course L0501: Joining of Polymer-Metal Lightweight Structures	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Marcus Rutner
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1660: Metallic Light-weight Materials	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Domonkos Tolnai
Language	EN
Cycle	WiSe
Content	Lightweight construction - Structural lightweight construction - Material lightweight construction - Choice criteria for metallic lightweight construction materials Steel as lightweight construction materials - Introduction to the fundamentals of steels - Modern steels for the lightweight construction - Fine grain steels - High-strength low-alloyed steels - Multi-phase steels (dual phase, TRIP) - Weldability - Applications Aluminium alloys: Introduction to the fundamentals of aluminium materials Alloy systems Non age-hardenable Al alloys: Processing and microstructure, mechanical qualities and applications Age-hardenable Al alloys: Processing and microstructure, mechanical qualities and applications Magnesium alloys Introduction to the fundamental of magnesium materials Alloy systems Magnesium casting alloys, processing, microstructure and qualities Magnesium wrought alloys, processing, microstructure and qualities Examples of applications Titanium alloys Introduction to the fundamental of the titanium materials Alloy systems Processing, microstructure and properties Examples of applications

	Exercises and excursions
Literature	George Krauss, Steels: Processing, Structure, and Performance, 978-0-87170-817-5, 2006, 613 S. Hans Berns, Werner Theisen, Ferrous Materials: Steel and Cast Iron, 2008. http://dx.doi.org/10.1007/978-3-540-71848-2 C. W. Wegst, Stahlschlüssel = Key to steel = La Clé des aciers = Chiave dell'acciaio = Liave del acero ISBN/ISSN: 3922599095 Bruno C., De Cooman / John G. Speer: Fundamentals of Steel Product Physical Metallurgy, 2011, 642 S. Harry Chandler, Steel Metallurgy for the Non-Metallurgist 0-87170-652-0, 2006, 84 S. Catrin Kammer, Aluminium Taschenbuch 1, Grundlagen und Werkstoffe, Beuth, 16. Auflage 2009. 784 S., ISBN 978-3-410-22028-2 Günter Drossel, Susanne Friedrich, Catrin Kammer und Wolfgang Lehnert, Aluminium Taschenbuch 2, Umformung von Aluminium-Werkstoffen, Gießen von Aluminiumteilen, Oberflächenbehandlung von Aluminium, Recycling und Ökologie, Beuth, 16. Auflage 2009. 768 S., ISBN 978-3-410-22029-9 Catrin Kammer, Aluminium Taschenbuch 3, Weiterverarbeitung und Anwendung, Beuith,17. Auflage 2014. 892 S., ISBN 978-3-410-22311-5 G. Lütjering, J.C. Williams: Titanium, 2nd ed., Springer, Berlin, Heidelberg, 2007, ISBN 978-3-540-71397 Magnesium - Alloys and Technologies, K. U. Kainer (Hrsg.), Wiley-VCH, Weinheim 2003, ISBN 3-527-30570-x Mihriban O. Pekguleryuz, Karl U. Kainer and Ali Kaya “Fundamentals of Magnesium Alloy Metallurgy”, Woodhead Publishing Ltd, 2013,ISBN 10: 0857090887

Module M1665: Design with fibre-polymer-composites

Courses

Title	Typ	Hrs/wk	CP
Design with fibre-polymer-composites (L1893)	Lecture	2	3
Design with fibre-polymer-composites (L2616)	Project-/problem-based Learning	2	2
Design with fibre-polymer-composites (L2615)	Recitation Section (large)	1	1

Module Responsible	Prof. Bodo Fiedler
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	
Skills	
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Materials Science: Specialisation Engineering Materials: Elective Compulsory

Course L1893: Design with fibre-polymer-composites

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Bodo Fiedler
Language	EN
Cycle	WiSe
Content	Designing with Composites: Laminate Theory; Failure Criteria; Design of Pipes and Shafts; Sandwich Structures; Notches; Joining Techniques; Compression Loading; Examples
Literature	Konstruieren mit Kunststoffen, Gunter Erhard , Hanser Verlag

Course L2616: Design with fibre-polymer-composites

Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Bodo Fiedler
Language	DE/EN
Cycle	WiSe
Content	
Literature	

Course L2615: Design with fibre-polymer-composites

Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Bodo Fiedler
Language	EN
Cycle	WiSe
Content	
Literature	

Module M0595: Examination of Materials, Structural Condition and Damages

Courses

Title	Typ	Hrs/wk	CP
Examination of Materials, Structural Condition and Damages (L0260)	Lecture	3	4
Examination of Materials, Structural Condition and Damages (L0261)	Recitation Section (small)	1	2

Module Responsible	Prof. Frank Schmidt-Döhl
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge about building materials or material science, for example by the module Building Materials and Building Chemistry.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to describe the rules for trading, use and marking of construction products in Germany. They know which methods for the testing of building material properties are usable and know the limitations and characterics of the most important testing methods.
Skills	The students are able to responsibly discover the rules for trading and using of building products in Germany. They are able to chose suitable methods for the testing and inspection of construction products, the examination of damages and the examination of the structural conditions of buildings. They are able to conclude from symptons to the cause of damages. They are able to describe an examination in form of a test report or expert opinion.
Personal Competence	
Social Competence	The students can describe the different roles of manufacturers as well as testing, supervisory and certification bodies within the framework of material testing. They can describe the different roles of the participants in legal proceedings.
Autonomy	The students are able to make the timing and the operation steps to learn the specialist knowledge of a very extensive field.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Elective Compulsory International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory Materials Science: Specialisation Engineering Materials: Elective Compulsory

Course L0260: Examination of Materials, Structural Condition and Damages

Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Frank Schmidt-Döhl
Language	DE
Cycle	WiSe
Content	Materials testing and marking process of construction products, testing methods for building materials and structures, testing reports and expert opinions, describing the condition of a structure, from symptons to the cause of damages
Literature	Frank Schmidt-Döhl: Materialprüfung im Bauwesen. Fraunhofer irb-Verlag, Stuttgart, 2013.

Course L0261: Examination of Materials, Structural Condition and Damages

Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Frank Schmidt-Döhl
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1291: Materials Science Seminar

Courses

Title	Typ	Hrs/wk	CP
Seminar (L1757)	Seminar	2	3
Seminar Composites (L1758)	Seminar	2	3
Seminar Advanced Ceramics (L1801)	Seminar	2	3
Seminar on interface-dominated materials (L1795)	Seminar	2	3

Module Responsible	Prof. Jörg Weißmüller
Admission Requirements	None
Recommended Previous Knowledge	Fundamental knowledge on nanomaterials, electrochemistry, interface science, mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the most important facts and relationships of a specific topic from the field of materials science.
Skills	Students are able to compile a specified topic from the field of materials science and to give a clear, structured and comprehensible presentation of the subject. They can comply with a given duration of the presentation. They can write in English a summary including illustrations that contains the most important results, relationships and explanations of the subject.
Personal Competence	
Social Competence	Students are able to adapt their presentation with respect to content, detailedness, and presentation style to the composition and previous knowledge of the audience. They can answer questions from the audience in a curt and precise manner.
Autonomy	Students are able to autonomously carry out a literature research concerning a given topic. They can independently evaluate the material. They can self-reliantly decide which parts of the material should be included in the presentation.
Workload in Hours	Depends on choice of courses
Credit points	6
Assignment for the Following Curricula	Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Materials Science: Specialisation Modeling: Elective Compulsory Materials Science: Specialisation Engineering Materials: Elective Compulsory

