Study packages for incoming exchange students of the School of Mechanical Engineering

Updated: 02.12.2019
The School of Mechanical Engineering (German: Studiendekanat Maschinenbau) is the largest School of Study at Hamburg University of Technology (TUHH) offering plenty of courses to choose from. You can of course create your own, completely individual curriculum according to your preferences and the requirements of your sending institution. However, to help you get started, we propose the following pre-defined study packages based on our Bachelor’s and Master’s programs which you may use unmodified or adapt to your liking, especially if you need to achieve a certain number of ECTS points during your stay at TUHH. For each Bachelor’s and Master’s program there is typically one package for the summer and one for the winter semester.

In some cases the timetable of a lecture course can change, therefore some of your courses might overlap. Please check for updated schedules in the current “Course Catalogue” on the homepage of TUHH. The link and a QR code can be found below.

We can of course help you checking and – if necessary – adapting your curriculum. Please also note that some courses only allow a limited number of participants. Therefore, you should check the availability of free spots as early as possible and respect the registration deadlines of the courses. The affected courses are marked with the symbol * in the list below.

Some of the provided Bachelor courses require an additional registration for their group exercise. Please note that the registration period takes place at the beginning of the semester. It is therefore recommended to visit the first lecture and if necessary, ask the lecturer about the group exercise. The affected Bachelor courses are marked with the symbol ** in the list below.

For the detailed information about modules and courses of the study packages, please visit the “Course Catalogue” and “Module Description” website of the TUHH.

Course Catalogue
https://intranet.tuhh.de/stud/vvz_eingabe.php?Lang=en

Module Description
https://intranet.tuhh.de/kvvz/index.html?Lang=en

* Number of participants may be limited
** Additional registration for the group exercise is required
Table of Contents

Overview of study packages (Bachelor of Science)................................................................. 4
Overview of study packages (Master of Science)................................................................. 5
Module descriptions for Bachelor Courses ............................................................................. 8
  Study package 1a – General Engineering Science – WiSe .................................................. 8
  Study package alternatives for 1a – General Engineering Science – WiSe ..................... 11
  Study package 1b – General Engineering Science – SuSe ............................................... 13
  Study package alternatives for 1b – General Engineering Science – SuSe .................... 16
Module descriptions for Master Courses ............................................................................. 19
  Study package 1a – Product Development, Materials and Production – WiSe ............... 19
  Study package 1b – Product Development, Materials and Production – SuSe .............. 21
  Study package 2a – Biomedical Engineering – WiSe ......................................................... 24
  Study package 2b – Biomedical Engineering – SuSe ......................................................... 27
  Study package 3a – Materials Science – WiSe ................................................................. 30
  Study package 3b – Materials Science – SuSe ................................................................. 33
  Study package 4a – Energy Systems – WiSe ................................................................. 36
  Study package 4b – Energy Systems – SuSe ................................................................. 39
  Study package 5a – Aircraft Systems Engineering – WiSe ............................................. 42
  Study package 5b – Aircraft Systems Engineering – SuSe ............................................. 45
  Study package 6a – Naval Architecture and Ocean Engineering – WiSe ...................... 48
  Study package 6b – Naval Architecture and Ocean Engineering – SuSe .................... 50
  Study package 7a – Theoretical Mech. Engineering – Numerics and Computer Science – WiSe .... 51
  Study package 7b – Theoretical Mech. Engineering – Numerics and Computer Science – SuSe .... 54
  Study package 8a – Mechanical Engineering and Management – WiSe ....................... 57
  Study package 8b – Mechanical Engineering and Management – SuSe ..................... 60
  Study package 9a – Mechatronics – WiSe ................................................................. 63
  Study package 9b – Mechatronics – SuSe ................................................................. 66

* Number of participants may be limited
** Additional registration for the group exercise is required
## Overview of study packages (Bachelor of Science)

<table>
<thead>
<tr>
<th>Study Package 1a (Winter Semester): General Engineering Science</th>
<th>Study Package 1b (Summer Semester): General Engineering Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemistry (GES)</td>
<td>**Fundamentals of Mechanical Engineering Design (GES)</td>
</tr>
<tr>
<td>**Electrical Engineering I</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>**Linear Algebra</td>
<td>8 ECTS</td>
</tr>
<tr>
<td>Mechanics I (GES)</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>**Physics for Engineers (GES)</td>
<td>4 ECTS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study Package alternatives for 1a (Winter Semester): General Engineering Science</th>
<th>Study Package alternatives for 1b (Summer Semester): General Engineering Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>**Mechanics III (GES)</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>**Computer networks and Internet Security</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>**Functional Programming</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>**Electromagnetics for Engineers I: Time-Independent Fields</td>
<td>6 ECTS</td>
</tr>
</tbody>
</table>

* Number of participants may be limited
** Additional registration for the group exercise is required
## Overview of study packages (Master of Science)

<table>
<thead>
<tr>
<th>Study Package 1a (Winter Semester): Product Development, Materials and Production</th>
<th>Study Package 1b (Summer Semester): Product Development, Materials and Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Protection and Management</td>
<td>*Selected Topics of Product Development, Materials Science and Production: Reliability in Engineering Dynamics</td>
</tr>
<tr>
<td>Vibration Theory</td>
<td>Fibre-Polymer-Composites</td>
</tr>
<tr>
<td>Technical Acoustics II (Room Acoustics, Computational Methods)</td>
<td>Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics)</td>
</tr>
<tr>
<td>Robotics</td>
<td>Mechanical Properties</td>
</tr>
<tr>
<td>Finite Elements Methods</td>
<td>High-Order FEM</td>
</tr>
<tr>
<td>-</td>
<td>*Business &amp; Management: Problem-based Learning: Internationalization Strategies</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study Package 2a (Winter Semester): Biomedical Engineering</th>
<th>Study Package 2b (Summer Semester): Biomedical Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Selected Topics of Biomedical Engineering: Lecture: Nature’s Hierarchical Materials</td>
<td>3ECTS</td>
</tr>
<tr>
<td>BIO II: Biomaterials</td>
<td>*Selected Topics of Biomedical Engineering: Lecture: Experimental Methods for the Characterization of Materials</td>
</tr>
<tr>
<td>Advanced Functional Materials</td>
<td>*Bioelectromagnetics: Principles and Applications</td>
</tr>
<tr>
<td>Vibration Theory</td>
<td>Linear and Nonlinear System Identification</td>
</tr>
<tr>
<td>Control Systems Theory and Design</td>
<td>Nonlinear Dynamics</td>
</tr>
<tr>
<td>Finite Elements Methods</td>
<td>Optimal and Robust Control</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study Package 3a (Winter Semester): Materials Science</th>
<th>Study Package 3b (Summer Semester): Materials Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIO II: Biomaterials</td>
<td>Fibre-Polymer-Composites</td>
</tr>
<tr>
<td>Microsystems Technology</td>
<td>Optoelectronics I - Wave Optics</td>
</tr>
<tr>
<td>Advanced Functional Materials</td>
<td>High-Order FEM</td>
</tr>
<tr>
<td>Optoelectronics II - Quantum Optics</td>
<td>Methods in Theoretical Materials Science</td>
</tr>
<tr>
<td>Nonlinear Structural Analysis</td>
<td>Quantum Mechanics of Solids</td>
</tr>
<tr>
<td>*German as a Foreign Language</td>
<td>*Business &amp; Management: Problem-based Learning: Internationalization Strategies</td>
</tr>
<tr>
<td>Business &amp; Management: Lecture: Project Management</td>
<td>2 ECTS</td>
</tr>
<tr>
<td>*Lecture: Marketing</td>
<td>2 ECTS</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* Number of participants may be limited
** Additional registration for the group exercise is required
<table>
<thead>
<tr>
<th>Study Package 4a (Winter Semester): Energy Systems</th>
<th>Study Package 4b (Summer Semester): Energy Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finite Elements Methods</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>Vibration Theory</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>Control Systems Theory and Design</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>Innovative CFD Approaches</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>*German as a Foreign Language</td>
<td>4 ECTS</td>
</tr>
<tr>
<td>Business &amp; Management: Lecture: Project Management</td>
<td>2 ECTS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study Package 5a (Winter Semester): Aircraft Systems Engineering</th>
<th>Study Package 5b (Summer Semester): Aircraft Systems Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Topics in Control</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>Technical Acoustics II (Room Acoustics, Computational Methods)</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>Industrial Process Automation</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>Robotics</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>*German as a Foreign Language</td>
<td>4 ECTS</td>
</tr>
<tr>
<td>*Business &amp; Management: Lecture: Marketing</td>
<td>2 ECTS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study Package 6a (Winter Semester): Naval Architecture and Ocean Engineering</th>
<th>Study Package 6b (Summer Semester): Naval Architecture and Ocean Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship Vibration</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>Structural Analysis of Ships and Offshore Structures</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>Fatigue Strength of Ships and Offshore Structures</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>*Arctic Technology</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>Vibration Theory</td>
<td>6 ECTS</td>
</tr>
</tbody>
</table>

* Number of participants may be limited
** Additional registration for the group exercise is required

Study packages | School of Mechanical Engineering
<table>
<thead>
<tr>
<th>Study Package 7a (Winter Semester): Theoretical Mechanical Engineering - Numerics and Computer Science</th>
<th>Study Package 7b (Summer Semester): Theoretical Mechanical Engineering - Numerics and Computer Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D Computer Vision</td>
<td>Boundary Element Methods</td>
</tr>
<tr>
<td>Digital Signal Processing and Digital Filters</td>
<td>Numerical Treatment of Ordinary Differential Equations</td>
</tr>
<tr>
<td>Intelligent Autonomous Agents and Cognitive Robotics</td>
<td>Machine Learning and Data Mining</td>
</tr>
<tr>
<td>Mathematical Image Processing</td>
<td>Pattern Recognition and Data Compression</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study Package 8a (Winter Semester): Mechanical Engineering and Management</th>
<th>Study Package 8b (Summer Semester): Mechanical Engineering and Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marketing and Communication</td>
<td>Economics</td>
</tr>
<tr>
<td>Computer Aided Design and Computation</td>
<td>Fibre-Polymer-Composites</td>
</tr>
<tr>
<td>Robotics</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>Selected Topics of Mechanical Engineering and Management:</td>
<td>*Selected Topics of Mechanical Engineering and Management:</td>
</tr>
<tr>
<td>*International Law for Engineers</td>
<td>2 ECTS</td>
</tr>
<tr>
<td>*Accounting</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>Business &amp; Management:</td>
<td>*German as a Foreign Language</td>
</tr>
<tr>
<td>*Lecture: Marketing</td>
<td>2 ECTS</td>
</tr>
<tr>
<td>*German as a Foreign Language</td>
<td>4 ECTS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study Package 9a (Winter Semester): Mechatronics</th>
<th>Study Package 9b (Summer Semester): Mechatronics</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Design and Implementation of Software Systems</td>
<td>*Mechatronic Systems</td>
</tr>
<tr>
<td>Finite Elements Methods</td>
<td>*Selected Topics of Mechatronics:</td>
</tr>
<tr>
<td>Robotics</td>
<td>Process Measurement Engineering</td>
</tr>
<tr>
<td></td>
<td>Linear and Nonlinear System Identification</td>
</tr>
<tr>
<td>Control Systems Theory and Design</td>
<td>Nonlinear Dynamics</td>
</tr>
<tr>
<td>Vibration Theory (GES)</td>
<td>Embedded Systems</td>
</tr>
<tr>
<td>*</td>
<td>Software for Embedded Systems</td>
</tr>
</tbody>
</table>

* Number of participants may be limited
** Additional registration for the group exercise is required

Study packages | School of Mechanical Engineering
Module descriptions for Bachelor Courses

Study package 1a – General Engineering Science – WiSe

Chemistry (GES) | 6 ECTS

Recommended Previous Knowledge:
None

Theoretical Knowledge
The students are able to name and to describe basic principles and applications of general chemistry (structure of matter, periodic table, chemical bonds), physical chemistry (aggregate states, separating processes, thermodynamics, kinetics), inorganic chemistry (acid/base, pH-value, salts, solubility, redox, metals) and organic chemistry (aliphatic hydrocarbons, functional groups, carbonyl compounds, aromates, reaction mechanisms, natural products, synthetic polymers). Furthermore students are able to explain basic chemical terms.

