Module Catalogue

Master of Science (M.Sc.)
in the subject Sustainable Systems Engineering
Subject-specific academic regulations 2016

Institut für Nachhaltige Technische Systeme
Technische Fakultät
Albert-Ludwigs-Universität Freiburg

UNI FREIBURG

INATECH

Table of content

Introduction to the international Master's programme Sustainable Systems Engineering

Science and engineering are basic tools to achieve sustainable development, not only in technology, but also in domains such as ecology, economics and society. The international Master's programme Sustainable Systems Engineering (SSE) provides an in-depth knowledge in fields such as sustainable materials, energy systems, renewable energies, resilience, natural resources, sustainable economy, as well as technology and society. The successful completion of the Master's programme qualifies for a further career in research. Furthermore it is designed to prepare graduates for leading positions in industries of conventional and renewable energy, in supply companies and of infrastructure operators active in fields like mobility or energy supply.

The Master's programme in SSE is designed for highly qualified graduate students holding a Bachelor‘s degree in engineering or science. An SSE student, will have the opportunity to:

- be involved in cutting-edge research with internationally renowned professors
- benefit from state-of-the-art equipment and research facilities of a modern university campus and the five Fraunhofer institutes in Freiburg
- live in one of Germany’s most appealing cities

This module catalogue has been compiled according to the 2016 academic regulations (Prüfungsordnung) for the study programme Master of Science in the subject SSE. Academic regulations define the modules which constitute the curriculum as well as how the curriculum is divided into terms and areas.

The module descriptions clarify how many credit points the student can earn according to the „European Credit Transfer and Accumulation System“ (short: ECTS system). These credit points also define the associated work load for the student. One credit point is equivalent to a work load of 30 hours. The recommended number of ECTS points to be completed per term is 30. The ECTS also define the weighting of a module within the whole study program and its impact on the final grade (similar to grade point average (GPA)). Students of the M. Sc. SSE have to complete at least 120 ECTS points, which usually requires four terms.

More information about the exam regulations of the Master’s programme can be found at http://www.jsl.uni-freiburg.de/studiengaenge/fachinfo/index.html?id_stud=686

Department of Sustainable Systems Engineering (INATECH)

The Department of Sustainable Systems Engineering (Institut für Nachhaltige Technische Systeme - INATECH) was founded by the University of Freiburg in October 2015. The aim was to connect teaching and research in the field of sustainable systems and to complement the University with an engineering research facility for sustainability research. Together with the Department of Microsystems Engineering (IMTEK) and the Department of Computer Science (IIF) it builds the Faculty of Engineering.

In cooperation with the Fraunhofer Institutes in Freiburg, the following research emphases were conceptualized:

- Sustainable Materials - which can be produced and applied in an energy and resource friendly way.
- Energy Systems - which can provide a reliable and efficient supply and storage of renewable energies.
- Resilience - which can secure the robustness and adaptability of systems towards environmental disasters and climate change.

Structure of the M.Sc. programme

1. Parts
The M.Sc. programme is divided into a mandatory and an elective part.

2. Modules
A module is a self-contained unit within a scientific topic or area and may consist of several part modules. Modules may consist of one or more courses, examinations and coursework.

3. Types of courses
A course is the smallest unit described in this catalogue. There are different types of courses, including lectures, exercises, laboratory courses and seminars.

4. Overview
The Master's programme is divided into the following two principal areas:

- Mandatory Modules with 65 ECTS (mandatory part)
- Elective Modules with 55 ECTS (elective part)

In the **mandatory part** of the M.Sc. programme SSE, eight mandatory modules with a total of 65 ECTS are offered. All eight compulsory modules must be completed (see first part of Table **2**).

The elective part of the SSE is divided into a technical and a non-technical specialisation area. 55 ECTS must be achieved within the elective part in total. The technical specialisation area is sub-divided into four different concentration areas. The non-technical specialisation is called "interdisciplinary profile". In addition, students have to complete two modules with a total amount of 10 ECTS from the following three modules (see elective part in Table **2**).

- Design of Large Infrastructures
- Power Electronic Circuits and Devices
- Security and Privacy in Resilient Systems

The four different concentration areas are:

1. Energy Systems
2. Information Processing Technologies
3. Sustainable Materials
4. Resilience Engineering

Within the concentration areas a variety of modules are offered – these can be originating from INATECH, but also from other departments and faculties (such as IMTEK; IIF, or Physics). A few modules are applicable to more than one concentration area and are therefore mentioned in both areas. Students must select a minimum of two concentration areas, and in each area a minimum of 10 ECTS points must be completed.

In the interdisciplinary profile students have to complete a minimum of 10 ECTS points. Students can select modules mentioned in this handbook but also modules from all over the University for the interdisciplinary profile (e.g. faculty of law, economics, or other). Before the students shall register for their course of choice, the module will be checked regarding its suitability for SSE. This is done by the dean of academic affairs and the examination board. Students therefore send an e-mail with all necessary information about their course of choice to the program coordinator.

The remaining 15 ECTS (to complete the 120 ECTS for the full programme) can be selected from either the technical or the non-technical specialisation areas (see Table **1**).

The Curriculum (study plan)

The following schedule of this curriculum is not obligatory. It is, however, expected to lead to a balanced work-load. Therefore it is recommended as a model curriculum.

In the first year, students will have mandatory courses in all areas which provide fundamental knowledge in sustainability engineering. From the second semester on they already start specializing.

Semester 1
Six mandatory modules
- Fundamentals of Resilience
- Material Life Cycles
- Computational Materials' Engineering
- Solar Energy
- Energy Storage
- Control and Integration of Grids

Semester 2
Two out of the following three modules:
- Power Electronic Circuits and Devices
- Design of Large Infrastructures
- Security and Privacy in Resilient Systems

Furthermore students start with
- technical specialisations in Energy Systems, Information Processing Technologies, Sustainable Materials, Resilience Engineering, and
- modules from the interdisciplinary profile.

Semester 3
Students choose again from technical specialisation areas as well as from the interdisciplinary profile – depending on their progress. Moreover, students should carry out the Master Project.

Semester 4
The last semester is dedicated to the Master Thesis.

This model curriculum is illustrated in the below figure (Table **1**).

SSE MODEL CURRICULUM							
Term 1	Energy Storage	Control and Integration of Grids	Computational Materials' Engineering	Fundamentals of Resilience	Material Life Cycles	Solar Energy	30 ECTS
Term 2	Design of Large Infrastructures		Interdisciplinary profile	Technical specialisation: Energy Systems; IPT; Sustainable Materials; Resilience Engineering	Technical specialisation: Energy Systems; IPT; Sustainable Materials; Resilience Engineering	Technical specialisation or interdisciplinary profile	30 ECTS
	Power Electronic Circuits and Devices						
	Security and Privacy in Resilient Systems						
Term 3	Technical specialisation: Energy Systems; IPT; Sustainable Materials; Resilience Engineering	Technical specialisation: Energy Systems; IPT; Sustainable Materials; Resilience Engineering	Interdisciplinary profile	Technical specialisation or interdisciplinary profile	Technical specialisation or interdisciplinary profile	Master Project	30 ECTS
Term 4	Master Thesis and Colloquium						30 ECTS

Mandatory modules: 65 ECTS	Elective modules (2 out of 3): 10 ECTS	Technical specialisations: min. 2*10 = 20 ECTS	Interdisciplinary profile: min. 10 ECTS	Electives: 15 ECTS
65 ECTS	Together: 55 ECTS			
In total: 120 ECTS				

Table 1

Overview of mandatory and elective modules

By clicking on the page number given next to the module name, you will be directed to the module description.
Note: There are modules which can be chosen for the SSE Master program but are offered by other departments of the University and not by the Department of Sustainable Systems Engineering (SSE; INATECH) itself. This is case for example with the University College Freiburg (UCF). For UCF courses, SSE students may not be able to register online through HISINONE but might have to register via e-mail with the SSE program coordinator taking into account that there are limited places available in UCF courses. Places will usually be allocated on a first-come-first-serve basis starting from the day of announcement by the program coordinator.