Course L1757: Seminar

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Referat
Examination duration and scale	
Lecturer	Prof. Jörg Weißmüller
Language	DE/EN
Cycle	WiSe/SoSe
Content	
Literature	

Course L1758: Seminar Composites

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Referat
Examination duration and scale	
Lecturer	Prof. Bodo Fiedler
Language	DE/EN
Cycle	WiSe/SoSe
Content	
Literature	

Course L1801: Seminar Advanced Ceramics	
Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Referat
Examination duration and scale	
Lecturer	Prof. Gerold Schneider
Language	DE/EN
Cycle	WiSe/SoSe
Content	
Literature	

Course L1795: Seminar on interface-dominated materials	
Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Referat
Examination duration and scale	
Lecturer	Prof. Patrick Huber
Language	DE/EN
Cycle	WiSe/SoSe
Content	
Literature	

Specialization Modeling

Module M1151: Material Modeling

Courses

Title	Typ	Hrs/wk	CP
Material Modeling (L1535)	Lecture	2	3
Material Modeling (L1536)	Recitation Section (small)	2	3

Module Responsible	Prof. Christian Cyron
Admission Requirements	None
Recommended Previous Knowledge	Basics of linear and nonlinear continuum mechanics as taught, e.g., in the modules Mechanics II and Continuum Mechanics (forces and moments, stress, linear and nonlinear strain, free-body principle, linear and nonlinear constitutive laws, strain energy)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can explain the fundamentals of multidimensional consitutive material laws
Skills	The students can implement their own material laws in finite element codes. In particular, the students can apply their knowledge to various problems of material science and evaluate the corresponding material models.
Personal Competence	
Social Competence	The students are able to develop solutions, to present them to specialists and to develop ideas further.
Autonomy	The students are able to assess their own strengths and weaknesses. They can independently and on their own identify and solve problems in the area of materials modeling and acquire the knowledge required to this end.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	45 min
Assignment for the Following Curricula	Materials Science: Specialisation Modeling: Elective Compulsory Mechanical Engineering and Management: Specialisation Materials: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L1535: Material Modeling

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Christian Cyron
Language	DE
Cycle	WiSe
Content	One of the most important questions when modeling mechanical systems in practice is how to model the behavior of the materials of their different components. In addition to simple isotropic elasticity in particular the following phenomena play key roles - anisotropy (material behavior depending on direction, e.g., in fiber-reinforced materials) - plasticity (permanent deformation due to one-time overload, e.g., in metal forming) - viscoelasticity (absorption of energy, e.g., in dampers) - creep (slow deformation under permanent load, e.g., in pipes) This lecture briefly introduces the theoretical foundations and mathematical modeling of the above phenomena. It is complemented by exercises where simple examples problems are solved by calculations and where the implementation of the content of the lecture in computer simulations is explained. It will also briefly discussed how important material parameters can be determined from experimental data.
Literature	

Course L1536: Material Modeling	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Christian Cyron
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0604: High-Order FEM

Courses

Title	Typ	Hrs/wk	CP
High-Order FEM (L0280)	Lecture	3	4
High-Order FEM (L0281)	Recitation Section (large)	1	2

Module Responsible	Prof. Alexander Düster
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of partial differential equations is recommended.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to + give an overview of the different (h, p, hp) finite element procedures. + explain high-order finite element procedures. + specify problems of finite element procedures, to identify them in a given situation and to explain their mathematical and mechanical background.
Skills	Students are able to + apply high-order finite elements to problems of structural mechanics. + select for a given problem of structural mechanics a suitable finite element procedure. + critically judge results of high-order finite elements. + transfer their knowledge of high-order finite elements to new problems.
Personal Competence	
Social Competence	Students are able to + solve problems in heterogeneous groups and to document the corresponding results.
Autonomy	Students are able to + assess their knowledge by means of exercises and E-Learning. + acquaint themselves with the necessary knowledge to solve research oriented tasks.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** No / 10 % / Presentation / Forschendes Lernen
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Energy Systems: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Materials Science: Specialisation Modeling: Elective Compulsory Mechanical Engineering and Management: Specialisation Product Development and Production: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L0280: High-Order FEM	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Alexander Düster
Language	EN
Cycle	SoSe
Content	1. Introduction 2. Motivation 3. Hierarchic shape functions 4. Mapping functions 5. Computation of element matrices, assembly, constraint enforcement and solution 6. Convergence characteristics 7. Mechanical models and finite elements for thin-walled structures 8. Computation of thin-walled structures 9. Error estimation and hp-adaptivity 10. High-order fictitious domain methods
Literature	[1] Alexander Düster, High-Order FEM, Lecture Notes, Technische Universität Hamburg-Harburg, 164 pages, 2014 [2] Barna Szabo, Ivo Babuska, Introduction to Finite Element Analysis – Formulation, Verification and Validation, John Wiley & Sons, 2011

Course L0281: High-Order FEM	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Alexander Düster
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0605: Computational Structural Dynamics

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Computational Structural Dynamics (L0282)	Lecture	3	4
Computational Structural Dynamics (L0283)	Recitation Section (small)	1	2

Module Responsible	Prof. Alexander Düster
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of partial differential equations is recommended.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to + give an overview of the computational procedures for problems of structural dynamics. + explain the application of finite element programs to solve problems of structural dynamics. + specify problems of computational structural dynamics, to identify them in a given situation and to explain their mathematical and mechanical background.
Skills	Students are able to + model problems of structural dynamics. + select a suitable solution procedure for a given problem of structural dynamics. + apply computational procedures to solve problems of structural dynamics. + verify and critically judge results of computational structural dynamics.
Personal Competence	
Social Competence	Students are able to + solve problems in heterogeneous groups and to document the corresponding results.
Autonomy	Students are able to + acquire independently knowledge to solve complex problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	2h
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Materials Science: Specialisation Modeling: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L0282: Computational Structural Dynamics

Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Alexander Düster
Language	DE
Cycle	SoSe
Content	1. Motivation 2. Basics of dynamics 3. Time integration methods 4. Modal analysis 5. Fourier transform 6. Applications
Literature	[1] K.-J. Bathe, Finite-Elemente-Methoden, Springer, 2002. [2] J.L. Humar, Dynamics of Structures, Taylor & Francis, 2012.

Course L0283: Computational Structural Dynamics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Alexander Düster
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0606: Numerical Algorithms in Structural Mechanics

Courses

Title	Typ	Hrs/wk	CP
Numerical Algorithms in Structural Mechanics (L0284)	Lecture	2	3
Numerical Algorithms in Structural Mechanics (L0285)	Recitation Section (small)	2	3

Module Responsible	Prof. Alexander Düster
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of partial differential equations is recommended.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to + give an overview of the standard algorithms that are used in finite element programs. + explain the structure and algorithm of finite element programs. + specify problems of numerical algorithms, to identify them in a given situation and to explain their mathematical and computer science background.
Skills	Students are able to + construct algorithms for given numerical methods. + select for a given problem of structural mechanics a suitable algorithm. + apply numerical algorithms to solve problems of structural mechanics. + implement algorithms in a high-level programming languate (here C++). + critically judge and verfiy numerical algorithms.
Personal Competence	
Social Competence	Students are able to + solve problems in heterogeneous groups and to document the corresponding results.
Autonomy	Students are able to + acquire independently knowledge to solve complex problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	2h
Assignment for the Following Curricula	Materials Science: Specialisation Modeling: Elective Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L0284: Numerical Algorithms in Structural Mechanics

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Düster
Language	DE
Cycle	SoSe
Content	1. Motivation 2. Basics of C++ 3. Numerical integration 4. Solution of nonlinear problems 5. Solution of linear equation systems 6. Verification of numerical algorithms 7. Selected algorithms and data structures of a finite element code
Literature	[1] D. Yang, C++ and object-oriented numeric computing, Springer, 2001. [2] K.-J. Bathe, Finite-Elemente-Methoden, Springer, 2002.