Capabilities
After successful completion of this module students are able to describe substance groups and chemical compounds. On this basis, they are capable of explaining, choosing and applying specific methods and various reaction mechanisms.

**Electrical Engineering I | 6 ECTS

Recommended Previous Knowledge:
None

Theoretical Knowledge
The students know the basic theory, relations and methods of direct current networks and of electric and magnetic fields. This includes especially:
- Kirchhoff’s voltage and current laws
- Ohm's law
- methods to simplify and analyze direct current networks
- description of electric and magnetic fields by use of vectorial field quantities
- Basic material relations
- Gauss's law
- Ampère's law
- induction law
- Maxwell's equation in the integral form
- concept and definition of resistance, capacitance and inductance

Capabilities
The students are able to establish relations between currents and voltages in simple direct current networks and to apply these to calculate and dimension networks. Student know to apply the fundamental laws of electric and magnetic fields and are able to derive and evaluate relations between field quantities. Students know to calculate resistance, capacitance and inductance of simple geometric arrangements.

* Number of participants may be limited
** Additional registration for the group exercise is required
**Linear Algebra | 8 ECTS**

**Recommended Previous Knowledge:**
None

**Theoretical Knowledge**
- Students can name the basic concepts in linear algebra. They are able to explain them using appropriate examples
- Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples
- They know proof strategies and can reproduce them

**Capabilities**
- Students can model problems in linear algebra with the help of the concepts studied in this course. Moreover, they are capable of solving them by applying established methods
- Students are able to discover and verify further logical connections between the concepts studied in the course
- For a given problem, the students can develop and execute a suitable approach, and are able to critically evaluate the results

**Mechanics I (GES) | 6 ECTS**

**Recommended Previous Knowledge:**
None

**Theoretical Knowledge**
The primary purpose of the study of Statics is to develop the capacity to predict the effects of forces on rigid bodies, structural elements and simple structures, which are at rest (in equilibrium). Such a capacity is critical to the design of many structural or engineering systems. The particular objectives of this course are to:
- Introduce the student to the basic principles required to analyse the effects of forces applied to rigid bodies, structural elements and simple structures in equilibrium
- Demonstrate sound techniques of constructing and solving idealised mathematical models of real engineering systems
- Promote the analytical and problem-solving skills required to solve a wide variety of real engineering problems effectively

**Capabilities**
At the end of this course the student is able to:
- Apply the properties of two- and three-dimensional force systems to the analysis of structural elements and simple structures in equilibrium
- Isolate a body in equilibrium by drawing its free-body diagram on which all forces acting on the body are represented
- Analyse the external effects of forces acting on a single body or a system of bodies in two- and three-dimensional equilibrium using the free-body diagram of the body or system
- Analyse the internal forces in trusses and beams
- Solve problems of equilibrium with account for dry friction
- Determine mass centres and centroids of lines, areas and volumes

* Number of participants may be limited
** Additional registration for the group exercise is required
**Physics for Engineers (GES) | 4 ECTS**

**Recommended Previous Knowledge:**
- Calculus and linear algebra on high school level
- Physics on high school level

**Theoretical Knowledge**
Students can explain fundamental topics and laws of physics such as in the areas of mechanics, oscillations, waves, and optics. Students can relate physics topics to technical problems.

**Capabilities**
Students can describe physical problems mathematically and solve such problems within the framework of their acquired mathematical expertise.

* Number of participants may be limited
** Additional registration for the group exercise is required
**Mechanics III (GES) | 6 ECTS**

**Recommended Previous Knowledge:**
None

**Theoretical Knowledge**
The primary purpose of the study of Mechanics III (Fluid Statics, Kinematics and Kinetics) is to develop the capacity to predict the effects of forces and motions, necessary for the analysis and design of moving machine parts, different machinery, vehicles, aircraft, spacecraft, automatic control systems, etc. The particular objectives of this course are to:

- Determine the hydrostatic forces acting on different objects
- Analyse stability of floating bodies
- Analyse the kinematics and kinetics of a particle in different reference systems
- Analyse the motion of the system of particles and forces acting on it
- Analyse the plane motion of a rigid body (simple mechanism) and forces acting on it.
- Analyse the three-dimensional motion of a rigid body and forces acting on it

**Capabilities**
At the end of this course the student should be able to:

- Solve the equilibrium problems with account for hydrostatic pressure forces
- Analyse stability of simple floating bodies
- Calculate the velocity and acceleration of a particle in different reference systems
- Derive and solve the equation of motion of a particle in different reference systems
- Analyse the motion of the system of particles and forces acting on it with the aid of work-energy and impulse-momentum relationships
- Calculate the instantaneous linear and angular velocities and accelerations of the planar mechanisms
- Derive and solve the equations of a plane motion of a rigid body and find forces acting on it
- Apply work-energy and impulse-momentum relationships to analyse plane kinetics of a rigid body
- Calculate the instantaneous linear and angular velocities and accelerations of the three-dimensional motion of a rigid body
- Derive the equations of a motion of a three-dimensional motion of a rigid body.
- Apply in three-dimensional kinematics and kinetics of rigid body both methods of vector algebra and matrix methods

**Computernetworks and Internet Security | 6 ECTS**

**Recommended Previous Knowledge:**
Basics of Computer Science.

**Theoretical Knowledge**
Students are able to explain important and common Internet protocols in detail and classify them, in order to be able to analyse and develop networked systems in further studies and job.

**Capabilities**
Students are able to analyse common Internet protocols and evaluate the use of them in different domains.

* Number of participants may be limited
** Additional registration for the group exercise is required
**Functional Programming | 6 ECTS**

**Recommended Previous Knowledge:**
Discrete mathematics at high-school level.

**Theoretical Knowledge**
Students apply the principles, constructs, and simple design techniques of functional programming. They demonstrate their ability to read Haskell programs and to explain Haskell syntax as well as Haskell's read-eval-print loop. They interpret warnings and find errors in programs. They apply the fundamental data structures, data types, and type constructors. They employ strategies for unit tests of functions and simple proof techniques for partial and total correctness. They distinguish laziness from other evaluation strategies.

**Capabilities**
Students break a natural-language description down in parts amenable to a formal specification and develop a functional program in a structured way. They assess different language constructs, make conscious selections both at specification and implementations level, and justify their choice. They analyze given programs and rewrite them in a controlled way. They design and implement unit tests and can assess the quality of their tests. They argue for the correctness of their program.

* Number of participants may be limited
** Additional registration for the group exercise is required
Study package 1b – General Engineering Science – SuSe

**Fundamentals of Mechanical Engineering Design (GES)** | 6 ECTS

**Recommended Previous Knowledge:**
- Basic knowledge about mechanics and production engineering
- Internship (Stage I Practical)

**Theoretical Knowledge**
After passing the module, students are able to:
- explain basic working principles and functions of machine elements
- explain requirements, selection criteria, application scenarios and practical examples of basic machine elements, indicate the background of dimensioning calculations

**Capabilities**
After passing the module, students are able to:
- accomplish dimensioning calculations of covered machine elements
- transfer knowledge learned in the module to new requirements and tasks (problem solving skills)
- recognize the content of technical drawings and schematic sketches
- technically evaluate basic designs

**Electrical Engineering II** | 6 ECTS

**Recommended Previous Knowledge:**
Content of the Lecture "Electrical Engineering I (Elektrotechnik I)"

**Theoretical Knowledge**
The students know the basic theory, relations and methods of time dependent network theory and basic nonlinear circuit elements. This includes, in particular:
- transients
- the use of complex numbers and phasors
- the concept of impedance
- steady state sinusoidal circuit analysis
- complex power and 3-phase systems
- transformers
- transfer function and filters
- the concept of resonance
- diodes and rectifiers
- bipolar transistors and operational amplifiers

**Capabilities**
The students are able to establish relations between time dependent currents and voltages in linear networks. The students know how to apply network theory to analyze 3-phase systems, transformers, filter-like structures, and resonating networks. The students know to include basic nonlinear circuit elements, such as diodes, bipolar transistors, and operational amplifiers, into the network analysis.

* Number of participants may be limited
** Additional registration for the group exercise is required
**Mathematical Analysis | 8 ECTS**

**Recommended Previous Knowledge:**
None

**Theoretical Knowledge**
- Students can name the basic concepts in analysis. They are able to explain them using appropriate examples
- Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples
- They know proof strategies and can reproduce them

**Capabilities**
- Students can model problems in analysis with the help of the concepts studied in this course. Moreover, they are capable of solving them by applying established methods
- Students are able to discover and verify further logical connections between the concepts studied in the course
- For a given problem, the students can develop and execute a suitable approach, and are able to critically evaluate the results

**Mechanics II (GES) | 6 ECTS**

**Recommended Previous Knowledge:**
None

**Theoretical Knowledge**
The primary purpose of the study of Mechanics of Materials/Solids is to develop the capacity to predict the effects of forces on elastic bodies, structural elements and simple structures, which are at rest (in equilibrium). Such a capacity is critical to the design of many structural or engineering systems. The particular objectives of this course are to:
- Introduce the student to the basic principles required to analyse the effects of forces applied to elastic bodies, structural elements and simple structures in equilibrium
- Demonstrate sound techniques of constructing and solving idealised mathematical models of real engineering systems
- Promote the analytical and problem-solving skills required to solve a wide variety of real engineering problems effectively

**Capabilities**
At the end of this course the student should be able to:
- Determine average normal and shear stresses
- Determine shear stresses and the angle of twist due to torsion of a circular shaft
- Determine thermal stresses in rods
- Analyse statically indeterminate rods and shafts
- Determine area moments of inertia as well as principal axes and moments of inertia
- Determine normal and shear stresses as well as deflections due to bending
- Analyse plane state of stress (stress transformation)
- Analyse stability of equilibrium of simple systems and buckling of elastic columns
- Determine displacements and solve statically indeterminate problems with the aid of energy (Castigliano's) method

---

* Number of participants may be limited
** Additional registration for the group exercise is required
**Fundamentals of Production and Quality Management** | 6 ECTS