Mandatory modules

- Energy Storage (p.14)
- Control and Integration of Grids (p.25)
- Computational Materials' Engineering (p.27)
- Fundamentals of Resilience (p.17)
- Material Life Cycles (p.23)
- Solar Energy (p.29)

- Master Project (p.21)
- Master Thesis and Colloquium (p.19)

Elective part

- Design of Large Infrastructures (p.53)
- Power Electronic Circuits and Devices (p.36)
- Security and Privacy in Resilient Systems (p.178)

} must select 2 out of 3

Technical specialization areas

Energy Systems

- Characterization of solar cells: From feedstock quality to final cell efficiency (p.173)
- Crystalline silicon photovoltaics (p.111)
- Electrochemical energy applications (p.67)
- Electromobility (p.69)
- Emerging and Future Photovoltaic Technology Options (p.187)
- Energy Economics and Energy Policy (p.75)
- Multi-junction solar cell technology and concentrator PV (p.189)
- Operations Research for Energy Systems (p.145)
- Photovoltaic Laboratory (p.154)

Information Processing Technologies

- Cyber-Physical Systems – Discrete Models (p.47)
- Cyber-Physical Systems – Hybrid Models (p.50)
- Embedded Control Laboratory (p.71)
- High-Performance Computing with Python (p.93)
- Introduction to Embedded Systems (p.62)
- Micro-electronics (p.125)
- Numerical Optimal Control in Science and Engineering (p.137)
- Numerical Optimal Control in Engineering – Project (p.139)
- Real-time Operating Systems (p.60)
- Security and Privacy in the Information Society (p.176)

• Power Electronics for E-Mobility (p.118) • Power Electronics for Photovoltaics and Wind Energy (p.120) • RF- and Microwave Devices and Circuits (p.167) • RF- and Microwave Design Course (p.170) • Systems theory and automatic control II (p.184) • Thermoelectric (p.193)	• Wireless Sensor Networks (p.57)
Resilience Engineering • Bionic Sensors (dtf) • Bionic Sensors Laboratory (dtf) • Continuum mechanics I (p.103) • Continuum mechanics I with exercises (p.105) • Continuum mechanics II (p.107) • Continuum mechanics II with exercises (p.109) • Dynamics of Materials: Material Characterization (p.195) • Functional Safety: Active Resilience (p.90) • Mechanical Properties and Degradation Mechanisms (p.122) • Particle Methods in Engineering (p.132) • Physics of Failure (p.101) • Quantification of Resilience (p.159) • Reliability Engineering (p.198) • Structural Robustness: Resilient Designs (p.180)	**Sustainable Materials** • Bioinspired functional materials (p.12) • Ceramic Materials for Sustainable Systems (p.99) • Contact, Adhesion, Friction (p.45) • Continuum mechanics I (p.103) • Continuum mechanics I with exercises (p.105) • Continuum mechanics II (p.107) • Continuum mechanics II with exercises (p.109) • Dynamics of Materials: Material Characterization (p.195) • Electrochemical Methods for Engineers (dtf) • Inelastic Material Behaviour: Viscoelasticity and Plasticity (p.95) • Lattice Gas Methods (p.115) • Mechanical Properties and Degradation Mechanisms (p.122) • Methods of Material Analysis (dtf) • Nanomaterials – Laboratory (p.130) • Nanomaterials – Lecture (p.128) • Optical Properties of Micro and Nano Structures (p.148) • Particle Methods in Engineering (p.132) • Particle Simulation Methods (p.151) • Surface Analysis (p.141) • Surface Analysis Lab (p.143) • Theory and Modeling of Materials (p.191)
Non-technical specialisation area	
Interdisciplinary profile • Basic Income and Social Justice (p.32) • Basiskompetenzen Kommunikation und Gesprächsführung (BOK) (p.34)	

- Climate Change & Biodiversity / cooperation with UCF (dtf)
- Computational Modeling / cooperation with UCF (p.41)
- Computational Modeling with Matlab (p.43)
- Desktop Publishing – Grundlagen grafischer Gestaltung am Computer (BOK) (p.55)
- Einführung in die allgemeine Ethik (p.65)
- Energy / cooperation with UCF (p.73)
- Energy Economics and Energy Policy (p.75)
- Entrepreneurship (lecture series) (p.78)
- Environmental Planning / cooperation with UCF (p.80)
- Environmental Psychology / cooperation with UCF (p.84)
- Environmental Psychology for Engineers (p.86)
- Environment, Risks, and Us / cooperation with UCF (p.82)
- Geohazards / cooperation with UCF (dtf)
- Introduction to Earth and Environmental Sciences / cooperation with UCF (p.97)
- Neuroscience for Engineers (p.135)
- Operations Research for Energy Systems (p.145)
- Project management for engineers (p.157)
- Resources and Sustainability / cooperation with UCF (p.165)
- Scientific writing and presentation (p.88)
- Seminar am Lehrstuhl Gender Studies in MINT (dtf)
- Verhaltenswissenschaftliche Grundlagen des Public und Non-Profit Management (dtf)

Table 2

“dtf” stands for “details to follow”

List of all mandatory modules (alphabetical order)

In the Master of Science Sustainable Systems Engineering eight mandatory modules with a total of 65 ECTS Points are offered. All 8 compulsory modules must be completed.

Modul / *Module*
1. Energiespeicherung / Energy Storage

Nummer: *Number*	11LE68MO-8010		
Modulverantwortlicher: *Responsible person*	M. Vetter, D. Schossig, T. Smolinka	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Mandatory Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture and exercises	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Basic understanding of Engineering Physics and Engineering Chemistry		

Empfohlenes Fachsemester:: *Recommended term of study*	1	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*	3 lectures + 1 exercises	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	150 hours (56 hours full-time attendance course of study + 94 hours self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*
Mandatory Module for students of the study program • Master of Science in Sustainable Systems Engineering

Lernziele / *Learning target*
- Understanding the necessity of energy storage (short-term, mid-term, seasonal) for stationary applications (electric, thermal and chemical) as well as their technical and economic requirements - Basic knowledge of different energy storage technologies such as pumped-hydro, SuperCaps, batteries, and thermal storage systems as well as hydrogen and Power-to-Gas (PtG) solutions - Knowledge in design of battery systems with a focus on lihtium-ion technologies - Knowledge in design of thermal storage systems - Knowledge in design of hydrogen storage and PtG systems

Inhalte Vorlesung / *Content of the lecture*
1. Introduction and motivation energy storage (electric, thermal, PtG): Large-scale integration of renewable energies and the role of energy storage; technical requirements of power grids; overview of energy storage options and applications; key parameter of energy

storage systems; technical requirements of storage systems; economic analyses for storage systems
2. Basics of energy storage systems: Mechanical (pumped hydro, CAES, fly wheels); Electric (SuperCaps); Electrochemical (Lead-acid, NiCd, NiMh, Lithium-ion; Sodium-ion; NaS / NaNiCl); thermal storage systems; chemical storage and PtG systems
3. Design of battery systems (focus Lithium-ion): Test and characterization of cells; Battery module and system design (components, construction, cooling); Safety issues; Battery management; Thermal management; System integration (system options, power and communication interface); Peripheral components (inverter, energy management) Groß/Klein???
4. Design of thermal storage systems
Description of technologies: sensible heat storage, latent heat storage, thermochemical storage.Ttechnical applications: long term storage, short term storage, from cold storage to high temperature storage. Component and system layout, best case examples, limits and future expectations
5. Design of hydrogen storage and PtG systems: different system layouts and main components of hydrogen and PtG storage systems, water electrolysis as core component for PtG systems, advantages and drawbacks for repowering in fuel cells and thermal engines, best case examples of PtG installations, intersectoral extention to further Power-to-X technologies

Inhalte Übung / *Content of the exercises*

The lecture will be accompanied by a weekly exercise to deepen the understanding of the lecture's content and to discuss further details.

Zu erbringende Prüfungsleistung / *Examination result*

The examination is completed by oral examination.

Zu erbringende Studienleistung / *Course Achievement*

Presentation of a selected topic related to energy storage

Benotung / *Grading*

In this module, the student has to choose whether he/she wishes to finish the module via an examination or a course achievement.

- Examination: The module grade is calculated from the result of the final examination.
- Course Achievement: Academic performance which is evaluated with pass.

Gewichtung der Prüfungsleistung / *Weight of examination result*

Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: If the student has chosen and passed the examination, the grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. If the student has chosen and passed the course achievement, the result will not be taken into account in the final grade.