Course L0285: Numerical Algorithms in Structural Mechanics	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Düster
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1152: Modeling Across The Scales

Courses

Title	Typ	Hrs/wk	CP
Modeling Across The Scales (L1537)	Lecture	2	3
Modeling Across The Scales - Excercise (L1538)	Recitation Section (small)	2	3

Module Responsible	Prof. Christian Cyron
Admission Requirements	None
Recommended Previous Knowledge	Basics of linear and nonlinear continuum mechanics as taught, e.g., in the modules Mechanics II and Continuum Mechanics (forces and moments, stress, linear and nonlinear strain, free-body principle, linear and nonlinear constitutive laws, strain energy).
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can describe different deformation mechanisms on different scales and can name the appropriate kind of modeling concept suited for its description.
Skills	The students are able to predict first estimates of the effective material behavior based on the material's microstructure. They are able to correlate and describe the damage behavior of materials based on their micromechanical behavior. In particular, they are able to apply their knowledge to different problems of material science and evaluate and implement material models into a finite element code.
Personal Competence	
Social Competence	The students are able to develop solutions, to present them to specialists and to develop ideas further.
Autonomy	The students are able to assess their own strengths and weaknesses. They can independently and on their own identify and solve problems in the area of scale-bridging modeling and acquire the knowledge required to this end.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	45 min
Assignment for the Following Curricula	Materials Science: Specialisation Modeling: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory

Course L1537: Modeling Across The Scales

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Christian Cyron
Language	DE
Cycle	SoSe
Content	• modeling of deformation mechanisms in materials at different scales (e.g., molecular dynamics, crystal plasticity, phenomenological models, ...) • relationship between microstructure and macroscopic mechanical material behavior • Eshelby problem • effective material properties, concept of RVE • homogenisation methods, coupling of scales (micro-meso-macro) • micromechanical concepts for the description of damage and failure behavior
Literature	D. Gross, T. Seelig, Bruchmechanik: Mit einer Einführung in die Mikromechanik, Springer T. Zohdi, P. Wriggers: An Introduction to Computational Micromechanics D. Raabe: Computational Materials Science, The Simulation of Materials, Microstructures and Properties, Wiley-Vch G. Gottstein., Physical Foundations of Materials Science, Springer

Course L1538: Modeling Across The Scales - Excercise	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Christian Cyron
Language	DE
Cycle	SoSe
Content	• modeling of deformation mechanisms in materials at different scales (e.g., molecular dynamics, crystal plasticity, phenomenological models, ...) • relationship between microstructure and macroscopic mechanical material behavior • Eshelby problem • effective material properties, concept of RVE • homogenisation methods, coupling of scales (micro-meso-macro) • micromechanical concepts for the description of damage and failure behavior
Literature	D. Gross, T. Seelig, Bruchmechanik: Mit einer Einführung in die Mikromechanik, Springer T. Zohdi, P. Wriggers: An Introduction to Computational Micromechanics D. Raabe: Computational Materials Science, The Simulation of Materials, Microstructures and Properties, Wiley-Vch G. Gottstein., Physical Foundations of Materials Science, Springer

Module M1237: Methods in Theoretical Materials Science

Courses

Title	Typ	Hrs/wk	CP
Methods in Theoretical Materials Science (L1677)	Lecture	2	4
Methods in Theoretical Materials Science (L1678)	Recitation Section (small)	1	2

Module Responsible	Prof. Stefan Fritz Müller
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of advanced mathematics like analysis, linear algebra, differential equations and complex functions, e.g., Mathematics I-IV Knowledge of physics, particularly solid state physics, e.g., Materials Physics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The master students will be able to… …explain how different modeling methods work. …assess the field of application of individual methodological approaches. …evaluate the strengths and weaknesses of different methods. The students are thereby able to assess which method is best suited to solve a scientific problem and what accuracy can be expected from the simulation results.
Skills	After completing the module, the students are able to… …select the most suitable modeling method as a function of various parameters such as length scale, time scale, temperature, material type, etc..
Personal Competence	
Social Competence	The students are able to discuss competently and adapted to the target group with experts from various fields including physics and materials science, for example at conferences or exhibitions. Further, this promotes their abilities to work in interdisciplinary groups.
Autonomy	The students are able to … …assess their own strengths and weaknesses. …acquire the knowledge they need on their own.
Workload in Hours	Independent Study Time 138, Study Time in Lecture 42
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	
Assignment for the Following Curricula	Materials Science: Specialisation Modeling: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1677: Methods in Theoretical Materials Science	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Stefan Fritz Müller
Language	DE/EN
Cycle	SoSe
Content	1. Introduction 1.1 Classification of Modelling Approaches and the Solid State 2. Quantum Mechanical Approaches 2.1 Electronic states : Atoms, Molecules, Solids 2.2 Density Functional Theory 2.3 Spin-Dynamics 3. Thermodynamic Approaches 3.1 Thermodynamic Potentials 3.2 Alloys 3.3 Cluster Expansion 3.4 Monte-Carlo-Methods
Literature	Solid State Physics, Ashcroft/Mermin, Saunders College Computational Physics, Thijsen, Cambridge Computational Materials Science, Ohno et al.. Springer Materials Science and Engineering: An Introduction, Callister/Rethwisch, Edition 9, Wiley

Course L1678: Methods in Theoretical Materials Science	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Stefan Fritz Müller
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1238: Quantum Mechanics of Solids

Courses

Title	Typ	Hrs/wk	CP
Quantum Mechanics of Solids (L1675)	Lecture	2	4
Quantum Mechanics of Solids (L1676)	Recitation Section (small)	1	2

Module Responsible	Prof. Stefan Fritz Müller
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of advanced mathematics like analysis, linear algebra, differential equations and complex functions, e.g., Mathematics I-IV Knowledge of mechanics and physics, particularly solid state physics, e.g., Materials Physics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The master students will be able to explain… …the basics of quantum mechanics. … the importance of quantum physics for the description of materials properties. … correlations between on quantum mechanics based phenomena between individual atoms and macroscopic properties of materials. The master students will then be able to connect essential materials properties in engineering with materials properties on the atomistic scale in order to understand these connections.
Skills	After attending this lecture the students can … …perform materials design on a quantum mechanical basis.
Personal Competence	
Social Competence	The students are able to discuss competently quantum-mechanics-based subjects with experts from fields such as physics and materials science.
Autonomy	The students are able to independently develop solutions to quantum mechanical problems. They can also acquire the knowledge they need to deal with more complex questions with a quantum mechanical background from the literature.
Workload in Hours	Independent Study Time 138, Study Time in Lecture 42
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	
Assignment for the Following Curricula	Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Materials Science: Specialisation Modeling: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1675: Quantum Mechanics of Solids	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Stefan Fritz Müller
Language	DE/EN
Cycle	SoSe
Content	1. Introduction 1.1 Relevance of Quantum Mechanics 1.2 Classification of Solids 2. Foundations of Quantum Mechanics 2.1 Reminder : Elements of Classical Mechanics 2.2 Motivation for Quantum Mechanics 2.3 Particle-Wave Duality 2.4 Formalism 3. Elementary QM Problems 3.1 Onedimensional Problems of a Particle in a Potential 3.2 Two-Level System 3.3 Harmonic Oscillator 3.4 Electrons in a Magnetic Field 3.5 Hydrogen Atom 4. Quantum Effects in Condensed Matter 4.1 Preliminary 4.2 Electronic Levels 4.3 Magnetism 4.4 Superconductivity 4.5 Quantum Hall Effect
Literature	Physik für Ingenieure, Hering/Martin/Stohrer, Springer Atom- und Quantenphysik, Haken/Wolf, Springer Grundkurs Theoretische Physik 5|1, Nolting, Springer Electronic Structure of Materials, Sutton, Oxford Materials Science and Engineering: An Introduction, Callister/Rethwisch, Edition 9, Wiley