**Recommended Previous Knowledge:**
None

**Theoretical Knowledge**
Students are able to explain the contents of the lecture of the module.

**Capabilities**
Students are able to apply the methods and models in the module to industrial problems.

* Number of participants may be limited
** Additional registration for the group exercise is required
Study package alternatives for 1b – General Engineering Science
– SuSe

**Automata Theory and Formal Languages | 6 ECTS**

**Recommended Previous Knowledge:**
Participating students should be able to
- specify algorithms for simple data structures (such as, e.g., arrays) to solve computational problems
- apply propositional logic and predicate logic for specifying and understanding mathematical proofs
- apply the knowledge and skills taught in the module Discrete Algebraic Structures

**Theoretical Knowledge**
Students can explain syntax, semantics, and decision problems of propositional logic, and they are able to give algorithms for solving decision problems. Students can show correspondences to Boolean algebra. Students can describe which application problems are hard to represent with propositional logic, and therefore, the students can motivate predicate logic, and define syntax, semantics, and decision problems for this representation formalism. Students can explain unification and resolution for solving the predicate logic SAT decision problem. Students can also describe syntax, semantics, and decision problems for various kinds of temporal logic, and identify their application areas. The participants of the course can define various kinds of finite automata and can identify relationships to logic and formal grammars. The spectrum that students can explain ranges from deterministic and nondeterministic finite automata and pushdown automata to Turing machines. Students can name those formalism for which nondeterminism is more expressive than determinism. They are also able to demonstrate which decision problems require which expressivity, and, in addition, students can transform decision problems w.r.t. one formalism into decision problems w.r.t. other formalisms. They understand that some formalisms easily induce algorithms whereas others are best suited for specifying systems and their properties. Students can describe the relationships between formalisms such as logic, automata, or grammars.

**Capabilities**
Students can apply propositional logic as well as predicate logic resolution to a given set of formulas. Students analyze application problems in order to derive propositional logic, predicate logic, or temporal logic formulas to represent them. They can evaluate which formalism is best suited for a particular application problem, and they can demonstrate the application of algorithms for decision problems to specific formulas. Students can also transform nondeterministic automata into deterministic ones, or derive grammars from automata and vice versa. They can show how parsers work, and they can apply algorithms for the language emptiness problem in case of infinite words.

* Number of participants may be limited
** Additional registration for the group exercise is required
**Embedded Systems | 6 ECTS**

**Recommended Previous Knowledge:**
Computer Engineering

**Theoretical Knowledge**
Embedded systems can be defined as information processing systems embedded into enclosing products. This course teaches the foundations of such systems. In particular, it deals with an introduction into these systems (notions, common characteristics) and their specification languages (models of computation, hierarchical automata, specification of distributed systems, task graphs, specification of real-time applications, translations between different models). Another part covers the hardware of embedded systems: Sensors, A/D and D/A converters, real-time capable communication hardware, embedded processors, memories, energy dissipation, reconfigurable logic and actuators. The course also features an introduction into real-time operating systems, middleware and real-time scheduling. Finally, the implementation of embedded systems using hardware/software co-design (hardware/software partitioning, high-level transformations of specifications, energy-efficient realizations, compilers for embedded processors) is covered.

**Capabilities**
After having attended the course, students shall be able to realize simple embedded systems. The students shall realize which relevant parts of technological competences to use in order to obtain a functional embedded systems. In particular, they shall be able to compare different models of computations and feasible techniques for system-level design. They shall be able to judge in which areas of embedded system design specific risks exist.

**Software Engineering | 6 ECTS**

**Recommended Previous Knowledge:**
- Automata theory and formal languages
- Procedural programming or Functional programming
- Object-oriented programming, algorithms, and data structures

**Theoretical Knowledge**
Students explain the phases of the software life cycle, describe the fundamental terminology and concepts of software engineering, and paraphrase the principles of structured software development. They give examples of software-engineering tasks of existing large-scale systems. They write test cases for different test strategies and devise specifications or models using different notations, and critique both. They explain simple design patterns and the major activities in requirements analysis, maintenance, and project planning.

**Capabilities**
For a given task in the software life cycle, students identify the corresponding phase and select an appropriate method. They choose the proper approach for quality assurance. They design tests for realistic systems, assess the quality of the tests, and find errors at different levels. They apply and modify non-executable artifacts. They integrate components based on interface specifications.

* Number of participants may be limited
** Additional registration for the group exercise is required
**Electromagnetics for Engineers I: Time-Independent Fields | 6 ECTS**

**Recommended Previous Knowledge:**
Basic principles of electrical engineering and advanced mathematics.

**Theoretical Knowledge**
Students can explain the fundamental formulas, relations, and methods of the theory of time-independent electromagnetic fields. They can explicate the principal behavior of electrostatic, magnetostatic, and current density fields with regard to respective sources. They can describe the properties of complex electromagnetic fields by means of superposition of solutions for simple fields. The students are aware of applications for the theory of time-independent electromagnetic fields and are able to explicate these.

**Capabilities**
Students can apply Maxwell’s Equations in integral notation in order to solve highly symmetrical, time-independent, electromagnetic field problems. Furthermore, they are capable of applying a variety of methods that require solving Maxwell’s Equations for more general problems. The students can assess the principal effects of given time-independent sources of fields and analyze these quantitatively. They can deduce meaningful quantities for the characterization of electrostatic, magnetostatic, and electrical flow fields (capacitances, inductances, resistances, etc.) from given fields and dimension them for practical applications.

* Number of participants may be limited

** Additional registration for the group exercise is required
Module descriptions for Master Courses

Study package 1a – Product Development, Materials and Production – WiSe

Environmental Protection and Management | 6 ECTS

Recommended Previous Knowledge:
- Good knowledge in Technologies for Environmental Protection (end-of-pipe, integrated solutions)
- Good knowledge of the relevant Environmental Legislation
- Basic knowledge of instruments for Environmental Assessment

Theoretical Knowledge
The students are able to describe the basics of regulations, economic instruments, voluntary initiatives, fundamentals of HSE legislation ISO 14001, EMAS and Responsible Care ISO 14001 requirements. They can analyse and discuss industrial processes, substance cycles and approaches from end-of-pipe technology to eco-efficiency and eco-effectiveness, showing their sound knowledge of complex industry related problems. They are able to judge environmental issues and to widely consider, apply or carry out innovative technical solutions, remediation measures and further interventions as well as conceptual problem solving approaches in the full range of problems in different industrial sectors.

Capabilities
Students are able to assess current problems and situations in the field of environmental protection. They can consider the best available techniques and to plan and suggest concrete actions in a company- or branch-specific context. By this means they can solve problems on a technical, administrative and legislative level.

Vibration Theory | 6 ECTS

Recommended Previous Knowledge:
- Calculus
- Linear Algebra
- Engineering Mechanics

Theoretical Knowledge
Students are able to denote terms and concepts of Vibration Theory and develop them further.

Capabilities
Students are able to denote methods of Vibration Theory and develop them further.

* Number of participants may be limited
** Additional registration for the group exercise is required
Technical Acoustics II (Room Acoustics, Computational Methods) | 6 ECTS

**Recommended Previous Knowledge:**
- Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics)
- Mechanics I (Statics, Mechanics of Materials) and Mechanics II (Hydrostatics, Kinematics, Dynamics)
- Mathematics I, II, III (in particular differential equations)

**Theoretical Knowledge**
The students possess an in-depth knowledge in acoustics regarding room acoustics and computational methods and are able to give an overview of the corresponding theoretical and methodical basis.

**Capabilities**
The students are capable to handle engineering problems in acoustics by theory-based application of the demanding computational methods and procedures treated within the module.

Robotics | 6 ECTS

**Recommended Previous Knowledge:**
- Fundamentals of electrical engineering
- Broad knowledge of mechanics
- Fundamentals of control theory

**Theoretical Knowledge**
Students are able to describe fundamental properties of robots and solution approaches for multiple problems in robotics.

**Capabilities**
- Students are able to derive and solve equations of motion for various manipulators
- Students can generate trajectories in various coordinate systems
- Students can design linear and partially nonlinear controllers for robotic manipulators

Finite Elements Methods | 6 ECTS

**Recommended Previous Knowledge:**
- Mechanics I (Statics, Mechanics of Materials)
- Mechanics II (Hydrostatics, Kinematics, Dynamics)
- Mathematics I, II, III (in particular differential equations)

**Theoretical Knowledge**
The students possess an in-depth knowledge regarding the derivation of the finite element method and are able to give an overview of the theoretical and methodical basis of the method.

**Capabilities**
The students are capable to handle engineering problems by formulating suitable finite elements, assembling the corresponding system matrices, and solving the resulting system of equations.

* Number of participants may be limited
** Additional registration for the group exercise is required
Study package 1b – Product Development, Materials and Production – SuSe

*Selected Topics of Product Development, Materials Science and Production: Reliability in Engineering Dynamics | 4 ECTS

Recommended Previous Knowledge:
None

Theoretical Knowledge
- Students are able to express their extended knowledge and discuss the connection of different special fields or application areas of product development, materials and production
- Students are qualified to connect different special fields with each other

Capabilities
- Students can apply specialized solution strategies and new scientific methods in selected areas
- Students are able to transfer learned skills to new and unknown problems and can develop own solution approaches

Fibre-Polymer-Composites | 6 ECTS

Recommended Previous Knowledge:
Basics: chemistry / physics / materials science

Theoretical 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).

Capabilities
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

* Number of participants may be limited
** Additional registration for the group exercise is required
Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics)  | 6 ECTS

**Recommended Previous Knowledge:**
- Mechanics I (Statics, Mechanics of Materials)
- Mechanics II (Hydrostatics, Kinematics, Dynamics)
- Mathematics I, II, III (in particular differential equations)

**Theoretical Knowledge**
The students possess an in-depth knowledge in acoustics regarding acoustic waves, noise protection, and psycho acoustics and are able to give an overview of the corresponding theoretical and methodical basis.

**Capabilities**
The students are capable to handle engineering problems in acoustics by theory-based application of the demanding methodologies and measurement procedures treated within the module.

Mechanical Properties  | 6 ECTS

**Recommended Previous Knowledge:**
Basics of materials science I/II

**Theoretical Knowledge**
The students are able to explain fundamental concepts of the crystallography, statics (free-body diagram, tractions) and basics of thermodynamics (energy minimization, energy barriers, entropy).

**Capabilities**
The students are able to perform standardized calculation methods: tensor calculations, derivatives, integrals, tensor transformations.

High-Order FEM  | 6 ECTS

**Recommended Previous Knowledge:**
Knowledge of partial differential equations is recommended.

**Theoretical 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

**Capabilities**
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

* Number of participants may be limited
** Additional registration for the group exercise is required
**Business & Management: Problem-based Learning: Internationalization Strategies | 2 ECTS**

**Recommended Previous Knowledge:**

None

**Theoretical 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

**Capabilities**

- 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

* Number of participants may be limited

** Additional registration for the group exercise is required
**Study package 2a – Biomedical Engineering – WiSe**

*Selected Topics of Biomedical Engineering: Lecture: Nature’s Hierarchical Materials | 3 ECTS*

**Recommended Previous Knowledge:**
None

**Theoretical Knowledge**
None

**Capabilities**
None

**BIO II: Biomaterials | 3 ECTS**

**Recommended Previous Knowledge:**
Basic knowledge of orthopedic and surgical techniques is recommended.

**Theoretical Knowledge**
The students can describe the materials of the human body and the materials being used in medical engineering, and their fields of use.