Literatur / *Literature*
T. Letcher: Storing Energy G. Pistoia: Lithium-Ion Batteries Advances and Applications A. Jossen: Moderne Akkumulatoren richtig einsetzen J.-C. Hadorn: Thermal energy storage for solar and low energy systems P. Moseley and J. Garche: Electrochemical Energy Storage for Renewable Sources and Grid Balancing

Modul / *Module*

2. Grundlagen resilienter/stabiler Systeme / Fundamentals of Resilience

Nummer: *Number*	11LE68MO-8020		
Modulverantwortlicher: *Responsible person*	S. Hiermaier	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Mandatory Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture and exercises	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Engineering Physics		

Empfohlenes Fachsemester:: *Recommended term of study*	1	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*	4 Lecture	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	150 hours (56 hours Full-time attendance course of study + 94 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Mandatory Module for students of the study program
- Master of Science in Sustainable Systems Engineering

Lernziele / *Learning target*

The lecture provides a clear understanding of the term “resilience” in an engineering context, specifically as compared to stability, robustness, flexibility or failure safety. Students realize that failure of transport systems, infrastructure, support chains and of other technical systems is not necessarily a consequence of technical malfunction or bad design. Students find that in contrast the ability to control failure of systems and catastrophes can be achieved by networks of perspective interaction, prevention and adaption. Continuous adaption of behavior of individuals and of the control of facilities will be understood as necessary steps towards increasing resilience.

Inhalte Vorlesung / *Content of the lecture*

- key concepts and ideas in resilience engineering
- collection of typical systems addressed concernign their resilience
- introduction to tools for quantitative risk analyses

Inhalte Übung / *Content of the exercises*
Not applicable

Zu erbringende Prüfungsleistung / *Examination result*
In this module, the student has to choose whether he/she wishes to finish the module via an examination or a study performance. The examination is completed by a written or oral examination.

Zu erbringende Studienleistung / *Course Achievement*
In this module, the student has to choose whether he/she wishes to finish the module via an examination or a course achievement. The course achievement is completed by a written or oral test.

Benotung / *Grading*
In this module, the student has to choose whether he/she wishes to finish the module via an examination or a course achievement. • Examination: The module grade is calculated from the result of the final examination. • Course Achievement: Academic performance which is evaluated with pass.

Gewichtung der Prüfungsleistung / *Weight of examination result*
Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: If the student has chosen and passed the examination, the grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. If the student has chosen and passed the course achievement, the result will not be taken into account in the final grade.

Literatur / *Literature*

Modul / *Module*
3. Masterarbeit / Master Thesis

Nummer: *Number*	11LE68MO-8700-672		
Modulverantwortlicher: *Responsible person*	Examiners of the Department of Sustainable Systems Engineering	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Mandatory module	**Moduldauer** *Module duration*	1 term
Lehrveranstaltungstyp: *Type of course*	Written thesis	**Sprache:** *Teaching language*	German or English
Zwingende Voraussetzungen: *Mandatory requirements*	Admission for the thesis can be granted once at least 70 ECTS-credits have been acquired within the course program.		

Empfohlenes Fachsemester:: *Recommended term of study*	4	**ECTS-Punkte:** *ECTS-points*	30
SWS: *Semester week hours*		**Angebotsfrequenz:** *Regular cycle*	Each term
Arbeitsaufwand: *Workload*	900 hours (900 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*
Mandatory Module for students of the study program • Master of Science in Sustainable Systems Engineering

Lernziele / *Learning target*
The student shows with his/her Master thesis the ability to solve a given problem from sustainable systems engineering in a given time frame using scientific methodology. Skills and competencies obtained in the course program have been verifiably applied in accordance to the state of the art. The student has proven his/her ability to apply methods and knowledge as well as research and development competencies in the project, the scientific documentation and the oral presentation.

Inhalte / *Content*
The Master thesis is an independent research project. Is consists of a written documentation and a final presentation with discussion. The student works on a given topic for a given timeframe and has to deliver a scientific documentation.

Zu erbringende Prüfungsleistung / *Examination result*
The Module consists of

- written documentation of the thesis
- oral presentation of the results of the thesis

The final module grade is calculated from the grade of the written thesis.

Benotung / *Grading*
The final module grade is calculated from the grade of the written thesis.

Gewichtung der Prüfungsleistung / *Weight of examination result*
Master of Science in Sustainable Systems Engineering, academic regulations of 2016: The grade of this module is single-weighted according to the number of its ECTS credits in the calculation of the overall grade.

Modul / *Module*
4. Masterprojekt / Master Project

Nummer: *Number*	11LE68MO-7160		
Modulverantwortlicher: *Responsible person*	Examiners of the Department of Sustainable Systems Engineering	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Mandatory module	**Moduldauer** *Module duration*	1 term
Lehrveranstaltungstyp: *Type of course*	Written project	**Sprache:** *Teaching language*	German or English
Empfohlene Voraussetzungen: *Recommended preconditions*			

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*		**Angebotsfrequenz:** *Regular cycle*	Each term
Arbeitsaufwand: *Workload*	150 hours		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Mandatory Module for students of the study program
- Master of Science in Sustainable Systems Engineering

Lernziele / *Learning target*

Students will be prepared and qualified for further scientific work. They will gain first experience in information retrieval, planning and setting up a specific project, and reporting.

Inhalte Vorlesung / *Content of the lecture*

Students will be instructed and guided by an academic supervisor.

Zu erbringende Studienleistung / *Course achievement*

Written project report and presentation

Benotung / *Grading*

Academic performance which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*
Master of Science in Sustainable Systems Engineering, academic regulations 2016: Academic performance which can be graded but is not taken into account in the final grade.

Literatur / *Literature*
• Project specific

Modul / *Module*
5. Materiallebenszyklen / Material Life Cycles

Nummer: *Number*	11LE68MO-8030		
Modulverantwortlicher: *Responsible person*	S. Hiermaier	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Mandatory Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture and exercises	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Fundamental knowledge of Materials Science and Technology		

Empfohlenes Fachsemester:: *Recommended term of study*	1	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*	2 lecture + 2 exercises	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	150 hours (56 hours Full-time attendance course of study + 94 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*
Mandatory Module for students of the study program • Master of Science in Sustainable Systems Engineering

Lernziele / *Learning target*
The aim of the lecture is to be introduced to a framework within which a student can form critical, independent assessments of Sustainable Developments. With a focus on the role of materials it recognizes the complexity inherent in discussions of sustainability and shows how to deal with it in a systematic way.

Inhalte Vorlesung / *Content of the lecture*
For that purpose the students are provided with procedures and tools, which allow them to analyze the financial, natural, human and social factors contributing to sustainable development. Within that context, the lecture addresses questions such as “How do we achieve sustainable development? How do we measure progress in achieving it? What does it mean in engineering practice? How do materials fit in?” The students will find that there is no completely “right“ answer to questions of sustainable development- instead, there is a thoughtful, well-researched response that recognizes the conflicting priorities of the environmental, the economic, the legal and the social aspects of a technological change.

Inhalte Übung / *Content of the exercises*
Students will learn to assess sustainability aspects of materials & processes via hands-on sessions using specialized databases.

Zu erbringende Prüfungsleistung / *Examination result*
In this module, the student has to choose whether he/she wishes to finish the module via an examination or a study performance. The examination is completed by a written or oral examination.

Zu erbringende Studienleistung / *Course Achievement*
In this module, the student has to choose whether he/she wishes to finish the module via an examination or a course achievement. The course achievement is completed by a written or oral test.

Benotung / *Grading*
In this module, the student has to choose whether he/she wishes to finish the module via an examination or a course achievement. • Examination: The module grade is calculated from the result of the final examination. • Course Achievement: Academic performance which is evaluated with pass.

Gewichtung der Prüfungsleistung / *Weight of examination result*
Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: If the student has chosen and passed the examination, the grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. If the student has chosen and passed the course achievement, the result will not be taken into account in the final grade.

Literatur / *Literature*
Michael F. Ashby, "Materials and Sustainable Development", Elsevier, 2016. Michael F. Ashby, "Materials and Environment", Elsevier, 2013.

Modul / *Module*
6. Netzintegration und Regelung / Control and Integration of Grids

Nummer: *Number*	11LE68MO-8090		
Modulverantwortlicher: *Responsible person*	A. Weidlich	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Mandatory Module	**Moduldauer** *Module duration*	1 Term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture and exercises	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Fundamentals of Electrical Engineering or Engineering Physics		

Empfohlenes Fachsemester:: *Recommended term of study*	1	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*	3 Lecture + 1 exercise	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	150 hours (42 hours full-time attendance course of study + 108 hours self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Mandatory module for students of the study program
- Master of Science in Sustainable Systems Engineering

Lernziele / *Learning target*

The aim of this module is to get an understanding of the power and energy definition in energy systems and distribution grids. The module will cover the traditional electrical energy system structures as well as the renewable energy systems. Focus will be on the analysis of electrical grids, used for optimized integration of distributed energy resources.