Course L1676: Quantum Mechanics of Solids	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Stefan Fritz Müller
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0603: Nonlinear Structural Analysis

Courses

Title	Typ	Hrs/wk	CP
Nonlinear Structural Analysis (L0277)	Lecture	3	4
Nonlinear Structural Analysis (L0279)	Recitation Section (small)	1	2

Module Responsible	Prof. Alexander Düster
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of partial differential equations is recommended.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to + give an overview of the different nonlinear phenomena in structural mechanics. + explain the mechanical background of nonlinear phenomena in structural mechanics. + to specify problems of nonlinear structural analysis, to identify them in a given situation and to explain their mathematical and mechanical background.
Skills	Students are able to + model nonlinear structural problems. + select for a given nonlinear structural problem a suitable computational procedure. + apply finite element procedures for nonlinear structural analysis. + critically verify and judge results of nonlinear finite elements. + to transfer their knowledge of nonlinear solution procedures to new problems.
Personal Competence	
Social Competence	Students are able to + solve problems in heterogeneous groups and to document the corresponding results. + share new knowledge with group members.
Autonomy	Students are able to + acquire independently knowledge to solve complex problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory Materials Science: Specialisation Modeling: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory Ship and Offshore Technology: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L0277: Nonlinear Structural Analysis	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Alexander Düster
Language	DE/EN
Cycle	WiSe
Content	1. Introduction 2. Nonlinear phenomena 3. Mathematical preliminaries 4. Basic equations of continuum mechanics 5. Spatial discretization with finite elements 6. Solution of nonlinear systems of equations 7. Solution of elastoplastic problems 8. Stability problems 9. Contact problems
Literature	[1] Alexander Düster, Nonlinear Structrual Analysis, Lecture Notes, Technische Universität Hamburg-Harburg, 2014. [2] Peter Wriggers, Nonlinear Finite Element Methods, Springer 2008. [3] Peter Wriggers, Nichtlineare Finite-Elemente-Methoden, Springer 2001. [4] Javier Bonet and Richard D. Wood, Nonlinear Continuum Mechanics for Finite Element Analysis, Cambridge University Press, 2008.

Course L0279: Nonlinear Structural Analysis	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Alexander Düster
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1150: Continuum Mechanics

Courses

Title	Typ	Hrs/wk	CP
Continuum Mechanics (L1533)	Lecture	2	3
Continuum Mechanics Exercise (L1534)	Recitation Section (small)	2	3

Module Responsible	Prof. Christian Cyron
Admission Requirements	None
Recommended Previous Knowledge	Basics of linear continuum mechanics as taught, e.g., in the module Mechanics II (forces and moments, stress, linear strain, free-body principle, linear-elastic constitutive laws, strain energy).
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can explain the fundamental concepts to calculate the mechanical behavior of materials.
Skills	The students can set up balance laws and apply basics of deformation theory to specific aspects, both in applied contexts as in research contexts.
Personal Competence	
Social Competence	The students are able to develop solutions, to present them to specialists in written form and to develop ideas further.
Autonomy	The students are able to assess their own strengths and weaknesses. They can independently and on their own identify and solve problems in the area of continuum mechanics and acquire the knowledge required to this end.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	60 min
Assignment for the Following Curricula	Materials Science: Specialisation Modeling: Elective Compulsory Mechanical Engineering and Management: Specialisation Materials: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L1533: Continuum Mechanics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Christian Cyron
Language	DE
Cycle	WiSe
Content	- Fundamentals of tensor calculus - Transformation invariance - Tensor algebra - Tensor analysis - Kinematics - Motion of continuum - Deformation of infinitesimal line, area and volume elements - Material and spatial description - Polar decomposition - Spectral decomposition - Objectivity - Strain measures - Time derivatives - Partial / material time derivatives - Objective time rates - Strain and deformation rates - Transport theorems - Balance equations (global and local form) - Balance of mass - The stress state - Surface traction vectors - Cauchy's fundamental theorem - Stress tensors (Cauchy, 1. and 2. Piola-Kirchhoff, Kirchhoff stress tensor) - Balance of linear momentum - Balance of angular momentum - Balance of energy - Balance of entropy - Clausius-Duhem inequality - Constitutive laws - Constitutive assumptions - Fluids - Elastic solids - Hyperelasticity - Material symmetry - Elasto-plastic solids - Analysis - Initial-boundary value problems and their numerical solution
Literature	R. Greve: Kontinuumsmechanik: Ein Grundkurs für Ingenieure und Physiker I-S. Liu: Continuum Mechanics, Springer weitere siehe in der Literaturliste des Scripts

Course L1534: Continuum Mechanics Exercise	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Christian Cyron
Language	DE
Cycle	WiSe
Content	• kinematics of undeformed and deformed bodies • balance equations (balance of mass, balance of energy, ...) • stress states • material modelling
Literature	R. Greve: Kontinuumsmechanik: Ein Grundkurs für Ingenieure und Physiker I-S. Liu: Continuum Mechanics, Springer

Module M1291: Materials Science Seminar

Courses

Title	Typ	Hrs/wk	CP
Seminar (L1757)	Seminar	2	3
Seminar Composites (L1758)	Seminar	2	3
Seminar Advanced Ceramics (L1801)	Seminar	2	3
Seminar on interface-dominated materials (L1795)	Seminar	2	3

Module Responsible	Prof. Jörg Weißmüller
Admission Requirements	None
Recommended Previous Knowledge	Fundamental knowledge on nanomaterials, electrochemistry, interface science, mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the most important facts and relationships of a specific topic from the field of materials science.
Skills	Students are able to compile a specified topic from the field of materials science and to give a clear, structured and comprehensible presentation of the subject. They can comply with a given duration of the presentation. They can write in English a summary including illustrations that contains the most important results, relationships and explanations of the subject.
Personal Competence	
Social Competence	Students are able to adapt their presentation with respect to content, detailedness, and presentation style to the composition and previous knowledge of the audience. They can answer questions from the audience in a curt and precise manner.
Autonomy	Students are able to autonomously carry out a literature research concerning a given topic. They can independently evaluate the material. They can self-reliantly decide which parts of the material should be included in the presentation.
Workload in Hours	Depends on choice of courses
Credit points	6
Assignment for the Following Curricula	Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Materials Science: Specialisation Modeling: Elective Compulsory Materials Science: Specialisation Engineering Materials: Elective Compulsory

Course L1757: Seminar

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Referat
Examination duration and scale	
Lecturer	Prof. Jörg Weißmüller
Language	DE/EN
Cycle	WiSe/SoSe
Content	
Literature	