**Capabilities**
The students can explain the advantages and disadvantages of different kinds of biomaterials.

**Advanced Functional Materials | 6 ECTS**

**Recommended Previous Knowledge:**
Basic knowledge in Materials Science, e.g. Materials Science I/II

**Theoretical 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.

**Capabilities**
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.
Vibration Theory | 6 ECTS

Recommended Previous Knowledge:
- Calculus
- Linear Algebra
- Engineering Mechanics

Theoretical Knowledge
Students are able to denote terms and concepts of Vibration Theory and develop them further.

Capabilities
Students are able to denote methods of Vibration Theory and develop them further.

Control Systems Theory and Design | 6 ECTS

Recommended Previous Knowledge:
Introduction to Control Systems

Theoretical Knowledge
- Students can explain how linear dynamic systems are represented as state space models; they can interpret the system response to initial states or external excitation as trajectories in state space
- They can explain the system properties controllability and observability, and their relationship to state feedback and state estimation, respectively
- They can explain the significance of a minimal realisation
- They can explain observer-based state feedback and how it can be used to achieve tracking and disturbance rejection
- They can extend all of the above to multi-input multi-output systems
- They can explain the z-transform and its relationship with the Laplace Transform
- They can explain state space models and transfer function models of discrete-time systems
- They can explain the experimental identification of ARX models of dynamic systems, and how the identification problem can be solved by solving a normal equation
- They can explain how a state space model can be constructed from a discrete-time impulse response

Capabilities
- Students can transform transfer function models into state space models and vice versa
- They can assess controllability and observability and construct minimal realisations
- They can design LQG controllers for multivariable plants
- They can carry out a controller design both in continuous-time and discrete-time domain, and decide which is appropriate for a given sampling rate
- They can identify transfer function models and state space models of dynamic systems from experimental data
- They can carry out all these tasks using standard software tools (Matlab Control Toolbox, System Identification Toolbox, Simulink)

* Number of participants may be limited
** Additional registration for the group exercise is required
Finite Elements Methods | 6 ECTS

**Recommended Previous Knowledge:**
- Mechanics I (Statics, Mechanics of Materials)
- Mechanics II (Hydrostatics, Kinematics, Dynamics)
- Mathematics I, II, III (in particular differential equations)

**Theoretical Knowledge**
The students possess an in-depth knowledge regarding the derivation of the finite element method and are able to give an overview of the theoretical and methodical basis of the method.

**Capabilities**
The students are capable to handle engineering problems by formulating suitable finite elements, assembling the corresponding system matrices, and solving the resulting system of equations.

* Number of participants may be limited
** Additional registration for the group exercise is required
Study package 2b – Biomedical Engineering – SuSe

*Selected Topics of Biomedical Engineering: Lecture: Experimental Methods for the Characterization of Materials | 3 ECTS

Recommended Previous Knowledge:
None

Theoretical Knowledge
None

Capabilities
None

*Bioelectromagnetics: Principles and Applications | 6 ECTS

Recommended Previous Knowledge:
Basic principles of physics

Theoretical Knowledge
Students can explain the basic principles, relationships, and methods of bioelectromagnetics, i.e. the quantification and application of electromagnetic fields in biological tissue. They can define and exemplify the most important physical phenomena and order them corresponding to wavelength and frequency of the fields. They can give an overview over measurement and numerical techniques for characterization of electromagnetic fields in practical applications. They can give examples for therapeutic and diagnostic utilization of electromagnetic fields in medical technology.

Capabilities
Students know how to apply various methods to characterize the behavior of electromagnetic fields in biological tissue. In order to do this they can relate to and make use of the elementary solutions of Maxwell’s Equations. They are able to assess the most important effects that these models predict for biological tissue, they can order the effects corresponding to wavelength and frequency, respectively, and they can analyze them in a quantitative way. They are able to develop validation strategies for their predictions. They are able to evaluate the effects of electromagnetic fields for therapeutic and diagnostic applications and make an appropriate choice.

* Number of participants may be limited
** Additional registration for the group exercise is required

Study packages | School of Mechanical Engineering
Linear and Nonlinear System Identification | 3 ECTS

**Recommended Previous Knowledge:**
- Classical control (frequency response, root locus)
- State space methods
- Discrete-time systems
- Linear algebra, singular value decomposition
- Basic knowledge about stochastic processes

**Theoretical Knowledge**
- Students can explain the general framework of the prediction error method and its application to a variety of linear and nonlinear model structures
- They can explain how multilayer perceptron networks are used to model nonlinear dynamics
- They can explain how an approximate predictive control scheme can be based on neural network models
- They can explain the idea of subspace identification and its relation to Kalman realization theory

**Capabilities**
- Students are capable of applying the prediction error method to the experimental identification of linear and nonlinear models for dynamic systems
- They are capable of implementing a nonlinear predictive control scheme based on a neural network model
- They are capable of applying subspace algorithms to the experimental identification of linear models for dynamic systems
- They can do the above using standard software tools (including the Matlab System Identification Toolbox)

Nonlinear Dynamics | 6 ECTS

**Recommended Previous Knowledge:**
- Calculus
- Linear Algebra
- Engineering Mechanics

**Theoretical Knowledge**
Students are able to reflect existing terms and concepts in Nonlinear Dynamics and to develop and research new terms and concepts.

**Capabilities**
Students are able to apply existing methods and procedures of Nonlinear Dynamics and to develop novel methods and procedures.

* Number of participants may be limited
** Additional registration for the group exercise is required
Optimal and Robust Control | 6 ECTS

Recommended Previous Knowledge:
- Classical control (frequency response, root locus)
- State space methods
- Linear algebra, singular value decomposition

Theoretical Knowledge
- Students can explain the significance of the matrix Riccati equation for the solution of LQ problems
- They can explain the duality between optimal state feedback and optimal state estimation
- They can explain how the H2 and H-infinity norms are used to represent stability and performance constraints
- They can explain how an LQG design problem can be formulated as special case of an H2 design problem
- They can explain how model uncertainty can be represented in a way that lends itself to robust controller design
- They can explain how - based on the small gain theorem - a robust controller can guarantee stability and performance for an uncertain plant
- They understand how analysis and synthesis conditions on feedback loops can be represented as linear matrix inequalities

Capabilities
- Students are capable of designing and tuning LQG controllers for multivariable plant models
- They are capable of representing a H2 or H-infinity design problem in the form of a generalized plant, and of using standard software tools for solving it
- They are capable of translating time and frequency domain specifications for control loops into constraints on closed-loop sensitivity functions, and of carrying out a mixed-sensitivity design
- They are capable of constructing an LFT uncertainty model for an uncertain system, and of designing a mixed-objective robust controller
- They are capable of formulating analysis and synthesis conditions as linear matrix inequalities (LMI), and of using standard LMI-solvers for solving them
- They can carry out all of the above using standard software tools (Matlab robust control toolbox)

* Number of participants may be limited
** Additional registration for the group exercise is required
Study package 3a – Materials Science – WiSe

BIO II: Biomaterials | 3 ECTS

**Recommended Previous Knowledge:**
Basic knowledge of orthopedic and surgical techniques is recommended.

**Theoretical Knowledge**
The students can describe the materials of the human body and the materials being used in medical engineering, and their fields of use.

**Capabilities**
The students can explain the advantages and disadvantages of different kinds of biomaterials.

Microsystems Technology | 4 ECTS

**Recommended Previous Knowledge:**
Basics in physics, chemistry and semiconductor technology.

**Theoretical 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
- explain in details operation principles of microsensors and microactuators and
- discuss the potential and limitation of microsystems in application.

**Capabilities**
Students are capable to
- analyze the feasibility of microsystems,
- develop process flows for the fabrication of microstructures and
- apply them

Advanced Functional Materials | 6 ECTS

**Recommended Previous Knowledge:**
Basic knowledge in Materials Science, e.g. Materials Science I/II

**Theoretical 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.

**Capabilities**
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.

* Number of participants may be limited
** Additional registration for the group exercise is required
Optoelectronics II: Quantum Optics | 4 ECTS

**Recommended Previous Knowledge:**
Basic principles of electrodynamics, optics and quantum mechanics.

**Theoretical Knowledge**
Students can explain the fundamental mathematical and physical relations of quantum optical phenomena such as absorption, stimulated and spontaneous emission. They can describe material properties as well as technical solutions. They can give an overview on quantum optical components in technical applications.

**Capabilities**
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.

Nonlinear Structural Analysis | 6 ECTS

**Recommended Previous Knowledge:**
Knowledge of partial differential equations is recommended.

**Theoretical 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
- specify problems of nonlinear structural analysis, to identify them in a given situation and to explain their mathematical and mechanical background

**Capabilities**
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
- transfer their knowledge of nonlinear solution procedures to new problems

*German as a Foreign Language | 4 ECTS

**Recommended Previous Knowledge:**
Check: https://intranet.tuhh.de/kvvz/vorlesung.php?Lang=en&mid=524&kvvz=1

**Theoretical Knowledge**
None

**Capabilities**
None

* Number of participants may be limited
** Additional registration for the group exercise is required
Business & Management: Lecture: Project Management | 2 ECTS

Recommended Previous Knowledge:
None

Theoretical 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

Capabilities
- 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

*Business & Management: Lecture: Marketing | 2 ECTS

Recommended Previous Knowledge:
None

Theoretical 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

Capabilities
- 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

* Number of participants may be limited
** Additional registration for the group exercise is required
Study package 3b – Materials Science – SuSe

Fibre-Polymer-Composites | 6 ECTS

**Recommended Previous Knowledge:**
Basics: chemistry / physics / materials science

**Theoretical 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).

**Capabilities**
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

Optoelectronics I: Wave Optics | 4 ECTS

**Recommended Previous Knowledge:**
Basics in electrodynamics, calculus

**Theoretical 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.

**Capabilities**
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.

* Number of participants may be limited
** Additional registration for the group exercise is required
High-Order FEM | 6 ECTS

Recommended Previous Knowledge:
Knowledge of partial differential equations is recommended.

Theoretical 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

Capabilities
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

Methods in Theoretical Materials Science | 6 ECTS

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.

Theoretical 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.

Capabilities
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..

* Number of participants may be limited
** Additional registration for the group exercise is required
Quantum Mechanics of Solids | 6 ECTS

**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.

**Theoretical 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.

**Capabilities**
After attending this lecture the students can perform materials design on a quantum mechanical basis.

*BEST: Problem-based Learning: Internationalization Strategies | 2 ECTS

**Recommended Previous Knowledge:**
None

**Theoretical 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

**Capabilities**
- 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

* Number of participants may be limited
** Additional registration for the group exercise is required
Study package 4a – Energy Systems – WiSe

**Finite Elements Methods** | 6 ECTS

**Recommended Previous Knowledge:**
- Mechanics I (Statics, Mechanics of Materials)
- Mechanics II (Hydrostatics, Kinematics, Dynamics)
- Mathematics I, II, III (in particular differential equations)

**Theoretical Knowledge**
The students possess an in-depth knowledge regarding the derivation of the finite element method and are able to give an overview of the theoretical and methodical basis of the method.