Inhalte Vorlesung / *Content of the lecture*

- Energy system overview – generation, transmission, distribution, consumption
- Energy transport; power and energy definition
- Power generation analysis;
- Transition of the energy systems; renewable energy grid integration
- Power plants, storage, inverters
- Grid theory; DC, AC circuits; system theory
- System components: lines; transformers; generators;
- Grid calculation; reactive and active power flow

- Grid codes, grid regulation
- Operation and control of electricity grids; primary, secondary and tertiary control; voltage control
- Economic dispatch problem

Zu erbringende Prüfungsleistung / *Examination result*

Written examination

Zu erbringende Studienleistung / *Course Achievement*

In this module, the student has to choose whether he/she wishes to finish the module via an examination or a course achievement. The course achievement is completed by a written or oral test.

Benotung / *Grading*

In this module, the student has to choose whether he/she wishes to finish the module via an examination or a course achievement.

- Examination: The module grade is calculated from the result of the final examination.
- Course Achievement: Academic performance which is evaluated with pass.

Gewichtung der Prüfungsleistung / *Weight of examination result*

Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: If the student has chosen and passed the examination, the grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. If the student has chosen and passed the course achievement, the result will not be taken into account in the final grade.

Literatur / *Literature*

Power Generation Technologies; Paul Breeze
ISBN 978-0-08-098330-1
Electric Power Generation Transmission and Disitribution; Leonard L. Grigsby;
ISBN 978-1-4398-5628-4

Modul / *Module*

7. Numerische Methoden der Materialwissenschaften / Computational Materials Engineering

Nummer: *Number*	11LE68MO-8050		
Modulverantwortlicher: *Responsible person*	M. Moseler	**Einrichtung:** *Organisational unit*	Physics/ Faculty of Engineering
Modultyp: *Module Type*	Mandatory Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture and exercises	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Basic knowledge in classical mechanics, analysis and vector calculus.		

Empfohlenes Fachsemester:: *Recommended term of study*	1	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*	2 lectures + 2 exercises	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	150 hours (64 hours full-time attendance course of study + 86 hours self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Mandatory module for students of the study program

- Master of Science in Sustainable Systems Engineering

Lernziele / *Learning target*

Students will become familiar with the various methods of computational materials science: density functional theory, tight-binding, semi-empirical interatomic potentials, coarse grained models, continuum models. Students will be able to set up density functional and molecular dynamics simulations to understand and design sustainable materials.

Inhalte Vorlesung / *Content of the lecture*

An introduction into basic concepts of computational materials science will be given. The computational tools for different time and length scales will be introduced and it will be discussed how these tools can be combined in order to solve multiscale materials problems.The lecture will start with a brief introduction to density functional theory and tight binding. With both methods the short term dynamics of small units of materials can be studied. For the simulation of larger systems and longer time scales, classical interatomic potentials will be introduced allowing for the description of the different types of bonding in

materials. The basic methodology of extended molecular dynamics simulations will be introduced. Finally, concepts for coarse grained methods to study the mesoscale and macroscale dynamics in solids and liquids will be discussed.

Inhalte Übung / *Content of the exercises*

The lecture is accompanied by a python-based hands-on programming course. For simple materials systems a working knowledge in molecular dynamics will be taught.

Zu erbringende Prüfungsleistung / *Examination result*

In this module, the student has to choose whether he/she wishes to finish the module via an examination or a study performance. The examination is completed by a written or oral examination.

Zu erbringende Studienleistung / *Course Achievement*

In this module, the student has to choose whether he/she wishes to finish the module via an examination or a course achievement. The course achievement is completed by a written or oral test.

Benotung / *Grading*

In this module, the student has to choose whether he/she wishes to finish the module via an examination or a course achievement.

- Examination: The module grade is calculated from the result of the final examination.
- Course Achievement: Academic performance which is evaluated with pass.

Gewichtung der Prüfungsleistung / *Weight of examination result*

Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: If the student has chosen and passed the examination, the grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. If the student has chosen and passed the course achievement, the result will not be taken into account in the final grade.

Literatur / *Literature*

- Daan Frenkel, Berend J. Smit, Understanding Molecular Simulation, Elsevier, ISBN: 978-0-12-267351-1
- Michael Griebel, Stephan Knapek, Gerhard Zumbusch, Numerical Simulation in Molecular Dynamics, Springer, ISBN 978-3-540-68095-6
- Tamar Schlick, Molecular Modelling and Simulation, An interdisciplinary guide, Springer. ISBN 978-1-4419-6351-2
- C. Fiolhais, F. Nogueira, M. Marques, A Primer in Density Functional Theory. Springer. ISBN: 3540030832
- Lecture script
  M.Moseler "A brief introduction into Computational Materials Science"

Modul / *Module*
8. Solare Energie / Solar Energy

Nummer: *Number*	11LE68MO-8060		
Modulverantwortlicher: *Responsible person*	S. Glunz, K. Kramer, P. Schossig	**Einrichtung:** *Organisational unit*	Faculty of Engineering / INATECH
Modultyp: *Module Type*	Mandatory Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture and exercises	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Basic understanding of physics		

Empfohlenes Fachsemester:: *Recommended term of study*	1	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*	3 lecture + 1 exercises	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	150 hours (42 hours full-time attendance course of study + 108 hours hours self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*
Mandatory module for students of the study program • Master of Science in Sustainable Systems Engineering

Lernziele / *Learning target*
Students will be able to understand the fundamentals and different technologies variants of solar energy conversion as photovoltaics and solar thermal. They will know the relevant physical background, technical characteristics, materials and designs used. The lecture will cover the component, product and system level. Furthermore students will understand trends of further development as well as limitations and possibilities in application of solar energy.

Inhalte Vorlesung / *Content of the lecture*
- Solar Energy - Theoretical and Technical Energy Potential (black body radiation, Carnot cycle, maximum efficiencies, …) - Solar Energy Technologies - Tapping the sun's energy (overview of conversion technologies, system boundaries, seasonal fluctuation, ...) - Photovoltaics - Physics of Solar Cells (introduction to semiconductors,

Fermi levels, IV curves, conversion efficiency, quantum efficiency …)
- Photovoltaics - Technology Review (short introduction to the structure and technology of crystalline silicon solar cells)
- Solar Thermal - Physics of Solar Collectors (basics of thermo dynamics, fluid dynamics, absorption, emission, power output and other performance criteria)
- Solar Thermal - Technology Review (from low temperature applications up to power plants - examples)
- Heat pumps - Thermodynamics, electrical and thermal driven heat pumps and chillers, main components (compressor, evaporator, condensor etc.), system configurations (layout, sources, storages, control strategies etc)
- Heat pumps: field tests and best case examples - Heat pumps and smart grid interaction, Heat pumps and PV, Heat pumps + solar thermal, storage integration)

Inhalte Übung / *Content of the exercises*

The lecture will be accompanied by a weekly exercise to deepen the understanding of the lecture's content and to discuss further details.

Zu erbringende Prüfungsleistung / *Examination result*

In this module, the student has to choose whether he/she wishes to finish the module via an examination or a study performance. The examination is completed by a written or oral examination.

Zu erbringende Studienleistung / *Course Achievement*

Written or oral examination.

Benotung / *Grading*

Examination: The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: If the student has chosen and passed the examination, the grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. If the student has chosen and passed the course achievement, the result will not be taken into account in the final grade.

Literatur / *Literature FORMAT bei allen Modulen konsistent*

- Duffie-Beckman: Solar Engineering of Thermal Processes,
- V. Quaschning: Understanding Renewable Energy,
- Peuser FA, Remmers K, et.al.:Solar thermal systems
- P. Würfel, Physik der Solarzelle, Spektrum - Akademischer Verlag 2000
- A. Goetzberger, B. Voß und J. Knobloch, Sonnenenergie: Photovoltaik, Teubner 1997
- M.A. Green, Solar Cells, University of New South Wales 1982

- K. Mertens, Photovoltaik, Hanser 2011
- J. Nelson, The physics of solar cells, Imperial College Press 2008

List of elective modules (alphabetical order)

Modul / *Module*
9. Basic Income and Social Justice (Seminar)

Nummer: *Number*	---		
Modulverantwortlicher: *Responsible person*	B. Neumärker	**Einrichtung:** *Organisational unit*	Dep. of Economic Policy and Constitutional Economic Theory
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term (partly block format)
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Semester week hours*	2 Seminar (partly block format)	**Angebotsfrequenz:** *Regular cycle*	Irregularly in summer term
Arbeitsaufwand: *Workload*			

Verwendbarkeit der Veranstaltung / *Usability of the module*
Elective Module for students of the study program • Master of Science in Sustainable Systems Engineering   ○ Interdisciplinary Profile

Lernziele / *Learning target*

Inhalte Vorlesung / *Content of the lecture*
SoCoLab seminar, winner of a University teaching award 2012, deviates from a usual seminar setting. The students after reading the necessary papers and finish the required assignments will be welcomed during class to participate and discuss the elements of the theories and their ideas with Prof. Neumärker and his co-workers. The seminar consists of an introduction, 2 blocked meetings, a day of experiments with the participants, a session for the team experiments, and a concluding session. In the first sessions (Part I), the theoretical foundations are laid, and after the experiment sessions (Part II) follows one session with critical discussion (Part III). The participation in all the classes is obligatory in order to achieve maximum participation and understanding of the subjects. After the classes and the experiments for seminar participants are over, teams are given a sufficient amount of time to develop an experiment on the topic. In the team experiments, the participants are expected to critically reflect on one of the issues/aspects

tackled in the seminar. The experiment design formalities and more specific information on the content will be provided to all participants.