Course L1758: Seminar Composites

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Referat
Examination duration and scale	
Lecturer	Prof. Bodo Fiedler
Language	DE/EN
Cycle	WiSe/SoSe
Content	
Literature	

Course L1801: Seminar Advanced Ceramics	
Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Referat
Examination duration and scale	
Lecturer	Prof. Gerold Schneider
Language	DE/EN
Cycle	WiSe/SoSe
Content	
Literature	

Course L1795: Seminar on interface-dominated materials	
Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Referat
Examination duration and scale	
Lecturer	Prof. Patrick Huber
Language	DE/EN
Cycle	WiSe/SoSe
Content	
Literature	

Specialization Nano and Hybrid Materials

Module M0766: Microsystems Technology

Courses

Title	Typ	Hrs/wk	CP
Microsystems Technology (L0724)	Lecture	2	4

Module Responsible	Prof. Hoc Khiem Trieu
Admission Requirements	None
Recommended Previous Knowledge	Basics in physics, chemistry and semiconductor technology
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able • to present and to explain current fabrication techniques for microstructures and especially methods for the fabrication of microsensors and microactuators, as well as the integration thereof in more complex systems • to explain in details operation principles of microsensors and microactuators and • to discuss the potential and limitation of microsystems in application.
Skills	Students are capable • to analyze the feasibility of microsystems, • to develop process flows for the fabrication of microstructures and • to apply them.
Personal Competence	
Social Competence	None
Autonomy	None
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Credit points	4
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory

Course L0724: Microsystems Technology	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Hoc Khiem Trieu
Language	EN
Cycle	WiSe
Content	• Introduction (historical view, scientific and economic relevance, scaling laws) • Semiconductor Technology Basics, Lithography (wafer fabrication, photolithography, improving resolution, next-generation lithography, nano-imprinting, molecular imprinting) • Deposition Techniques (thermal oxidation, epitaxy, electroplating, PVD techniques: evaporation and sputtering; CVD techniques: APCVD, LPCVD, PECVD and LECVD; screen printing) • Etching and Bulk Micromachining (definitions, wet chemical etching, isotropic etch with HNA, electrochemical etching, anisotropic etching with KOH/TMAH: theory, corner undercutting, measures for compensation and etch-stop techniques; plasma processes, dry etching: back sputtering, plasma etching, RIE, Bosch process, cryo process, XeF2 etching) • Surface Micromachining and alternative Techniques (sacrificial etching, film stress, stiction: theory and counter measures; Origami microstructures, Epi-Poly, porous silicon, SOI, SCREAM process, LIGA, SU8, rapid prototyping) • Thermal and Radiation Sensors (temperature measurement, self-generating sensors: Seebeck effect and thermopile; modulating sensors: thermo resistor, Pt-100, spreading resistance sensor, pn junction, NTC and PTC; thermal anemometer, mass flow sensor, photometry, radiometry, IR sensor: thermopile and bolometer) • Mechanical Sensors (strain based and stress based principle, capacitive readout, piezoresistivity, pressure sensor: piezoresistive, capacitive and fabrication process; accelerometer: piezoresistive, piezoelectric and capacitive; angular rate sensor: operating principle and fabrication process) • Magnetic Sensors (galvanomagnetic sensors: spinning current Hall sensor and magneto-transistor; magnetoresistive sensors: magneto resistance, AMR and GMR, fluxgate magnetometer) • Chemical and Bio Sensors (thermal gas sensors: pellistor and thermal conductivity sensor; metal oxide semiconductor gas sensor, organic semiconductor gas sensor, Lambda probe, MOSFET gas sensor, pH-FET, SAW sensor, principle of biosensor, Clark electrode, enzyme electrode, DNA chip) • Micro Actuators, Microfluidics and TAS (drives: thermal, electrostatic, piezo electric and electromagnetic; light modulators, DMD, adaptive optics, microscanner, microvalves: passive and active, micropumps, valveless micropump, electrokinetic micropumps, micromixer, filter, inkjet printhead, microdispenser, microfluidic switching elements, microreactor, lab-on-a-chip, microanalytics) • MEMS in medical Engineering (wireless energy and data transmission, smart pill, implantable drug delivery system, stimulators: microelectrodes, cochlear and retinal implant; implantable pressure sensors, intelligent osteosynthesis, implant for spinal cord regeneration) • Design, Simulation, Test (development and design flows, bottom-up approach, top-down approach, testability, modelling: multiphysics, FEM and equivalent circuit simulation; reliability test, physics-of-failure, Arrhenius equation, bath-tub relationship) • System Integration (monolithic and hybrid integration, assembly and packaging, dicing, electrical contact: wire bonding, TAB and flip chip bonding; packages, chip-on-board, wafer-level-package, 3D integration, wafer bonding: anodic bonding and silicon fusion bonding; micro electroplating, 3D-MID)
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press, 2002 N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009 T. M. Adams, R. A. Layton:Introductory MEMS, Springer, 2010 G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008

Module M1334: BIO II: Biomaterials

Courses

Title	Typ	Hrs/wk	CP
Biomaterials (L0593)	Lecture	2	3

Module Responsible	Prof. Michael Morlock
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of orthopedic and surgical techniques is recommended.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can describe the materials of the human body and the materials being used in medical engineering, and their fields of use.
Skills	The students can explain the advantages and disadvantages of different kinds of biomaterials.
Personal Competence	
Social Competence	The students are able to discuss issues related to materials being present or being used for replacements with student mates and the teachers.
Autonomy	The students are able to acquire information on their own. They can also judge the information with respect to its credibility.
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Credit points	3
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L0593: Biomaterials	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Michael Morlock
Language	EN
Cycle	WiSe
Content	Topics to be covered include: 1. Introduction (Importance, nomenclature, relations) 2. Biological materials 2.1 Basics (components, testing methods) 2.2 Bone (composition, development, properties, influencing factors) 2.3 Cartilage (composition, development, structure, properties, influencing factors) 2.4 Fluids (blood, synovial fluid) 3 Biological structures 3.1 Menisci of the knee joint 3.2 Intervertebral discs 3.3 Teeth 3.4 Ligaments 3.5 Tendons 3.6 Skin 3.7 Nervs 3.8 Muscles 4. Replacement materials 4.1 Basics (history, requirements, norms) 4.2 Steel (alloys, properties, reaction of the body) 4.3 Titan (alloys, properties, reaction of the body) 4.4 Ceramics and glas (properties, reaction of the body) 4.5 Plastics (properties of PMMA, HDPE, PET, reaction of the body) 4.6 Natural replacement materials Knowledge of composition, structure, properties, function and changes/adaptations of biological and technical materials (which are used for replacements in-vivo). Acquisition of basics for theses work in the area of biomechanics.
Literature	Hastings G and Ducheyne P.: Natural and living biomaterials. Boca Raton: CRC Press, 1984. Williams D.: Definitions in biomaterials. Oxford: Elsevier, 1987. Hastings G.: Mechanical properties of biomaterials: proceedings held at Keele University, September 1978. New York: Wiley, 1998. Black J.: Orthopaedic biomaterials in research and practice. New York: Churchill Livingstone, 1988. Park J. Biomaterials: an introduction. New York: Plenum Press, 1980. Wintermantel, E. und Ha, S.-W : Biokompatible Werkstoffe und Bauweisen. Berlin, Springer, 1996.