**Capabilities**
The students are capable to handle engineering problems by formulating suitable finite elements, assembling the corresponding system matrices, and solving the resulting system of equations.

**Vibration Theory** | 6 ECTS

**Recommended Previous Knowledge:**
- Calculus
- Linear Algebra
- Engineering Mechanics

**Theoretical Knowledge**
Students are able to denote terms and concepts of Vibration Theory and develop them further.

**Capabilities**
Students are able to denote methods of Vibration Theory and develop them further.

* Number of participants may be limited
** Additional registration for the group exercise is required
Control Systems Theory and Design | 6 ECTS

**Recommended Previous Knowledge:**
Introduction to Control Systems

**Theoretical Knowledge**
- Students can explain how linear dynamic systems are represented as state space models; they can interpret the system response to initial states or external excitation as trajectories in state space
- They can explain the system properties controllability and observability, and their relationship to state feedback and state estimation, respectively
- They can explain the significance of a minimal realisation
- They can explain observer-based state feedback and how it can be used to achieve tracking and disturbance rejection
- They can extend all of the above to multi-input multi-output systems
- They can explain the z-transform and its relationship with the Laplace Transform
- They can explain state space models and transfer function models of discrete-time systems
- They can explain the experimental identification of ARX models of dynamic systems, and how the identification problem can be solved by solving a normal equation
- They can explain how a state space model can be constructed from a discrete-time impulse response

**Capabilities**
- Students can transform transfer function models into state space models and vice versa
- They can assess controllability and observability and construct minimal realisations
- They can design LQG controllers for multivariable plants
- They can carry out a controller design both in continuous-time and discrete-time domain, and decide which is appropriate for a given sampling rate
- They can identify transfer function models and state space models of dynamic systems from experimental data
- They can carry out all these tasks using standard software tools (Matlab Control Toolbox, System Identification Toolbox, Simulink)

Innovative CFD Approaches | 6 ECTS

**Recommended Previous Knowledge:**
Attendance of a computational fluid dynamics course (CFD1/CFD2). Competent knowledge of numerical analysis in addition to general and computational thermo/fluid dynamics

**Theoretical Knowledge**
Student can explain the theoretical background of different CFD strategies (e.g. Lattice-Boltzmann, Smoothed Particle-Hydrodynamics, Finite-Volume methods) and describe the fundamentals of simulation-based optimization.

**Capabilities**
Student is able to identify an appropriate CFD-based solution strategy on a justified basis.

* Number of participants may be limited
** Additional registration for the group exercise is required

Study packages | School of Mechanical Engineering
*German as a Foreign Language | 4 ECTS

**Recommended Previous Knowledge:**
Check: https://intranet.tuhh.de/kvvz/vorlesung.php?Lang=en&mid=524&kvvz=1

**Theoretical Knowledge**
None

**Capabilities**
None

**Business & Management: Lecture: Project Management | 2 ECTS**

**Recommended Previous Knowledge:**
None

**Theoretical 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

**Capabilities**
- 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

* Number of participants may be limited
** Additional registration for the group exercise is required
Study package 4b – Energy Systems – SuSe

**Boundary Element Methods** | 6 ECTS

**Recommended Previous Knowledge:**
- Mechanics I (Statics, Mechanics of Materials)
- Mechanics II (Hydrostatics, Kinematics, Dynamics)
- Mathematics I, II, III (in particular differential equations)

**Theoretical Knowledge**
The students possess an in-depth knowledge regarding the derivation of the boundary element method and are able to give an overview of the theoretical and methodical basis of the method.

**Capabilities**
The students are capable to handle engineering problems by formulating suitable boundary elements, assembling the corresponding system matrices, and solving the resulting system of equations.

**Fibre-Polymer-Composites** | 6 ECTS

**Recommended Previous Knowledge:**
Basics: chemistry / physics / materials science

**Theoretical 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).

**Capabilities**
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

* Number of participants may be limited
** Additional registration for the group exercise is required
Numerical Treatment of Ordinary Differential Equations | 6 ECTS

**Recommended Previous Knowledge:**
- Mathematics I, II, III for engineering students (German or English) or Analysis & Linear Algebra I + II as well as Analysis III for technomathematicians
- Basic MATLAB knowledge

**Theoretical Knowledge**
Students are able to
- list numerical methods for the solution of ordinary differential equations and explain their core ideas
- repeat convergence statements for the treated numerical methods (including the prerequisites tied to the underlying problem)
- explain aspects regarding the practical execution of a method
- select the appropriate numerical method for concrete problems, implement the numerical algorithms efficiently and interpret the numerical results

**Capabilities**
Students are able to
- implement (MATLAB), apply and compare numerical methods for the solution of ordinary differential equations
- to justify the convergence behavior of numerical methods with respect to the posed problem and selected algorithm
- for a given problem, develop a suitable solution approach, if necessary by the composition of several algorithms, to execute this approach and to critically evaluate the results

* Number of participants may be limited
** Additional registration for the group exercise is required

Study packages | School of Mechanical Engineering
**Optimal and Robust Control | 6 ECTS**

**Recommended Previous Knowledge:**
- Classical control (frequency response, root locus)
- State space methods
- Linear algebra, singular value decomposition

**Theoretical Knowledge**
- Students can explain the significance of the matrix Riccati equation for the solution of LQ problems
- They can explain the duality between optimal state feedback and optimal state estimation
- They can explain how the H2 and H-infinity norms are used to represent stability and performance constraints
- They can explain how an LQG design problem can be formulated as special case of an H2 design problem
- They can explain how model uncertainty can be represented in a way that lends itself to robust controller design
- They can explain how - based on the small gain theorem - a robust controller can guarantee stability and performance for an uncertain plant
- They understand how analysis and synthesis conditions on feedback loops can be represented as linear matrix inequalities

**Capabilities**
- Students are capable of designing and tuning LQG controllers for multivariable plant models
- They are capable of representing a H2 or H-infinity design problem in the form of a generalized plant, and of using standard software tools for solving it
- They are capable of translating time and frequency domain specifications for control loops into constraints on closed-loop sensitivity functions, and of carrying out a mixed-sensitivity design
- They are capable of constructing an LFT uncertainty model for an uncertain system, and of designing a mixed-objective robust controller
- They are capable of formulating analysis and synthesis conditions as linear matrix inequalities (LMI), and of using standard LMI-solvers for solving them
- They can carry out all of the above using standard software tools (Matlab robust control toolbox)

**Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics) | 6 ECTS**

**Recommended Previous Knowledge:**
- Mechanics I (Statics, Mechanics of Materials)
- Mechanics II (Hydrostatics, Kinematics, Dynamics)
- Mathematics I, II, III (in particular differential equations)

**Theoretical Knowledge**
The students possess an in-depth knowledge in acoustics regarding acoustic waves, noise protection, and psycho acoustics and are able to give an overview of the corresponding theoretical and methodical basis.

**Capabilities**
The students are capable to handle engineering problems in acoustics by theory-based application of the demanding methodologies and measurement procedures treated within the module.

---

* Number of participants may be limited
** Additional registration for the group exercise is required
Study package 5a – Aircraft Systems Engineering – WiSe

Advanced Topics in Control | 6 ECTS

Recommended Previous Knowledge:
H-infinity optimal control, mixed-sensitivity design, linear matrix inequalities.

Theoretical Knowledge
- Students can explain the advantages and shortcomings of the classical gain scheduling approach
- They can explain the representation of nonlinear systems in the form of quasi-LPV systems
- They can explain how stability and performance conditions for LPV systems can be formulated as LMI conditions
- They can explain how gridding techniques can be used to solve analysis and synthesis problems for LPV systems
- They are familiar with polytopic and LFT representations of LPV systems and some of the basic synthesis techniques associated with each of these model structures
- Students can explain how graph theoretic concepts are used to represent the communication topology of multiagent systems
- They can explain the convergence properties of first order consensus protocols
- They can explain analysis and synthesis conditions for formation control loops involving either LTI or LPV agent models
- Students can explain the state space representation of spatially invariant distributed systems that are discretized according to an actuator/sensor array
- They can explain (in outline) the extension of the bounded real lemma to such distributed systems and the associated synthesis conditions for distributed controllers

Capabilities
- Students are capable of constructing LPV models of nonlinear plants and carry out a mixed-sensitivity design of gain-scheduled controllers; they can do this using polytopic, LFT or general LPV models
- They are able to use standard software tools (Matlab robust control toolbox) for these tasks
- Students are able to design distributed formation controllers for groups of agents with either LTI or LPV dynamics, using Matlab tools provided
- Students are able to design distributed controllers for spatially interconnected systems, using the Matlab MD-toolbox

Technical Acoustics II (Room Acoustics, Computational Methods) | 6 ECTS

Recommended Previous Knowledge:
- Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics)
- Mechanics I (Statics, Mechanics of Materials) and Mechanics II (Hydrostatics, Kinematics, Dynamics)
- Mathematics I, II, III (in particular differential equations)

Theoretical Knowledge
The students possess an in-depth knowledge in acoustics regarding room acoustics and computational methods and are able to give an overview of the corresponding theoretical and methodical basis.

Capabilities
The students are capable to handle engineering problems in acoustics by theory-based application of the demanding computational methods and procedures treated within the module.

* Number of participants may be limited
** Additional registration for the group exercise is required

Study packages | School of Mechanical Engineering
Industrial Process Automation | 6 ECTS

**Recommended Previous Knowledge:**
- mathematics and optimization methods
- principles of automata
- principles of algorithms and data structures
- programming skills

**Theoretical Knowledge**
The students can evaluate and assess discrete event systems. They can evaluate properties of processes and explain methods for process analysis. The students can compare methods for process modelling and select an appropriate method for actual problems. They can discuss scheduling methods in the context of actual problems and give a detailed explanation of advantages and disadvantages of different programming methods. The students can relate process automation to methods from robotics and sensor systems as well as to recent topics like 'cyberphysical systems' and 'industry 4.0'.

**Capabilities**
The students are able to develop and model processes and evaluate them accordingly. This involves taking into account optimal scheduling, understanding algorithmic complexity, and implementation using PLCs.

Robotics | 6 ECTS

**Recommended Previous Knowledge:**
- Fundamentals of electrical engineering
- Broad knowledge of mechanics
- Fundamentals of control theory

**Theoretical Knowledge**
Students are able to describe fundamental properties of robots and solution approaches for multiple problems in robotics.