The overall grade is the weighted as a sum of all three elements of the seminar with the following weights: Team Experiment and Paper/Report on a Basic Income Experiment: 60%, Assignments: 20%, Class Participation: 20%. The teams will be built, at the latest, after the "Experimental Sessions for Participants".

More information: https://www.wipo.uni-freiburg.de/Lehre/summer-semester-2017-1/basic-income-and-social-justice

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Zu erbringende Studienleistung / *Course Achievement*
written or oral examination

Benotung / *Grading*
Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Literatur / *Literature*
Will be announced during the seminar.

Modul / *Module*

10. Basiskompetenzen Kommunikation und Gesprächsführung

Nummer: *Number*	00LE55MO-990/3135		
Modulverantwortlicher: *Responsible person*	FRAUW ZfS	**Einrichtung:** *Organisational unit*	FRAUW ZfS
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	German only

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	4
SWS: *Semester week hours*	2	**Angebotsfrequenz:** *Regular cycle*	Irregularly
Arbeitsaufwand: *Workload*	120 hours		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Interdisciplinary Profile

Lernziele / *Learning target*

Studierende haben grundlegende Kompetenzen der Kommunikation und Gesprächsführung erworben und können diese in beruflichen und privaten Situationen wirksam und zufriedenstellend anwenden. Sie verfügen über Kenntnisse und Fertigkeiten im Umgang mit Methoden zur Analyse und Bewertung der eigenen Übungsgespräche und die der anderen Studierenden. Sie können diese Methoden einsetzen, um die eigenen Kommunikations- und Gesprächskompetenzen bewusster wahrzunehmen, sie zu vertiefen und zu erweitern.

Inhalte Vorlesung / *Content of the lecture*

Relevanz
Gelungene Kommunikations- und Gesprächskompetenz sind eine Grundlage für ein befriedigendes Zusammenleben und eine konstruktive Zusammenarbeit im Beruf, Studium und Privatleben.

Inhalt
Theoretische und methodische Grundlagen menschlicher Kommunikation; Basiskompetenzen von Kommunikation (u.a. Haltung und Technik, aktives Zuhören und Paraphrasieren, Empathie, Perspektivenübernahme, Fragen). Definition von Gespräch; Gesprächsarten; Gesprächskompetenz. Spezifika und Unterschiede von Kommunikation und Gesprächen im Beruf, Studium und Privatleben. Durchführung von Übungsgesprächen,

in welchen die Basiskompetenzen angewandt und erprobt werden. Vermittlung von Arbeitshilfen und Methoden zur Vorbereitung, Analyse und Bewertung von Gesprächen.

Zu erbringende Studienleistung / *Course Achievement*
Regelmäßige Teilnahme an allen Veranstaltungsterminen, Durchführung von Übungsgesprächen, Transkription von Gesprächsausschnitten, Vorbereitung der Gesprächsausschnitte für die Supervision anhand eines Leitfadens und Hausarbeit.

Benotung / *Grading*
Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Literatur / *Literature*

Modul / *Module*

11. Bauelemente und Schaltungen der Leistungselektronik/ Power Electronic Circuits and Devices

Nummer: *Number*	11LE68MO-9010		
Modulverantwortlicher: *Responsible person*	O. Ambacher, R. Quay, B. Burger, M. Diehl	**Einrichtung:** *Organisational unit*	IMTEK & INATECH
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture and exercise	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Basic knowledge of electric and electronic circuits		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*	3 lectures + 1 exercises	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	150 h		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Sustainable Systems Engineering

Lernziele / *Learning target*

The students will be enabled to understand materials, concepts, functioning, design and control of modern power devices, circuits, and converter systems suitable for microscopic and macroscopic energy systems. It comprises three aspects: fundamental power conversion-concepts with focus on DC-DC and –AC conversion, more complex power circuitry, and actual power conversion systems including their control. This includes, e.g., solar energy photovoltaic converters and engines in traffic. The basic concepts of power conversion (AC theory), of passive and active semiconductor devices, high-voltage operation, converter-, and control concepts, device protection and aspects of system and power network theory are treated.
The students will be competent to analyze, understand the fabrication, design, and control passive and active power devices such as MOSFET, Insulated Gate Bipolar IGBT, Junction FETs (JFET), diodes, and thyristors. Circuits parts, converter functions, integration, and full circuits and system concepts are analyzed. Students will be able to design and analyze feedback control systems based on state space control technologies and apply them to

power devices.

Inhalte Vorlesung / *Content of the lecture*

The lecture deals with the fundamentals and concepts of power devices and circuits. It comprises three parts: fundamental power conversion-concepts with focus on DC-DC and –AC conversion, devices, more complex power circuitry, and actual power conversion systems including the basics of control. At the interface of modern electronics, circuit design, and control theory, advanced analysis, fabrication, and characterization techniques are introduced in order to bridge the gap from modern power conversion to the understanding of systems and network systems with all aspects of power conversion. The methodologies of power-analysis, design of circuits, complex power flow, processing of devices, their modelling, their characterization, and control are introduced along with the demonstration of their relevance to real power-components and -systems. Circuits and system concepts for power conversion, such as half and full bridges, current controls, aspects high voltage operation, and design for robustness are presented, and several examples are discussed in detail. Students are introduced to the design and analysis of feedback control systems using state space design technologies such as the Luenberger Observer, Kalman Filter, the Linear Quadratic Regulator (LQR) and Model Predictive Control (MPC). Typical applications include DC-DC conversion for server systems, photovoltaic power conversion, application to microscopic power converters, and high-voltage windcraft systems.

Inhalte Übung / *Content of the exercises*

Zu erbringende Prüfungsleistung / *Examination result*

Oral exam (30 min)/written exam, the exercise is a requirement for the acceptance to the final exam.

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

Master of Science in Sustainable Systems Engineering, academic regulations of 2016: The grade of this module is single-weighted according to the number of its ECTS credits in the calculation of the overall grade.

Literatur / *Literature*

An Electronic script is provided at the beginning of the lecture.

Joachim Specovices, „Grundkurs Leistungselektronik“, Vieweg + Teubner (2009), ISBN 9783834805577

Manfred Michel,

„Leistungselektronik“, Springer (2011), ISBN 9783642159831

C. Kamalakannan et al., „Power Electronics and Renewable Energy Systems“, Springer (2014), ISBN 8132221184

J. Lutz, Halbleiter-Leistungsbauelemente (in German), Springer, Berlin-Heidelberg, 2006.

N. Mohan, Power Electronics, A first course, John Wiley and Sons, 2012.

G.F. Franklin, J.D. Powell, A. Emami-Naeini: Feedback Control of Dyna- mic Systems, Pearson (ISBN-13: 978-0-13-601969-5)

Modul / *Module*

12. Bioinspirierte Funktionsmaterialien / Bioinspired functional materials

Nummer: *Number*	11LE50MO-5125	**Gültig seid:** *Valid since*	22.02.2017
Modulverantwortlicher: *Responsible person*	Dr. Osorio-Madroza	**Einrichtung:** *Organisational unit*	Chair for Sensors
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	German or English
Empfohlene Voraussetzungen: *Recommended requirements*	-		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Only in the summer term
Arbeitsaufwand: *Workload*	90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / *Learning target*

In this module the students will get fundamental knowledge on the structure and functionality of biological materials as to apply their design principle in the development of bioinspired biomaterials. At the end of the module, the student should be able to describe the interrelation between microstructure and properties in biological materials; apply advance

methods for the characterization of microstructure and properties of biological and artificially developed bioinspired materials and explain the method theoretical principle; and describe the physico-chemistry of the processing of different bioinspired materials studied in the course.