Module M0643: Optoelectronics I - Wave Optics

Courses

Title	Typ	Hrs/wk	CP
Optoelectronics I: Wave Optics (L0359)	Lecture	2	3
Optoelectronics I: Wave Optics (Problem Solving Course) (L0361)	Recitation Section (small)	1	1

Module Responsible	Prof. Manfred Eich
Admission Requirements	None
Recommended Previous Knowledge	Basics in electrodynamics, calculus
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the fundamental mathematical and physical relations of freely propagating optical waves. They can give an overview on wave optical phenomena such as diffraction, reflection and refraction, etc. Students can describe waveoptics based components such as electrooptical modulators in an application oriented way.
Skills	Students can generate models and derive mathematical descriptions in relation to free optical wave propagation. They can derive approximative solutions and judge factors influential on the components' performance.
Personal Competence	
Social Competence	Students can jointly solve subject related problems in groups. They can present their results effectively within the framework of the problem solving course.
Autonomy	Students are capable to extract relevant information from the provided references and to relate this information to the content of the lecture. They can reflect their acquired level of expertise with the help of lecture accompanying measures such as exam typical exam questions. Students are able to connect their knowledge with that acquired from other lectures.
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Credit points	4
Course achievement	None
Examination	Written exam
Examination duration and scale	40 minutes
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory

Course L0359: Optoelectronics I: Wave Optics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Manfred Eich
Language	EN
Cycle	SoSe
Content	• Introduction to optics • Electromagnetic theory of light • Interference • Coherence • Diffraction • Fourier optics • Polarisation and Crystal optics • Matrix formalism • Reflection and transmission • Complex refractive index • Dispersion • Modulation and switching of light
Literature	Bahaa E. A. Saleh, Malvin Carl Teich, Fundamentals of Photonics, Wiley 2007 Hecht, E., Optics, Benjamin Cummings, 2001 Goodman, J.W. Statistical Optics, Wiley, 2000 Lauterborn, W., Kurz, T., Coherent Optics: Fundamentals and Applications, Springer, 2002

Course L0361: Optoelectronics I: Wave Optics (Problem Solving Course)	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Manfred Eich
Language	EN
Cycle	SoSe
Content	see lecture Optoelectronics 1 - Wave Optics
Literature	see lecture Optoelectronics 1 - Wave Optics

Module M0930: Semiconductor Seminar

Courses

Title	Typ	Hrs/wk	CP
Semiconductor Seminar (L0760)	Seminar	2	2

Module Responsible	Prof. Matthias Kuhl
Admission Requirements	None
Recommended Previous Knowledge	Semiconductors
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the most important facts and relationships of a specific topic from the field of semiconductors.
Skills	Students are able to compile a specified topic from the field of semiconductors and to give a clear, structured and comprehensible presentation of the subject. They can comply with a given duration of the presentation. They can write in English a summary including illustrations that contains the most important results, relationships and explanations of the subject.
Personal Competence	
Social Competence	Students are able to adapt their presentation with respect to content, detailedness, and presentation style to the composition and previous knowledge of the audience. They can answer questions from the audience in a curt and precise manner.
Autonomy	Students are able to autonomously carry out a literature research concerning a given topic. They can independently evaluate the material. They can self-reliantly decide which parts of the material should be included in the presentation.
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	None
Examination	Presentation
Examination duration and scale	15 minutesw presentation + 5-10 minutes discussion + 2 pages written abstract
Assignment for the Following Curricula	Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory

Course L0760: Semiconductor Seminar

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Matthias Kuhl, Prof. Manfred Kasper, Prof. Manfred Eich, Prof. Hoc Khiem Trieu
Language	EN
Cycle	SoSe
Content	Prepare, present, and discuss talks about recent topics from the field of semiconductors. The presentations must be given in English. ***Evaluation Criteria:*** • understanding of subject, discussion, response to questions • structure and logic of presentation (clarity, precision) • coverage of the topic, selection of subjects presented • linguistic presentation (clarity, comprehensibility) • visual presentation (clarity, comprehensibility) • handout (see below) • compliance with timing requirement. ***Handout:*** Before your presentation, it is mandatory to distribute a printed handout (short abstract) of your presentation in English language. This must be no longer than two pages A4, and include the most important results, conclusions, explanations and diagrams.
Literature	Aktuelle Veröffentlichungen zu dem gewählten Thema

Module M1220: Interfaces and interface-dominated Materials

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Nature's Hierarchical Materials (L1663)	Seminar	2	3
Interfaces (L1654)	Lecture	2	3

Module Responsible	Prof. Patrick Huber
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in Materials Science, e.g. Materials Science I/II, and physical chemistry
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students will be able to explain the structural and thermodynamic properties of interfaces in comparison to the bulk systems. They will be able to describe the relevance of interfaces and physico-chemical modifications of interfaces. Moreover, they are able to outline the characteristics of biomaterials and to relate them to classical materials systems, such as metals, ceramics and polymers.
Skills	The students are able to rationalize the impact of interfaces on material properties and functionalities. Moreover, they are able to trace the peculiar properties of biomaterials to their hierarchical hybrid structure.
Personal Competence	
Social Competence	The students are able to present solutions to specialists and to develop ideas further.
Autonomy	The students are able to ... • assess their own strengths and weaknesses. • define tasks independently.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Mechanical Engineering and Management: Specialisation Materials: Elective Compulsory

Course L1663: Nature's Hierarchical Materials

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Gerold Schneider
Language	EN
Cycle	WiSe
Content	Biological materials are omnipresent in the world around us. They are the main constituents in plant and animal bodies and have a diversity of functions. A fundamental function is obviously mechanical providing protection and support for the body. But biological materials may also serve as ion reservoirs (bone is a typical example), as chemical barriers (like cell membranes), have catalytic function (such as enzymes), transfer chemical into kinetic energy (such as the muscle), etc.This lecture will focus on materials with a primarily (passive) mechanical function: cellulose tissues (such as wood), collagen tissues (such as tendon or cornea), mineralized tissues (such as bone, dentin and glass sponges). The main goal is to give an introduction to the current knowledge of the structure in these materials and how these structures relate to their (mostly mechanical) functions.
Literature	Peter Fratzl, Richard Weinkamer, Nature’s hierarchical materialsProgress, in Materials Science 52 (2007) 1263-1334 Journal publications

Course L1654: Interfaces	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Patrick Huber
Language	DE
Cycle	SoSe
Content	• Microscopic structure and thermodynamics of interfaces (gas/solid, gas/liquid, liquid/liquid, liquid/solid) • Experimental methods for the study of interfaces • Interfacial forces • wetting • surfactants, foams, bio-membranes • chemical grafting of interfaces
Literature	"Physics and Chemistry of Interfaces", K.H. Butt, K. Graf, M. Kappl, Wiley-VCH Weinheim (2006) "Interfacial Science", G.T. Barnes, I.R. Gentle, Oxford University Press (2005)

Module M1238: Quantum Mechanics of Solids

Courses

Title	Typ	Hrs/wk	CP
Quantum Mechanics of Solids (L1675)	Lecture	2	4
Quantum Mechanics of Solids (L1676)	Recitation Section (small)	1	2