**Capabilities**
- Students are able to derive and solve equations of motion for various manipulators
- Students can generate trajectories in various coordinate systems
- Students can design linear and partially nonlinear controllers for robotic manipulators

*German as a Foreign Language | 4 ECTS

**Recommended Previous Knowledge:**
Check: https://intranet.tuhh.de/kvvz/vorlesung.php?Lang=en&mid=524&kvvz=1

**Theoretical Knowledge**
None

**Capabilities**
None

* Number of participants may be limited
** Additional registration for the group exercise is required

Study packages | School of Mechanical Engineering
**Business & Management: Lecture: Marketing** | 2 ECTS

**Recommended Previous Knowledge:**
None

**Theoretical 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

**Capabilities**
- 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
Study package 5b – Aircraft Systems Engineering – SuSe

**Fibre-Polymer-Composites | 6 ECTS**

**Recommended Previous Knowledge:**
Basics: chemistry / physics / materials science

**Theoretical 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).

**Capabilities**
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

**Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics) | 6 ECTS**

**Recommended Previous Knowledge:**
- Mechanics I (Statics, Mechanics of Materials)
- Mechanics II (Hydrostatics, Kinematics, Dynamics)
- Mathematics I, II, III (in particular differential equations)

**Theoretical Knowledge**
The students possess an in-depth knowledge in acoustics regarding acoustic waves, noise protection, and psycho acoustics and are able to give an overview of the corresponding theoretical and methodical basis.

**Capabilities**
The students are capable to handle engineering problems in acoustics by theory-based application of the demanding methodologies and measurement procedures treated within the module.

* Number of participants may be limited
** Additional registration for the group exercise is required
Optimal and Robust Control | 6 ECTS

Recommended Previous Knowledge:
- Classical control (frequency response, root locus)
- State space methods
- Linear algebra, singular value decomposition

Theoretical Knowledge
- Students can explain the significance of the matrix Riccati equation for the solution of LQ problems
- They can explain the duality between optimal state feedback and optimal state estimation
- They can explain how the H2 and H-infinity norms are used to represent stability and performance constraints
- They can explain how an LQG design problem can be formulated as special case of an H2 design problem
- They can explain how model uncertainty can be represented in a way that lends itself to robust controller design
- They can explain how - based on the small gain theorem - a robust controller can guarantee stability and performance for an uncertain plant
- They understand how analysis and synthesis conditions on feedback loops can be represented as linear matrix inequalities

Capabilities
- Students are capable of designing and tuning LQG controllers for multivariable plant models
- They are capable of representing a H2 or H-infinity design problem in the form of a generalized plant, and of using standard software tools for solving it
- They are capable of translating time and frequency domain specifications for control loops into constraints on closed-loop sensitivity functions, and of carrying out a mixed-sensitivity design
- They are capable of constructing an LFT uncertainty model for an uncertain system, and of designing a mixed-objective robust controller
- They are capable of formulating analysis and synthesis conditions as linear matrix inequalities (LMI), and of using standard LMI-solvers for solving them
- They can carry out all of the above using standard software tools (Matlab robust control toolbox)

* Number of participants may be limited
** Additional registration for the group exercise is required
**Embedded Systems** | 6 ECTS

**Recommended Previous Knowledge:**
Computer Engineering

**Theoretical Knowledge**
Embedded systems can be defined as information processing systems embedded into enclosing products. This course teaches the foundations of such systems. In particular, it deals with an introduction into these systems (notions, common characteristics) and their specification languages (models of computation, hierarchical automata, specification of distributed systems, task graphs, specification of real-time applications, translations between different models). Another part covers the hardware of embedded systems: Sensors, A/D and D/A converters, real-time capable communication hardware, embedded processors, memories, energy dissipation, reconfigurable logic and actuators. The course also features an introduction into real-time operating systems, middleware and real-time scheduling. Finally, the implementation of embedded systems using hardware/software co-design (hardware/software partitioning, high-level transformations of specifications, energy-efficient realizations, compilers for embedded processors) is covered.

**Capabilities**
After having attended the course, students shall be able to realize simple embedded systems. The students shall realize which relevant parts of technological competences to use in order to obtain a functional embedded systems. In particular, they shall be able to compare different models of computations and feasible techniques for system-level design. They shall be able to judge in which areas of embedded system design specific risks exist.

*German as a Foreign Language | 4 ECTS

**Recommended Previous Knowledge:**
Check: [https://intranet.tuhh.de/kvvz/vorlesung.php?Lang=en&mid=524&kvzz=1](https://intranet.tuhh.de/kvvz/vorlesung.php?Lang=en&mid=524&kvzz=1)

**Theoretical Knowledge**
None

**Capabilities**
None

**Business & Management: Problem-based Learning: Internationalization Strategies | 2 ECTS**

**Recommended Previous Knowledge:**
None

**Theoretical 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

**Capabilities**
- 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

* Number of participants may be limited
** Additional registration for the group exercise is required

Study packages | School of Mechanical Engineering
Study package 6a – Naval Architecture and Ocean Engineering – WiSe

Ship Vibration | 6 ECTS
Recommended Previous Knowledge:
- Mechanics I - III
- Structural Analysis of Ships I
- Fundamentals of Ship Structural Design

Theoretical Knowledge
Students can reproduce the acceptance criteria for vibrations on ships; they can explain the methods for the calculation of natural frequencies and forced vibrations of structural components and the entire hull girder; they understand the effect of exciting forces of the propeller and main engine and methods for their determination.

Capabilities
Students are capable to apply methods for the calculation of natural frequencies and exciting forces and resulting vibrations of ship structures including their assessment; they can model structures for the vibration analysis.

Structural Analysis of Ships and Offshore Structures | 6 ECTS
Recommended Previous Knowledge:
- Differential Equations 2 (Partial Differential Equations)

Theoretical Knowledge
Students are able to
- give an overview of the basics of structural mechanics for the analysis of ships and offshore structures
- explain structural models for thin-walled structures
- specify problems of linear structural analysis, to identify them in a given situation and to explain their mathematical and mechanical background
- classify finite elements with respect to their suitability for the structural analysis of ships and offshore structures

Capabilities
Students are able to
- model linear structural problems of ships and offshore structures
- select a suitable finite element formulation for a given linear problem of structural mechanics
- apply finite element procedures to the linear structural analysis of ships and offshore structures
- verify and critically judge the results of linear finite element computations
- transfer their knowledge of linear structural analysis with finite elements to new problems

* Number of participants may be limited
** Additional registration for the group exercise is required
Fatigue Strength of Ships and Offshore Structures | 6 ECTS

**Recommended Previous Knowledge:**
Structural analysis of ships and/or offshore structures and fundamental knowledge in mechanics and mechanics of materials.

**Theoretical Knowledge**
Students are able to
- describe fatigue loads and stresses, as well as
- describe structural behavior under cyclic loads.

**Capabilities**
Students are able to calculate life prediction based on the S-N approach as well as life prediction based on the crack propagation.

*Arctic Technology | 6 ECTS

**Recommended Previous Knowledge:**
None

**Theoretical Knowledge**
The challenges and requirements due to ice can be explained. Ice loads can be explained and ice strengthening can be understood.

**Capabilities**
The challenges and requirements due to ice can be assessed and the accuracy of these assessment can be evaluated. Calculation models to assess ice loads can be used and a structure can be designed accordingly.

Vibration Theory | 6 ECTS

**Recommended Previous Knowledge:**
- Calculus
- Linear Algebra
- Engineering Mechanics

**Theoretical Knowledge**
Students are able to denote terms and concepts of Vibration Theory and develop them further.

**Capabilities**
Students are able to denote methods of Vibration Theory and develop them further.
Study package 6b – Naval Architecture and Ocean Engineering – SuSe

Not enough courses with compatible schedules available for this specialization during summer term.
**Study package 7a – Theoretical Mech. Engineering – Numerics and Computer Science – WiSe**

**3D Computer Vision | 6 ECTS**

**Recommended Previous Knowledge:**
- Knowledge of the modules Digital Image Analysis and Pattern Recognition and Data Compression are used in the practical task
- Linear Algebra (including PCA, SVD), nonlinear optimization (Levenberg-Marquardt), basics of stochastics and basics of Matlab are required and cannot be explained in detail during the lecture.

**Theoretical Knowledge**
Students can explain and describe the field of projective geometry.

**Capabilities**
Students are capable of
- Implementing an exemplary 3D or volumetric analysis task
- Using highly sophisticated methods and procedures of the subject area
- Identifying problems and
- Developing and implementing creative solution suggestions

With assistance from the teacher students are able to link the contents of the three subject areas (modules)
- Digital Image Analysis
- Pattern Recognition and Data Compression
- 3D Computer Vision

in practical assignments.

**Digital Signal Processing and Digital Filters | 6 ECTS**

**Recommended Previous Knowledge:**
- Mathematics 1-3
- Signals and Systems
- Fundamentals of signal and system theory as well as random processes.
- Fundamentals of spectral transforms (Fourier series, Fourier transform, Laplace transform)

**Theoretical Knowledge**
The students know and understand basic algorithms of digital signal processing. They are familiar with the spectral transforms of discrete-time signals and are able to describe and analyse signals and systems in time and image domain. They know basic structures of digital filters and can identify and assess important properties including stability. They are aware of the effects caused by quantization of filter coefficients and signals. They are familiar with the basics of adaptive filters. They can perform traditional and parametric methods of spectrum estimation, also taking a limited observation window into account.

**Capabilities**
The students are able to apply methods of digital signal processing to new problems. They can choose and parameterize suitable filter structures. In particular, the can design adaptive filters according to the minimum mean squared error (MMSE) criterion and develop an efficient implementation, e.g. based on the LMS or RLS algorithm. Furthermore, the students are able to apply methods of spectrum estimation and to take the effects of a limited observation window into account.

* Number of participants may be limited
** Additional registration for the group exercise is required
Intelligent Autonomous Agents and Cognitive Robotics | 6 ECTS

**Recommended Previous Knowledge:**
Vectors, matrices, Calculus

**Theoretical Knowledge**
Students can explain the agent abstraction, define intelligence in terms of rational behavior, and give details about agent design (goals, utilities, environments). They can describe the main features of environments. The notion of adversarial agent cooperation can be discussed in terms of decision problems and algorithms for solving these problems. For dealing with uncertainty in real-world scenarios, students can summarize how Bayesian networks can be employed as a knowledge representation and reasoning formalism in static and dynamic settings. In addition, students can define decision making procedures in simple and sequential settings, with and with complete access to the state of the environment. In this context, students can describe techniques for solving (partially observable) Markov decision problems, and they can recall techniques for measuring the value of information. Students can identify techniques for simultaneous localization and mapping, and can explain planning techniques for achieving desired states. Students can explain coordination problems and decision making in a multi-agent setting in term of different types of equilibria, social choice functions, voting protocol, and mechanism design techniques.

**Capabilities**
Students can select an appropriate agent architecture for concrete agent application scenarios. For simplified agent application students can derive decision trees and apply basic optimization techniques. For those applications they can also create Bayesian networks/dynamic Bayesian networks and apply bayesian reasoning for simple queries. Students can also name and apply different sampling techniques for simplified agent scenarios. For simple and complex decision making students can compute the best action or policies for concrete settings. In multi-agent situations students will apply techniques for finding different equilibria states, e.g., Nash equilibria. For multi-agent decision making students will apply different voting protocols and compare and explain the results.