Inhalte Vorlesung / *Content of the lecture*

- Organic-based biological materials. Hierarchical structure and functionality
- Mineralized biological materials. Hierarchical structure and functionality
- Advanced methods to characterize the microstructure and properties of biological and bioinspired materials (Materials physical-chemistry and materials physics: mechanical testings; scattering techniques SAXS and WAXS for microstructure characterization; spectroscopic techniques for chemical structure characterization). Establishment of structure-properties relationship in biomaterials
- Examples of preparation methods of bioinspired materials. Processing physical-chemistry and optimization
- Interrelation between processing, structure and properties in bioinspired materials
- - Examples of bioinspired materials for technological and biomedical applications

Inhalte Übung / *Content of the exercises*

Zu erbringende Prüfungsleistung / *Examination result*

Written or oral examination

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*

Modul / *Module*

13. Computational Modeling

Nummer: *Number*	00LE62S-LAS-LSEE0001		
Modulverantwortlicher: *Responsible person*	Dr. Reto Schölly	**Einrichtung:** *Organisational unit*	University College Freiburg (UCF)
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English
Voraussetzungen zwingend / *Preconditions mandatory*	Maths & Physics (may be waived if you can show that you have sufficient maths background)		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Semester week hours*	4	**Angebotsfrequenz:** *Regular cycle*	Irregularly
Arbeitsaufwand: *Workload*			

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Interdisciplinary Profile

Lernziele / *Learning target*

MATLAB is considered to be one of the most important languages for mathematical computing; it is capable of simulating any mathematical model that can be solved numerically. This course shall provide insight into the basics of mathematical modelling with MATLAB.

Inhalte Vorlesung / *Content of the lecture*

1. Introduction to basic operations (numeric calculations), matrix operations (matrix multiplication, inversion, vector transformation), functions (calculation, parameterization and return values), m-files, and proper formatting.
2. Writing documentations using MATLAB.
3. Fundamentals of modeling with MATLAB: economic systems, chaotic functions, mechanical systems and biological predator/prey systems.
4. Modeling of feedback control using SIMULINK.
5. Introduction to mathematical art. Lecture notes will be provided as a reference and for guidance in the exercises.

The subjects of the students' MATLAB projects can be from various fields – economical simulations are as welcome as physical simulations or geological data analyses. It should be of appropriate complexity, although no bachelor thesisgrade work is expected. Students can either choose to cover a subject that may be already part of their studies or ask the lecturer for a suggestion. Students must have a laptop available throughout the course. Working in pairs is fine.

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Benotung / *Grading*
Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*
Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Literatur / *Literature*
Students must have a laptop available throughout the course.

14. Computational Modeling with Matlab

Nummer: *Number*	11LE68MO-5557		
Modulverantwortlicher: *Responsible person*	R. Schölly	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English
Voraussetzungen zwingend / *Preconditions mandatory*	Maths & Physics (may be waived if you can show that you have sufficient maths background). Students must bring their own laptop throughout the course.		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Semester week hours*	4	**Angebotsfrequenz:** *Regular cycle*	Irregularly in winter
Arbeitsaufwand: *Workload*			

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Sustainable Systems Engineering
  - Interdisciplinary Profile

Lernziele / *Learning target*

MATLAB is considered to be one of the most important languages for mathematical computing; it is capable of simulating any mathematical model that can be solved numerically. This course shall provide insight into mathematical modelling with MATLAB.

Inhalte Vorlesung / *Content of the lecture*

Information to follow

Zu erbringende Prüfungsleistung / *Examination result*

written or oral examination

Benotung / *Grading*

Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*
Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Literatur / *Literature*
Students must have a laptop available throughout the course.

Modul / *Module*

15. Contact, Adhesion, Friction / Kontakt, Adhäsion, Reibung

Nummer: *Number*	11LE50MO-5252		
Modulverantwortlicher: *Responsible person*	L. Pastewska	**Einrichtung:** *Organisational unit*	IMTEK
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English or German
Empfohlene Voraussetzungen: *Recommended preconditions*	Micromechanics		
Zwingende Voraussetzungen: *Mandatory requirements*	Knowledge of a programming language (e.g. Python, C, C++, Fortran, MATLAB)		

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Semester week hours*	2 lecture + 2 exercise	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	180 Hours (64 full-time attendance course of study + 116 self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Sustainable Materials

Lernziele / *Learning target*

The student
- can explain the physical origins of surface forces and the role of elastic deformation in contact;
- knows models for contact and sliding of smooth and rough interfaces in non-adhesive and adhesive limits and can explain their respective range of applicability;
- can explain the mathematical origin of the boundary element method and apply it to solve contact problems in engineering.

Inhalte Vorlesung / *Content of the lecture*

This lecture introduces models for the mechanics of smooth and rough contacts for non-adhesive and adhesive interfaces. Contact mechanical models are applied in many

technological areas, from interpreting atomic-force microscopy data to designing biomimetic adhesives. Examples of these applications will be given throughout the lecture.

1. Introduction: Contact area and contact stiffness
2. Theory of the elastic half-space
3. Contact of nonadhesive spheres: Hertz's theory
4. Physical origins of surface forces
5. Contact of adhesive spheres: Johnson-Kendall-Roberts, Derjaguin-Muller-Toporov, Maugis-Dugdale
6. Surface roughness: Power spectral density, random process model
7. Contact of nonadhesive rough interfaces: Greenwood-Williamson, Persson, modern numerical results
8. Contact of adhesive rough interfaces: Fuller-Tabor, Persson, modern numerical results
9. Tangential and sliding contact: Interfacial shear strength, Cattaneo-Mindlin, Savkoor
10. Contact and sliding of viscoelastic bodies: Persson's model
11. Applications of contact models: Atomic-force microscopy, biological adhesive systems and biomimetic adhesives, failure of MEMS, leakage of seals.

The lecture is accompanied by a computer lab, where the students implement a boundary element method for the solution of contact problems. The computer lab will use the programming language Python. A short introduction into Python is part of the lab sessions.

Zu erbringende Prüfungsleistung / *Examination result*

Oral examination

Zu erbringende Studienleistung / *Course Achievement*

Review/demonstration of boundary element code from exercise sessions.

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*

K. L. Johnson, Contact Mechanics (Cambridge University Press, 1985)
D. Maugis, Contact, Adhesion and Rupture of Elastic Solids (Springer-Verlag, 2000)
J. Israelachvili, Intermolecular and Surface Forces (Academic Press, 1985)

Modul / *Module*

16. Cyber-Physikalische Systeme – Diskrete Modelle / Cyber-Physical Systems – Discrete Models

Nummer: *Number*	11LE13MO-2070		
Modulverantwortlicher: *Responsible person*	Prof. Dr. B. Becker, Prof. Dr. A. Podelski, Prof. Dr. P. Thiemann, Prof. Dr. C. Scholl,	**Einrichtung:** *Organisational unit*	Chair Rechnerarchitektur, Chair Softwaretechnik, Chair Programmiersprachen, Chair Betriebssysteme
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 Term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture and exercises	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Knowledge in Rechnerarchitektur / Computer Architecture and Softwaretechnik / Software Engineering		

Empfohlenes Fachterm:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Term week hours*	3 Lecture + 1 Exercises	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	180 hours (64 full-time attendance course of study + 116 self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Lehramt an Gymnasien in Informatik major subject
- Lehramt an Gymnasien in Informatik additional major subject
- Lehramt an Gymnasien in Informatik major subject in combination with Visual Arts or Music
- Master of Science in Embedded Systems Engineering
- Master of Science in Informatik
  - Cyber-Physical Systems
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technologies

Lernziele / *Learning target*

Students understand how cyber-physical systems, in the wide range of their heterogeneous aspects (large-scale systems, system of systems, embedded systems, concurrent systems, hardware systems, software systems) can be modeled using the basic notion of transition systems. They know relevant formalisms for modeling correctness properties of cyber-

physical systems, and they understand how the models can be analyzed using algorithmic methods in order to prove correctness or find errors.

Inhalte Vorlesung / *Content of the lecture*

The course provides an introduction to discrete models of cyberphysical systems, their analysis and verification:

- The students learn how to model cyber-physical systems as transition systems. Here, the main focus lies on software and hardware aspects of cyber-physical systems and on methods for modeling parallelism and communication.
- Moreover, the students learn how to express properties about such systems. The course covers different mechanisms to specify temporal properties including linear time properties and branching time properties such as LTL, CTL, and CTL* properties.
- Finally, the course demonstrates how to develop algorithms for checking whether these properties hold. After presenting algorithms for explicit state systems we introduce symbolic BDDbased algorithms which are able to tackle the well-known “state explosion problem”. In addition, the course covers basic “Bounded Model Checking” (BMC) techniques which restrict the analysis to computation paths up to a certain length and reduce the verification problem to a Boolean Satisfiability problem.
- All necessary foundations for these algorithms such as fixed point theory, data structures like Binary Decision Diagrams (BDDs), and Satisfiability (SAT) solvers are introduced in the course as well.