Module Responsible	Prof. Stefan Fritz Müller
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of advanced mathematics like analysis, linear algebra, differential equations and complex functions, e.g., Mathematics I-IV Knowledge of mechanics and physics, particularly solid state physics, e.g., Materials Physics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The master students will be able to explain... ...the basics of quantum mechanics. ... the importance of quantum physics for the description of materials properties. ... correlations between on quantum mechanics based phenomena between individual atoms and macroscopic properties of materials. The master students will then be able to connect essential materials properties in engineering with materials properties on the atomistic scale in order to understand these connections.
Skills	After attending this lecture the students can ... ...perform materials design on a quantum mechanical basis.
Personal Competence	
Social Competence	The students are able to discuss competently quantum-mechanics-based subjects with experts from fields such as physics and materials science.
Autonomy	The students are able to independently develop solutions to quantum mechanical problems. They can also acquire the knowledge they need to deal with more complex questions with a quantum mechanical background from the literature.
Workload in Hours	Independent Study Time 138, Study Time in Lecture 42
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	
Assignment for the Following Curricula	Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Materials Science: Specialisation Modeling: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1675: Quantum Mechanics of Solids	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Stefan Fritz Müller
Language	DE/EN
Cycle	SoSe
Content	1. Introduction 1.1 Relevance of Quantum Mechanics 1.2 Classification of Solids 2. Foundations of Quantum Mechanics 2.1 Reminder : Elements of Classical Mechanics 2.2 Motivation for Quantum Mechanics 2.3 Particle-Wave Duality 2.4 Formalism 3. Elementary QM Problems 3.1 Onedimensional Problems of a Particle in a Potential 3.2 Two-Level System 3.3 Harmonic Oscillator 3.4 Electrons in a Magnetic Field 3.5 Hydrogen Atom 4. Quantum Effects in Condensed Matter 4.1 Preliminary 4.2 Electronic Levels 4.3 Magnetism 4.4 Superconductivity 4.5 Quantum Hall Effect
Literature	Physik für Ingenieure, Hering/Martin/Stohrer, Springer Atom- und Quantenphysik, Haken/Wolf, Springer Grundkurs Theoretische Physik 5|1, Nolting, Springer Electronic Structure of Materials, Sutton, Oxford Materials Science and Engineering: An Introduction, Callister/Rethwisch, Edition 9, Wiley

Course L1676: Quantum Mechanics of Solids	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Stefan Fritz Müller
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1239: Experimental Micro- and Nanomechanics

Courses

Title	Typ	Hrs/wk	CP
Experimental Micro- and Nanomechanics (L1673)	Lecture	2	4
Experimental Micro- and Nanomechanics (L1674)	Recitation Section (small)	1	2

Module Responsible	Dr. Erica Lilleodden
Admission Requirements	None
Recommended Previous Knowledge	Basics in Materials Science I/II, Mechanical Properties, Phenomena and Methods in Materials Science
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe the principles of mechanical behavior (e.g., stress, strain, modulus, strength, hardening, failure, fracture). Students can explain the principles of characterization methods used for investigating microstructure (e.g., scanning electron microscopy, x-ray diffraction) They can describe the fundamental relations between microstructure and mechanical properties.
Skills	Students are capable of using standardized calculation methods to calculate and evaluate mechanical properties (modulus, strength) of different materials under varying loading states (e.g., uniaxial stress or plane strain).
Personal Competence	
Social Competence	Students can provide appropriate feedback and handle feedback on their own performance constructively.
Autonomy	Students are able to - assess their own strengths and weaknesses - assess their own state of learning in specific terms and to define further work steps on this basis guided by teachers. - to be able to work independently based on lectures and notes to solve problems, and to ask for help or clarifications when needed
Workload in Hours	Independent Study Time 138, Study Time in Lecture 42
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	60 min
Assignment for the Following Curricula	Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1673: Experimental Micro- and Nanomechanics	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Dr. Erica Lilleodden
Language	DE/EN
Cycle	SoSe

Content	This class will cover the principles of mechanical testing at the micron and nanometer scales. A focus will be made on metallic materials, though issues related to ceramics and polymeric materials will also be discussed. Modern methods will be explored, along with the scientific questions investigated by such methods.
	
	• Principles of micromechanics
	  ◦ Motivations for small-scale testing
	  ◦ Sample preparation methods for small-scale testing
	  ◦ General experimental artifacts and quantification of measurement resolution
	• Complementary structural analysis methods
	  ◦ Electron back scattered diffraction
	  ◦ Transmission electron microscopy
	  ◦ Micro-Laue diffraction
	• Nanoindentation-based testing
	  ◦ Principles of contact mechanics
	  ◦ Berkovich indentation
	    ▪ Loading geometry
	    ▪ Governing equations for analysis of stress & strain
	    ▪ Case study:
	      ▪ Indentation size effects
	  ◦ Microcompression
	    ▪ Loading geometry
	    ▪ Governing equations for analysis of stress & strain
	    ▪ Case study:
	      ▪ Size effects in yield strength and hardening
	  ◦ Microbeam-bending
	    ▪ Loading geometry
	    ▪ Governing equations for analysis of stress & strain
	    ▪ Case study:
	      ▪ Fracture strength & toughness
	•

Literature	Vorlesungsskript Aktuelle Publikationen

Course L1674: Experimental Micro- and Nanomechanics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Dr. Erica Lilleodden
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1335: BIO II: Artificial Joint Replacement

Courses

Title	Typ	Hrs/wk	CP
Artificial Joint Replacement (L1306)	Lecture	2	3

Module Responsible	Prof. Michael Morlock
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of orthopedic and surgical techniques is recommended.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can name the different kinds of artificial limbs.
Skills	The students can explain the advantages and disadvantages of different kinds of endoprotheses.
Personal Competence	
Social Competence	The students are able to discuss issues related to endoprothese with student mates and the teachers.
Autonomy	The students are able to acquire information on their own. They can also judge the information with respect to its credibility.
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Credit points	3
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Orientierungsstudium: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L1306: Artificial Joint Replacement

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Michael Morlock
Language	DE
Cycle	SoSe
Content	Inhalt (deutsch) 1. EINLEITUNG (Bedeutung, Ziel, Grundlagen, allg. Geschichte des künstlichen Gelenker-satzes) 2. FUNKTIONSANALYSE (Der menschliche Gang, die menschliche Arbeit, die sportliche Aktivität) 3. DAS HÜFTGELENK (Anatomie, Biomechanik, Gelenkersatz Schaftseite und Pfannenseite, Evolution der Implantate) 4. DAS KNIEGELENK (Anatomie, Biomechanik, Bandersatz, Gelenkersatz femorale, tibiale und patelläre Komponenten) 5. DER FUß (Anatomie, Biomechanik, Gelen-kersatz, orthopädische Verfahren) 6. DIE SCHULTER (Anatomie, Biomechanik, Gelenkersatz) 7. DER ELLBOGEN (Anatomie, Biomechanik, Gelenkersatz) 8. DIE HAND (Anatomie, Biomechanik, Ge-lenkersatz) 9. TRIBOLOGIE NATÜRLICHER UND KÜNST-LICHER GELENKE (Korrosion, Reibung, Verschleiß)
Literature	Literatur: Kapandji, I..: Funktionelle Anatomie der Gelenke (Band 1-4), Enke Verlag, Stuttgart, 1984. Nigg, B., Herzog, W.: Biomechanics of the musculo-skeletal system, John Wiley&Sons, New York 1994 Nordin, M., Frankel, V.: Basic Biomechanics of the Musculoskeletal System, Lea&Febiger, Philadelphia, 1989. Czichos, H.: Tribologiehandbuch, Vieweg, Wiesbaden, 2003. Sobotta und Netter für Anatomie der Gelenke

Module M0519: Particle Technology and Solid Matter Process Technology

Courses

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

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

Course L0051: Advanced Particle Technology II

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

Course L0050: Advanced Particle Technology II	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Stefan Heinrich
Language	DE/EN
Cycle	WiSe
Content	• Exercise in form of "Project based Learning" • Agglomeration, particle size enlargement • advanced particle size reduction • Advanced theorie of fluid/particle flows • CFD-methods for the simulation of disperse fluid/solid flows, Euler/Euler methids, Descrete Particle Modeling • Treatment of simulation problems with distributed properties, solution of population balances
Literature	Schubert, H.; Heidenreich, E.; Liepe, F.; Neeße, T.: Mechanische Verfahrenstechnik. Deutscher Verlag für die Grundstoffindustrie, Leipzig, 1990. Stieß, M.: Mechanische Verfahrenstechnik I und II. Springer Verlag, Berlin, 1992.