Mathematical Image Processing | 6 ECTS

**Recommended Previous Knowledge:**
- Analysis: partial derivatives, gradient, directional derivative
- Linear Algebra: eigenvalues, least squares solution of a linear system

**Theoretical Knowledge**
Students are able to
- characterize and compare diffusion equations
- explain elementary methods of image processing
- explain methods of image segmentation and registration
- sketch and interrelate basic concepts of functional analysis

**Capabilities**
Students are able to
- implement and apply elementary methods of image processing
- explain and apply modern methods of image processing

* Number of participants may be limited
** Additional registration for the group exercise is required
Soft Computing - Introduction to Machine Learning | 6 ECTS

**Recommended Previous Knowledge:**
- Bachelor in Computer Science.
- Basics in higher mathematics are inevitable, like calculus, linear algebra, graph theory, and optimization

**Theoretical Knowledge**
Students are able to formalize, compute, and analyze belief networks, alignments of sequences, hidden Markov models, phylogenetic tree models, neural networks, and fuzzy controllers. In particular, inference and learning in belief networks are important topics that the students should be able to master.

**Capabilities**
Students can apply the relevant algorithms and determine their complexity, and they can make use of the statistics language R.

* Number of participants may be limited
** Additional registration for the group exercise is required

**Boundary Element Methods | 6 ECTS**

**Recommended Previous Knowledge:**
- Mechanics I (Statics, Mechanics of Materials)
- Mechanics II (Hydrostatics, Kinematics, Dynamics)
- Mathematics I, II, III (in particular differential equations)

**Theoretical Knowledge**
The students possess an in-depth knowledge regarding the derivation of the boundary element method and are able to give an overview of the theoretical and methodical basis of the method.

**Capabilities**
The students are capable to handle engineering problems by formulating suitable boundary elements, assembling the corresponding system matrices, and solving the resulting system of equations.

**Numerical Treatment of Ordinary Differential Equations | 6 ECTS**

**Recommended Previous Knowledge:**
- Mathematics I, II, III for engineering students (German or English) or Analysis & Linear Algebra I + II as well as Analysis III for technomathematicians
- Basic MATLAB knowledge

**Theoretical Knowledge**
Students are able to
- list numerical methods for the solution of ordinary differential equations and explain their core ideas
- repeat convergence statements for the treated numerical methods (including the prerequisites tied to the underlying problem)
- explain aspects regarding the practical execution of a method
- select the appropriate numerical method for concrete problems, implement the numerical algorithms efficiently and interpret the numerical results

**Capabilities**
Students are able to
- implement (MATLAB), apply and compare numerical methods for the solution of ordinary differential equations
- to justify the convergence behavior of numerical methods with respect to the posed problem and selected algorithm
- for a given problem, develop a suitable solution approach, if necessary by the composition of several algorithms, to execute this approach and to critically evaluate the results

* Number of participants may be limited
** Additional registration for the group exercise is required
**Machine Learning and Data Mining | 6 ECTS**

**Recommended Previous Knowledge:**
Calculus, Stochastics

**Theoretical Knowledge**
Students can explain the difference between instance-based and model-based learning approaches, and they can enumerate basic machine learning techniques for each of the two basic approaches, either on the basis of static data, or on the basis of incrementally incoming data. For dealing with uncertainty, students can describe suitable representation formalisms, and they explain how axioms, features, parameters, or structures used in these formalisms can be learned automatically with different algorithms. Students are also able to sketch different clustering techniques. They depict how the performance of learned classifiers can be improved by ensemble learning, and they can summarize how this influences computational learning theory. Algorithms for reinforcement learning can also be explained by students.

**Capabilities**
Student derive decision trees and, in turn, propositional rule sets from simple and static data tables and are able to name and explain basic optimization techniques. They present and apply the basic idea of first-order inductive learning. Students apply the BME, MAP, ML, and EM algorithms for learning parameters of Bayesian networks and compare the different algorithms. They also know how to carry out Gaussian mixture learning. They can contrast kNN classifiers, neural networks, and support vector machines, and name their basic application areas and algorithmic properties. Students can describe basic clustering techniques and explain the basic components of those techniques. Students compare related machine learning techniques, e.g., k-means clustering and nearest neighbor classification. They can distinguish various ensemble learning techniques and compare the different goals of those techniques.

**Pattern Recognition and Data Compression | 6 ECTS**

**Recommended Previous Knowledge:**
Linear algebra (including PCA, unitary transforms), stochastics and statistics, binary arithmetics.

**Theoretical Knowledge**
- Students can name the basic concepts of pattern recognition and data compression
- Students are able to discuss logical connections between the concepts covered in the course and to explain them by means of examples

**Capabilities**
Students can apply statistical methods to classification problems in pattern recognition and to prediction in data compression. On a sound theoretical and methodical basis they can analyze characteristic value assignments and classifications and describe data compression and video signal coding. They are able to use highly sophisticated methods and processes of the subject area. Students are capable of assessing different solution approaches in multidimensional decision-making areas.

---

* Number of participants may be limited
** Additional registration for the group exercise is required

Study packages | School of Mechanical Engineering
**Numerical Mathematics II | 6 ECTS**

**Recommended Previous Knowledge:**
- Numerical Mathematics I
- MATLAB knowledge

**Theoretical Knowledge**

Students are able to
- name advanced numerical methods for interpolation, integration, linear least squares problems, eigenvalue problems, nonlinear root finding problems and explain their core ideas
- repeat convergence statements for the numerical methods
- sketch convergence proofs
- explain practical aspects of numerical methods concerning runtime and storage needs
- explain aspects regarding the practical implementation of numerical methods with respect to computational and storage complexity

**Capabilities**

Students are able to
- implement, apply and compare advanced numerical methods in MATLAB
- justify the convergence behavior of numerical methods with respect to the problem and solution algorithm and to transfer it to related problems
- for a given problem, develop a suitable solution approach, if necessary through composition of several algorithms, to execute this approach and to critically evaluate the results

* Number of participants may be limited
** Additional registration for the group exercise is required

Study packages | School of Mechanical Engineering
Study package 8a – Mechanical Engineering and Management – WiSe

Marketing and Communication | 6 ECTS

Recommended Previous Knowledge:
No specific knowledge required. Bachelor-level knowledge in business administration with some insights into marketing and international management is helpful.

Theoretical Knowledge
The students will develop a thorough understanding of the following:
- Selling to organizations and industrial buyers
- Overview of basic strategic decisions in B2B markets
- Relevant theories, methods and tools for operational B2B marketing (Marketing Mix)
- Relevant theories for intercultural communication
- Communication theories (verbal, non-verbal communication, role of formality, interpretation of cues such as symbols)
- The nature of “culture” is and its impact on human interaction
- Approaches for managing cultural diversity

Capabilities
The students will be able to apply this knowledge to:
- choosing appropriate cooperation forms when selling to business organizations
- decide about different target markets, ways of market entry, and timing-strategies
- develop appropriate value-propositions to customers
- place, price and communicate industrial products with the help state-of-the-art B2B marketing tools
- interpret symbols, rituals and gestures appropriately in an intercultural context
- managing cultural diversity across the employees of a company
- communicating appropriately with customers in different regional markets
- apply the theoretical knowledge to business cases or real examples
- apply the theoretical knowledge to interpret research studies

Computer Aided Design and Computation | 6 ECTS

Recommended Previous Knowledge:
- Mechanical parts and basic operations of manufacturing techniques
- Basic knowledge in mathematics, physics, and statics
- Mechanics I (statics, mechanics of materials) and mechanics II (hydrostatics, kinematics, dynamics)
- Mathematics I, II, III (in particular differential equations)

Theoretical Knowledge
- Understanding of the capabilities and limitations of 3D-CAD-Systems, PDM systems, and computer aided simulation Tools
- General knowledge of the finite element method in combination with a basic theoretical and methodology basis
- Basic understanding of the structural optimizations potential and fields of application

Capabilities
- Hands-on practice with an exemplary 3D-CAD-system to demonstrate basic modeling techniques as well as interfaces for concurrent finite element analysis

* Number of participants may be limited
** Additional registration for the group exercise is required
Robotics | 6 ECTS

**Recommended Previous Knowledge:**
- Fundamentals of electrical engineering
- Broad knowledge of mechanics
- Fundamentals of control theory

**Theoretical Knowledge**
Students are able to describe fundamental properties of robots and solution approaches for multiple problems in robotics.

**Capabilities**
- Students are able to derive and solve equations of motion for various manipulators
- Students can generate trajectories in various coordinate systems
- Students can design linear and partially nonlinear controllers for robotic manipulators

*Selected Topics of Mechanical Engineering and Management:*

**International Law for Engineers** | 2 ECTS

**Recommended Previous Knowledge:**
None

**Theoretical Knowledge**
- Students are able to express their extended knowledge and discuss the connection of different special fields or application areas of Materials, Mechatronics and Product Development and Production
- Students are qualified to connect different special fields with each other

**Capabilities**
- Students can apply specialized solution strategies and new scientific methods in selected areas
- Students are able to transfer learned skills to new and unknown problems and can develop own solution approaches

*Selected Topics of Mechanical Engineering and Management: Accounting* | 4 ECTS

**Recommended Previous Knowledge:**
None

**Theoretical Knowledge**
- Students are able to express their extended knowledge and discuss the connection of different special fields or application areas of Materials, Mechatronics and Product Development and Production
- Students are qualified to connect different special fields with each other

**Capabilities**
- Students can apply specialized solution strategies and new scientific methods in selected areas
- Students are able to transfer learned skills to new and unknown problems and can develop own solution approaches

* Number of participants may be limited
** Additional registration for the group exercise is required

Study packages | School of Mechanical Engineering
**Business & Management: Lecture: Marketing** | 2 ECTS

**Recommended Previous Knowledge:**
None

**Theoretical 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

**Capabilities**
- 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

*German as a Foreign Language* | 4 ECTS

**Recommended Previous Knowledge:**
Check: https://intranet.tuhh.de/kvvz/vorlesung.php?Lang=en&mid=524&kvvz=1

**Theoretical Knowledge**
None

**Capabilities**
None

* Number of participants may be limited
** Additional registration for the group exercise is required
Study package 8b – Mechanical Engineering and Management – SuSe

**Economics | 6 ECTS**

**Recommended Previous Knowledge:**
- Basic Knowledge in Economics
- Relevant previous knowledge is taught and tested by an online module

**Theoretical Knowledge**
The students know
- the most important principles of individual decision making in a national and international context
- different market structures
- types of market failure
- the functioning of a single economy (including money market, financial and goods markets, labor market)
- the difference between and the interdependence of short and long run equilibria
- the significance of expectations on the effects of economic policy
- the various links between economies
- different economic policies (trade, monetary, fiscal and exchange rate policy) and their effects on the home and foreign economies

**Capabilities**
The students are able to model analytically or graphically
- the most important principles of individual decision making in a national and international context
- the market results of different market structures and market failure
- the welfare effects of the market results
- expectations hypothesis
- the functioning of an economy (including money market, financial and goods markets, labor market)
- links between economies
- the effects of economic policies (trade, monetary, fiscal and exchange rate policies)
- to understand advanced economic models

* Number of participants may be limited
** Additional registration for the group exercise is required
Fibre-Polymer-Composites | 6 ECTS

Recommended Previous Knowledge:
Basics: chemistry / physics / materials science

Theoretical 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).

Capabilities
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

*Technology Entrepreneurship | 6 ECTS

Recommended Previous Knowledge:
Basic knowledge in business economics obtained in the compulsory modules as well as an interest in new technologies and the pursuit of new business opportunities either in corporate or startup contexts.