Zu erbringende Prüfungsleistung / *Examination result*

written or oral examination

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
• Christel Baier, Joost-Pieter Katoen, Principles of Model Checking, MIT, 2008, ISBN 9780262026499 • B. Berard, M. Bidoit, A. Finkel, F. Laroussinie, Systems and Software Verification, Springer, 2001, ISBN 3642074782 • E. Clarke, O. Grumberg, D. Peled, "Model Checking”, MIT Press 1999 • Kropf, Thomas, "Introduction to Formal Hardware Verification", Springer, 1999, ISBN 3-540-65445-3

Modul / *Module*
17. Cyber-Physikalische Systeme – Hybrid-Modelle / Cyber-Physical Systems – Hybrid Models

Nummer: *Number*	11LE13MO-1207		
Modulverantwortlicher: *Responsible person*	Prof. Dr. B. Becker, Prof. Dr. A. Podelski, Prof. Dr. P. Thiemann, Prof. Dr. C. Scholl,	**Einrichtung:** *Organisational unit*	Chair Rechnerarchitektur, Chair Softwaretechnik, Chair Programmiersprachen, Chair Betriebssysteme
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 Term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture and exercises	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Knowledge in Rechnerarchitektur / Computer Architecture and Softwaretechnik / Software Engineering		

Empfohlenes Fachterm:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Term week hours*	3 Lecture + 1 Exercises	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	180 hours (56 full-time attendance course of study + 124 self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Lehramt an Gymnasien in Informatik major subject
- Lehramt an Gymnasien in Informatik additional major subject
- Lehramt an Gymnasien in Informatik major subject in combination with Visual Arts or Music
- Master of Science in Embedded Systems Engineering
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technologies

Lernziele / *Learning target*

Students understand how cyber-physical systems handling continuous data (e.g. receiving

sensor values and controlling actuators) can be modeled based on transition systems. They know relevant formalisms for modeling systems with continuous parameters including time and probabilities, and they understand how the models can be analyzed using algorithmic methods in order to prove correctness or find errors.

Inhalte Vorlesung / *Content of the lecture*

The course provides an introduction to the modeling and analysis of hybrid systems, i.e. systems with discrete-continuous behavior, from the viewpoint of computer science.

- Hybrid automata are introduced as a syntactic model for hybrid systems. Corresponding labeled transition systems are used to define their semantics.
- Timed automata, as an important subclass of hybrid automata that extend discrete systems with a notion of time are considered. The branching time temporal logic TCTL is introduced to specify properties of timed automata and corresponding model checking algorithms are developed.
- As a further important subclass – more general than timed automata – we define linear hybrid automata. We show that the reachability problem for linear hybrid automata is in general andecidable, whereas boanded reachability, i.e., reachability within a fixed number of steps, is still decidable and can be efficiently computed. We also consider boanded reachability for general hybrid automata and discuss corresponding solution approaches.
- Finally, the course provides basic knowledge on stochastic systems and corresponding model checking algorithms. To do so, we introduce discrete-time Markov chains (DTMMs) and probabilistic computation tree logic (PCTL).

Zu erbringende Prüfungsleistung / *Examination result*

written or oral examination

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2009: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*

Christel Baier, Joost-Pieter Katoen, Principles of Model Checking, MIT, 2008, ISBN 9780262026499

Modul / *Module*

18. Design großer Infrastrukturen / Design of Large Infrastructures

Nummer: *Number*	11LE68MO-9020		
Modulverantwortlicher: *Responsible person*	A. Reiterer	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture and exercises	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	-		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*	2 lectures + 2 exercises	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	150 hours (56 hours Full-time attendance course of study + 94 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering

Lernziele / *Learning target*

The growing world population, the ongoing urbanization, the ever-increasing size, height and complexity of large scale built infrastructure lead to higher risks with respect to natural and manmade threats. Therefore smart designs and monitoring of large infrastructures are required.

Within this context the lecture provides insights in the basic requirements for a safe, secure and resilient design of construction and monitoring of those large urban infrastructures.

In detail students will learn about
- A set of fundamentals and tools to enable architects, structural engineers and building installation engineers assess the safety, security and resilience of designs and to optimize the integral design
- An overview about measurement techniques for monitoring such structures
- A deep view on the corresponding sensor and measurement concepts (focusing on optical systems)
- Using real time data streams for monitoring the resilience of infrastructure

- Smart and reinforced building elements, to measure the actual building condition combined with an increased bearing capacity and resistance

Inhalte Vorlesung / *Content of the lecture*

- Key concepts and ideas to design and monitor large urban infrastructures with respect to safety, security and resilience
- Design concepts for sensor application and structural health monitoring
- Data analysis methods for interoperating and visualizing measurements
- Software aided assessment of infrastructures

Inhalte Übung / *Content of the exercises*

- Key concepts and ideas to design and monitor a large urban infrastructure safe, secure and resilient
- Design concepts for sensor application and structural health monitoring
- Data analysis methods for interoperating and visualizing measurements
- Software aided assessment of infrastructures

Zu erbringende Prüfungsleistung / *Examination result*

Written examination and presentation

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

Master of Science in Sustainable Systems Engineering, academic regulations of 2016: The grade of this module is single-weighted according to the number of its ECTS credits in the calculation of the overall grade.

Literatur / *Literature*

- Literature will be provided at the beginning of the lecture

Modul / *Module*

19. Desktop Publishing – Fundamentals of Graphic Design on the Computer

Nummer: *Number*	00LE55T-BOK-5078		
Modulverantwortlicher: *Responsible person*	FRAUW ZfS	**Einrichtung:** *Organisational unit*	FRAUW ZfS
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	German only
Empfohlene Voraussetzungen: *Recommended preconditions*	Grundkenntnisse in Textverarbeitung und grundlegende Computerkenntnisse. Es werden keine Vorkenntnisse im gestalterischen Bereich oder von Grafik-Programmen erwartet.		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	4
SWS: *Semester week hours*	2	**Angebotsfrequenz:** *Regular cycle*	Irregularly
Arbeitsaufwand: *Workload*			

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Interdisciplinary Profile

Lernziele / *Learning target*

Nach Abschluss der Veranstaltung sind die Studierenden in der Lage, eigene Print- und Digitalmedien mit einer geeigneten Auswahl an Materialien, Grafikformaten, Schriftarten und Exportformaten für den jeweiligen Anwendungszweck zu erstellen. Sie können eigene Projekte von der Skizze bis zum fertigen Produkt selbständig unter Berücksichtigung der jeweiligen Medien- und Materialanforderungen konzipieren und durchführen.

Inhalte Vorlesung / *Content of the lecture*

Relevanz
Kaum ein Unternehmen kommt mehr ohne Internetauftritt, Flyer, Broschüren, Kataloge und grafisch dazu passende digitale Informationsmaterialien in einem ansprechenden Corporate Design und -Identity aus. In den Bereichen Forschung und Lehre müssen Publikationen von Forschungsergebnissen oder Lehrmaterialien ansprechend aufbereitet werden. In öffentlichen Einrichtungen werden digitale Formulare online zur Verfügung gestellt. In all diesen Bereichen setzen DTP-Programme an, die mittlerweile in vielen Berufsfeldern zur Standardausstattung der Arbeitsplatzrechner zählen.

Inhalt
Ziel der Veranstaltung ist es, ein einführendes Verständnis von grafischer Gestaltung und deren softwaretechnischen Umsetzungsmöglichkeiten zu bekommen. Im Einzelnen behandelt werden:

- Arbeitsoberfläche, Dokumente anlegen und einrichten, Funktionen, Werkzeugleisten, Paletten, Symbolleisten, Tabellen, Text- und Bildverarbeitung, Grafik-, Satz- und Layout-Funktionen, Arbeit mit Objekten, Pfaden und Effekten
- Bildformate, Schriftarten, technische Anforderungen an Print- und Digitalmedien sowie an die zu verarbeitenden Materialien, Grundlagen in Typographie und Layout, Umsetzen vorgegebener Gestaltungsrichtlinien
- Vorlagen, Assistenten, Hilfsmittel und Werkzeuge, die einen wichtigen Beitrag zur Vereinfachung, Standardisierung und Rationalisierung von Arbeitsprozessen leisten sowie zur Wiederverwendbarkeit von Workflows
- Im- und Export, Zusammenspiel mit anderen Programmen, Erstellen von digitalen Produkten

Zu erbringende Studienleistung / *Course Achievement*

Regelmäßige Teilnahme an allen Veranstaltungsterminen, Anfertigung eines gestalterischen Projekts, an dem die erworbenen Kenntnisse demonstriert werden. Das gestalterische Projekt wird in Teamarbeit im Anschluss an die Veranstaltung fertig gestellt.