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

Module M0644: Optoelectronics II - Quantum Optics

Courses

Title	Typ	Hrs/wk	CP
Optoelectronics II: Quantum Optics (L0360)	Lecture	2	3
Optoelectronics II: Quantum Optics (Problem Solving Course) (L0362)	Recitation Section (small)	1	1

Module Responsible	Dr. Alexander Petrov
Admission Requirements	None
Recommended Previous Knowledge	Basic principles of electrodynamics, optics and quantum mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the fundamental mathematical and physical relations of quantum optical phenomena such as absorption, stimulated and spontanous emission. They can describe material properties as well as technical solutions. They can give an overview on quantum optical components in technical applications.
Skills	Students can generate models and derive mathematical descriptions in relation to quantum optical phenomena and processes. They can derive approximative solutions and judge factors influential on the components' performance.
Personal Competence	
Social Competence	Students can jointly solve subject related problems in groups. They can present their results effectively within the framework of the problem solving course.
Autonomy	Students are capable to extract relevant information from the provided references and to relate this information to the content of the lecture. They can reflect their acquired level of expertise with the help of lecture accompanying measures such as exam typical exam questions. Students are able to connect their knowledge with that acquired from other lectures.
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Credit points	4
Course achievement	None
Examination	Written exam
Examination duration and scale	60 minutes
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective Compulsory

Course L0360: Optoelectronics II: Quantum Optics

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Alexander Petrov
Language	EN
Cycle	WiSe
Content	• Generation of light • Photons • Thermal and nonthermal light • Laser amplifier • Noise • Optical resonators • Spectral properties of laser light • CW-lasers (gas, solid state, semiconductor) • Pulsed lasers
Literature	Bahaa E. A. Saleh, Malvin Carl Teich, Fundamentals of Photonics, Wiley 2007 Demtröder, W., Laser Spectroscopy: Basic Concepts and Instrumentation, Springer, 2002 Kasap, S.O., Optoelectronics and Photonics: Principles and Practices, Prentice Hall, 2001 Yariv, A., Quantum Electronics, Wiley, 1988 Wilson, J., Hawkes, J., Optoelectronics: An Introduction, Prentice Hall, 1997, ISBN: 013103961X Siegman, A.E., Lasers, University Science Books, 1986

Course L0362: Optoelectronics II: Quantum Optics (Problem Solving Course)	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Alexander Petrov
Language	EN
Cycle	WiSe
Content	see lecture Optoelectronics 1 - Wave Optics
Literature	see lecture Optoelectronics 1 - Wave Optics

Module M1291: Materials Science Seminar

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Seminar (L1757)	Seminar	2	3
Seminar Composites (L1758)	Seminar	2	3
Seminar Advanced Ceramics (L1801)	Seminar	2	3
Seminar on interface-dominated materials (L1795)	Seminar	2	3

Module Responsible	Prof. Jörg Weißmüller
Admission Requirements	None
Recommended Previous Knowledge	Fundamental knowledge on nanomaterials, electrochemistry, interface science, mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the most important facts and relationships of a specific topic from the field of materials science.
Skills	Students are able to compile a specified topic from the field of materials science and to give a clear, structured and comprehensible presentation of the subject. They can comply with a given duration of the presentation. They can write in English a summary including illustrations that contains the most important results, relationships and explanations of the subject.
Personal Competence	
Social Competence	Students are able to adapt their presentation with respect to content, detailedness, and presentation style to the composition and previous knowledge of the audience. They can answer questions from the audience in a curt and precise manner.
Autonomy	Students are able to autonomously carry out a literature research concerning a given topic. They can independently evaluate the material. They can self-reliantly decide which parts of the material should be included in the presentation.
Workload in Hours	Depends on choice of courses
Credit points	6
Assignment for the Following Curricula	Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Materials Science: Specialisation Modeling: Elective Compulsory Materials Science: Specialisation Engineering Materials: Elective Compulsory

Course L1757: Seminar

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Referat
Examination duration and scale	
Lecturer	Prof. Jörg Weißmüller
Language	DE/EN
Cycle	WiSe/SoSe
Content	
Literature	

Course L1758: Seminar Composites

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Referat
Examination duration and scale	
Lecturer	Prof. Bodo Fiedler
Language	DE/EN
Cycle	WiSe/SoSe
Content	
Literature	

Course L1801: Seminar Advanced Ceramics	
Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Referat
Examination duration and scale	
Lecturer	Prof. Gerold Schneider
Language	DE/EN
Cycle	WiSe/SoSe
Content	
Literature	

Course L1795: Seminar on interface-dominated materials	
Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Referat
Examination duration and scale	
Lecturer	Prof. Patrick Huber
Language	DE/EN
Cycle	WiSe/SoSe
Content	
Literature	

Thesis

Module M-002: Master Thesis

Courses			
Title	Typ	Hrs/wk	CP

Module Responsible	Professoren der TUHH
Admission Requirements	• According to General Regulations §21 (1): At least 60 credit points have to be achieved in study programme. The examinations board decides on exceptions.
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• The students can use specialized knowledge (facts, theories, and methods) of their subject competently on specialized issues. • The students can explain in depth the relevant approaches and terminologies in one or more areas of their subject, describing current developments and taking up a critical position on them. • The students can place a research task in their subject area in its context and describe and critically assess the state of research.
Skills	The students are able: • To select, apply and, if necessary, develop further methods that are suitable for solving the specialized problem in question. • To apply knowledge they have acquired and methods they have learnt in the course of their studies to complex and/or incompletely defined problems in a solution-oriented way. • To develop new scientific findings in their subject area and subject them to a critical assessment.
Personal Competence	
Social Competence	Students can • Both in writing and orally outline a scientific issue for an expert audience accurately, understandably and in a structured way. • Deal with issues competently in an expert discussion and answer them in a manner that is appropriate to the addressees while upholding their own assessments and viewpoints convincingly.
Autonomy	Students are able: • To structure a project of their own in work packages and to work them off accordingly. • To work their way in depth into a largely unknown subject and to access the information required for them to do so. • To apply the techniques of scientific work comprehensively in research of their own.
Workload in Hours	Independent Study Time 900, Study Time in Lecture 0
Credit points	30
Course achievement	None
Examination	Thesis
Examination duration and scale	According to General Regulations
Assignment for the Following Curricula	Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy and Environmental Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Global Innovation Management: Thesis: Compulsory Computational Science and Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory Interdisciplinary Mathematics: Thesis: Compulsory International Management and Engineering: Thesis: Compulsory Joint European Master in Environmental Studies - Cities and Sustainability: Thesis: Compulsory Logistics, Infrastructure and Mobility: Thesis: Compulsory Materials Science: Thesis: Compulsory Mechanical Engineering and Management: Thesis: Compulsory

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