Theoretical Knowledge
Subject-related knowledge and understanding:
- develop a working knowledge and understanding of the entrepreneurial perspective
- understand the difference between a good idea and scalable business opportunity
- understand the process of taking a technology idea and finding a high-potential commercial opportunity
- understand the components of business models
- understand the components of business opportunity assessment and business plans

Capabilities
Subject-related skills:
- identify and define business opportunities
- assess and validate entrepreneurial opportunities
- create and verify a business model of how to sell and market an entrepreneurial opportunity
- formulate and test business model assumptions and hypotheses
- conduct customer and expert interviews regarding business opportunities
- prepare business opportunity assessment
- create and verify a plan for gathering resources such as talent and capital
- pitch a business opportunity to your classmates and the teaching team

* Number of participants may be limited
** Additional registration for the group exercise is required
*Selected Topics of Mechanical Engineering and Management: Advanced Research Seminar | 2 ECTS

Recommended Previous Knowledge:
None

Theoretical Knowledge
- Students are able to express their extended knowledge and discuss the connection of different special fields or application areas of Materials, Mechatronics and Product Development and Production
- Students are qualified to connect different special fields with each other

Capabilities
- Students can apply specialized solution strategies and new scientific methods in selected areas
- Students are able to transfer learned skills to new and unknown problems and can develop own solution approaches

Additive Production | 6 ECTS

Recommended Previous Knowledge:
- Production Engineering
- Fundamental of Material Science
- Fundamentals of Mechanical Engineering Design

Theoretical Knowledge
Students will be able to:
- give an overview of Additive Manufacturing Technologies, namely
- describe basics of Laser Technologies
- discuss laser Additive Manufacturing, specifically
- design Guidelines for Additive Manufacturing
- describe the Digital Process Chain for Additive Manufacturing
- discuss Quality Assurance for Additive Manufacturing
- describe Product Development for Additive Manufacturing

Capabilities
The students will be able to:
- give an overview of Potential and Challenges of Additive Manufacturing Technologies
- show that Additive Manufacturing offers new possibilities for product development
- show major differences between Additive Manufacturing and conventional manufacturing technologies
- apply basic skills to develop and design Additive Manufacturing parts
- design and build own Additive Manufacturing parts

*German as a Foreign Language | 4 ECTS

Recommended Previous Knowledge:
Check: https://intranet.tuhh.de/kvvz/vorlesung.php?Lang=en&mid=524&kvvz=1

Theoretical Knowledge
None

Capabilities
None

* Number of participants may be limited
** Additional registration for the group exercise is required

Study packages | School of Mechanical Engineering
**Study package 9a – Mechatronics – WiSe**

*Design and Implementation of Software Systems | 6 ECTS*

**Recommended Previous Knowledge:**
- Imperative programming languages (C, Pascal, Fortran or similar)
- Simple data types (integer, double, char, boolean), arrays, if-then-else, for, while, procedure and function calls

**Theoretical Knowledge**
Students are able to describe mechatronic systems and define requirements.

**Capabilities**
Students are able to design and implement mechatronic systems. They are able to argue the combination of Hard- and Software and the interfaces.

**Finite Elements Methods | 6 ECTS**

**Recommended Previous Knowledge:**
- Mechanics I (Statics, Mechanics of Materials)
- Mechanics II (Hydrostatics, Kinematics, Dynamics)
- Mathematics I, II, III (in particular differential equations)

**Theoretical Knowledge**
The students possess an in-depth knowledge regarding the derivation of the finite element method and are able to give an overview of the theoretical and methodical basis of the method.

**Capabilities**
The students are capable to handle engineering problems by formulating suitable finite elements, assembling the corresponding system matrices, and solving the resulting system of equations.

**Robotics | 6 ECTS**

**Recommended Previous Knowledge:**
- Fundamentals of electrical engineering
- Broad knowledge of mechanics
- Fundamentals of control theory

**Theoretical Knowledge**
Students are able to describe fundamental properties of robots and solution approaches for multiple problems in robotics.

**Capabilities**
- Students are able to derive and solve equations of motion for various manipulators
- Students can generate trajectories in various coordinate systems
Students can design linear and partially nonlinear controllers for robotic manipulators

* Number of participants may be limited
** Additional registration for the group exercise is required
Control Systems Theory and Design | 6 ECTS

Recommended Previous Knowledge:
Introduction to Control Systems

Theoretical Knowledge
- Students can explain how linear dynamic systems are represented as state space models; they can interpret the system response to initial states or external excitation as trajectories in state space
- They can explain the system properties controllability and observability, and their relationship to state feedback and state estimation, respectively
- They can explain the significance of a minimal realisation
- They can explain observer-based state feedback and how it can be used to achieve tracking and disturbance rejection
- They can extend all of the above to multi-input multi-output systems
- They can explain the z-transform and its relationship with the Laplace Transform
- They can explain state space models and transfer function models of discrete-time systems
- They can explain the experimental identification of ARX models of dynamic systems, and how the identification problem can be solved by solving a normal equation
- They can explain how a state space model can be constructed from a discrete-time impulse response

Capabilities
- Students can transform transfer function models into state space models and vice versa
- They can assess controllability and observability and construct minimal realisations
- They can design LQG controllers for multivariable plants
- They can carry out a controller design both in continuous-time and discrete-time domain, and decide which is appropriate for a given sampling rate
- They can identify transfer function models and state space models of dynamic systems from experimental data
They can carry out all these tasks using standard software tools (Matlab Control Toolbox, System Identification Toolbox, Simulink)

* Number of participants may be limited
** Additional registration for the group exercise is required
**Vibration Theory (GES) | 6 ECTS**

**Recommended Previous Knowledge:**
None

**Theoretical Knowledge**
The primary purpose of the study of Vibration Theory is to develop the capacity to understand vibrations and the capacity to analyse, measure, predict and control vibrations, which is needed by the engineers involved in the analysis and design of machines and their supporting structures, vehicles, aircraft, etc. The particular objectives of this course are to:
- Analyse mechanical structures taking into account the effects of dynamic loads
- Appreciate the importance of vibration in structures and mechanical devices
- Formulate and solve the equations of motion of mechanical systems
- Determine the natural frequencies and normal modes of complex mechanical systems

**Capabilities**
At the end of this course the student should be able to:
- Develop simple mathematical models for vibration analysis of complex systems; formulate and solve the equation of motion to determine the dynamic response
- Carry out the linearization of equations of motion
- Determine natural frequencies and normal modes of multi-degree-of-freedom and continuous systems (rods, shafts, taut strings, beams)
- Carry out modal analysis to predict the dynamic response of linear mechanical systems to external excitations
- Analyse, in terms of eigenvalues, stability of time-invariant linear dynamic systems

* Number of participants may be limited
** Additional registration for the group exercise is required

Study packages | School of Mechanical Engineering
Study package 9b – Mechatronics – SuSe

*Mechatronic Systems | 6 ECTS

**Recommended Previous Knowledge:**
Fundamentals of mechanics, electromechanics and control theory.

**Theoretical Knowledge**
Students are able to describe methods and calculations to design, model, simulate and optimize mechatronic systems and can repeat methods to verify and validate models.

**Capabilities**
Students are able to plan and execute mechatronic experiments. Students are able to model Mechatronic systems and derive simulations and optimizations.

*Selected Topics of Mechatronics: Process Measurement Engineering | 4 ECTS

**Recommended Previous Knowledge:**
None

**Theoretical Knowledge**
- Students are able to express their extended knowledge and discuss the connection of different special fields or application areas of mechatronics
- Students are qualified to connect different special fields with each other

**Capabilities**
- Students can apply specialized solution strategies and new scientific methods in selected areas
- Students are able to transfer learned skills to new and unknown problems and can develop own solution approaches

* Number of participants may be limited
** Additional registration for the group exercise is required
Linear and Nonlinear System Identification | 3 ECTS

**Recommended Previous Knowledge:**
- Classical control (frequency response, root locus)
- State space methods
- Discrete-time systems
- Linear algebra, singular value decomposition
- Basic knowledge about stochastic processes

**Theoretical Knowledge**
- Students can explain the general framework of the prediction error method and its application to a variety of linear and nonlinear model structures
- They can explain how multilayer perceptron networks are used to model nonlinear dynamics
- They can explain how an approximate predictive control scheme can be based on neural network models
- They can explain the idea of subspace identification and its relation to Kalman realisation theory

**Capabilities**
- Students are capable of applying the prediction error method to the experimental identification of linear and nonlinear models for dynamic systems
- They are capable of implementing a nonlinear predictive control scheme based on a neural network model
- They are capable of applying subspace algorithms to the experimental identification of linear models for dynamic systems
- They can do the above using standard software tools (including the Matlab System Identification Toolbox)

Nonlinear Dynamics | 6 ECTS

**Recommended Previous Knowledge:**
- Calculus
- Linear Algebra
- Engineering Mechanics

**Theoretical Knowledge**
Students are able to reflect existing terms and concepts in Nonlinear Dynamics and to develop and research new terms and concepts.

**Capabilities**
Students are able to apply existing methods and procedures of Nonlinear Dynamics and to develop novel methods and procedures.

* Number of participants may be limited
** Additional registration for the group exercise is required
**Embedded Systems | 6 ECTS**

**Recommended Previous Knowledge:**  
Computer Engineering

**Theoretical Knowledge**  
Embedded systems can be defined as information processing systems embedded into enclosing products. This course teaches the foundations of such systems. In particular, it deals with an introduction into these systems (notions, common characteristics) and their specification languages (models of computation, hierarchical automata, specification of distributed systems, task graphs, specification of real-time applications, translations between different models). Another part covers the hardware of embedded systems: Sensors, A/D and D/A converters, real-time capable communication hardware, embedded processors, memories, energy dissipation, reconfigurable logic and actuators. The course also features an introduction into real-time operating systems, middleware and real-time scheduling. Finally, the implementation of embedded systems using hardware/software co-design (hardware/software partitioning, high-level transformations of specifications, energy-efficient realizations, compilers for embedded processors) is covered.

**Capabilities**  
After having attended the course, students shall be able to realize simple embedded systems. The students shall realize which relevant parts of technological competences to use in order to obtain a functional embedded systems. In particular, they shall be able to compare different models of computations and feasible techniques for system-level design. They shall be able to judge in which areas of embedded system design specific risks exist.

**Software for Embedded Systems | 6 ECTS**

**Recommended Previous Knowledge:**  
- Good knowledge and experience in programming language C  
- Basis knowledge in software engineering  
- Basic understanding of assembly language

**Theoretical Knowledge**  
Students know the basic principles and procedures of software engineering for embedded systems. They are able to describe the usage and pros of event based programming using interrupts. They know the components and functions of a concrete microcontroller. The participants explain requirements of real time systems. They know at least three scheduling algorithms for real time operating systems including their pros and cons.

**Capabilities**  
Students build interrupt-based programs for a concrete microcontroller. They build and use a preemptive scheduler. They use peripheral components (timer, ADC, EEPROM) to realize complex tasks for embedded systems. To interface with external components they utilize serial protocols.

* Number of participants may be limited  
** Additional registration for the group exercise is required