Benotung / *Grading*

Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Literatur / *Literature*

Modul / *Module*

20. Drahtlose Sensornetze / Wireless Sensor Networks

Nummer: *Number*	11LE13MO-1323	**Gültig seid:** *Valid since*	01.04.2016
Modulverantwortlicher: *Responsible person*	Prof. Dr. C. Schindelhauer	**Einrichtung:** *Organisational unit*	Faculty of Engineering, LS Rechnernetze und Telematik
Modultyp: *Module Type*	Wahlmodul	**Moduldauer** *Module duration*	1 Semester
Zugehörige Lehrveranstaltungen: *Connected events*	Vorlesung und Übung	**Sprache:** *Language*	English

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Semester week hours*	3 lecture + 1 exercise	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	180 hours (56 hours full-time attendance course of study + 124 hours self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Wahlmodul für Studierende des Studiengangs

- Bachelor of Science in Embedded Systems Engineering
- Lehramt an Gymnasien in Informatik, Hauptfach
- Lehramt an Gymnasien in Informatik, Erweiterungshauptfach
- Lehramt an Gymnasien in Informatik, Hauptfach in Verbindung mit Bildende Kunst oder Musik
- Master of Science in Embedded Systems Engineering
  - Verteilte Systeme
  - Sensors
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Process Technologies

Lernziele / *Learning target*

Die Studierenden kennen die konkreten Einsatzmöglichkeiten und Anforderungen drahtloser Sensornetze und können Standardmethoden in den einzelnen Schichten anwenden.

Inhalte Vorlesung / *Content of the lecture*
Abgrenzung von drahtlosen Sensornetzen zu mobilen Ad-Hoc-Netzwerken und zellulären Netzwerken, Hardware-Architektur, Software-Aufbau in WSN, die physikalische Schicht, Medium-Zugriff 802.15.4, Sensor-Mac, Routing, Datenzentralität, Informationsaggregation, Energie-Effizienz, Energy Harvesting, Resilienz in drahtlosen Sensor-Netzen, Lokalisierung

Inhalte Übung / *Content of the exercises*
Modulation, Fourier-Transformation, Routing, Lokalisierung, Medium-Zugriff, Synchronisierung, Netzwerk-Lebenszeit aktive Teilnahme im Übungsbetrieb

Zu erbringende Prüfungsleistung / *Examination result*
Schriftliche oder mündliche Abschlussprüfung

Benotung / *Grading*
Die Modulnote errechnet sich zu 100% aus der schriftlichen oder mündlichen Abschlussprüfung.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Bachelor of Science im Fach Embedded Systems Engineering Prüfungsordnungsversion 2011: Die Modulnote wird nach ECTS-Punkten dreifach gewichtet in die Gesamtnote eingerechnet. • Master of Science im Fach Embedded Systems Engineering Prüfungsordnungsversion 2012: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet. • Master of Science im Fach Informatik, Prüfungsordnungsversion 2011: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet. • Master of Science im Fach Sustainable Systems Engineering, Prüfungsordnungsversion 2009: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet. • Master of Science im Fach Mikrosystemtechnik, Prüfungsordnungsversion 2009: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet. • Master of Science im Fach Sustainable Systems Engineering, Prüfungsordnungsversion 2016: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.

Literatur / *Literature*
• Holger Karl and Andreas Willig, Protocols and Architectures for Wireless Sensor

Networks, Wiley, 2005
- Jie Wu, Handbook on Theoretical and Algorithmic Aspects of Sensor
- Ad Hoc Networks and Peer-to-Per Networks, Auerbach, 2005

Modul / *Module*

21. Echtzeitbetriebssysteme / Real-time Operating Systems

Nummer: *Number*	11LE13MO-1217	**Gültig ab:** *Valid from*	01. April 2016
Modulverantwortlicher: *Responsible person*	Prof. Dr. B. Becker, Prof. Dr. C. Scholl,	**Einrichtung:** *Organisational unit*	Chair Rechnerarchitektur, Chair Betriebssysteme
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 Term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture and exercises	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Knowledge in operation systems and technical computer science		

Empfohlenes Fachterm:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Term week hours*	3 Lecture + 1 Exercises	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	180 hours (56 Full-time attendance course of study + 124 Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Lehramt an Gymnasien in Informatik major subject
- Lehramt an Gymnasien in Informatik additional major subject
- Lehramt an Gymnasien in Informatik major subject in combination with Visual Arts or Music
- Master of Science in Embedded Systems Engineering
  - Verteilte Systeme
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technologies

Lernziele / *Learning target*

The students are familiar with basic methods of real-time operating systems. In particular, they know the essential differences between standard operating systems and real-time operating systems for embedded systems both concerning requirements and concerning concepts of realization (especially in the area of scheduling). The students know basic

functions of real-time operating systems and have experience with programming of real-time systems.

Inhalte Vorlesung / *Content of the lecture*
After a brief review of standard operating systems and the hardware requirements for the implementation of operating systems the lecture deals with operating systems for embedded systems and the question how real-time requirements can be fulfilled. In order to answer this question the lecture looks into methods which compute upper bounds to the run time of processes (“worst case execution times”) and into scheduling methods which guarantee meeting certain deadlines under the condition that the run times do not exceed given worst case execution times. Various scheduling approaches are classified with respect to their application area and analyzed with respect to their quality and cost. Moreover, the lecture looks into basic concepts like synchronization and communication of several processes, shared resources, mutual exclusion etc. together with their role in the design of real-time operating systems.

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
Will be announced at the beginning of the course.

Modul / *Module*
22. Einführung in Embedded Systems / Introduction to Embedded Systems

Nummer: *Number*	11LE13MO-910		
Modulverantwortlicher: *Responsible person*	Prof. Dr. B. Becker, Prof. Dr. C. Scholl, Prof. Dr. van Laerhoven	**Einrichtung:** *Organisational unit*	Lehrstuhl Rechnerarchitektur, Lehrstuhl Betriebssysteme, Lehrstuhl Eingebettete Systeme
Modultyp: *Module Type*	Wahlpflichtmodul	**Moduldauer** *Module duration*	1 Semester
Zugehörige Lehrveranstaltungen: *Connected events*	Vorlesung und Übung	**Sprache:** *Language*	Deutsch
Empfohlene Voraussetzungen: *Recommended preconditions*	Wissen und Kenntnisse des vermittelten Lernstoffs des Moduls Technische Informatik		

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Semester week hours*	3 Vorlesung + 1 Übung	**Angebotsfrequenz:** *Regular cycle*	nur im Wintersemester
Arbeitsaufwand: *Workload*	180 Stunden (64 Stunden Präsenzstudium + 116 Stunden Selbststudium)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Pflichtmodul für Studierende des Studiengangs
- Bachelor of Science im Fach Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs
- Lehramt an Gymnasien im Fach Informatik, Hauptfach
- Lehramt an Gymnasien im Fach Informatik, Erweiterungshauptfach
- Lehramt an Gymnasien im Fach Informatik, Hauptfach in Verbindung mit Bildende Kunst und Musik
- Master of Science im Fach Embedded Systems Engineering
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science im Fach Informatik
  - Cyber-Physical Systems
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technologies

Lernziele / *Educational objectives*
Die Studierenden haben ein grundlegendes Verständnis für die spezifischen Eigenschaften von Eingebetteten Systemen. Sie kennen die elementaren Konzepte zum Entwurf derartiger Systeme sowie Kriterien für die Partitionierung in Hardware bzw. Software. Sie kennen die Eigenschaften der Bauelemente eines Eingebetteten Systems und erfassen die daraus resultierenden Anforderungen an Schnittstellen und das Gesamtsystem. Sie sind in der Lage, die spezifischen Restriktionen, die sich durch die physikalischen Gesetze des umgebenden Systems ergeben, einzuschätzen und können diese gezielt in den Entwurfsprozess einbeziehen. Schließlich sind sie sich darüber im Klaren, wie spezifische Methoden aus der Softwaretechnik einerseits und dem Hardwareentwurf andererseits zu einer leistungsfähigen Entwurfsmethodik kombiniert werden können, die Anforderungen bzgl. Größe, Reaktionszeiten, Kosten und Energieverbrauch des resultierenden Gesamtsystems berücksichtigt.

Inhalte Vorlesung / *Content of the lecture*
Eingebettete Systeme gelten als die Schlüsselanwendung der Informationstechnologie in den kommenden Jahren und sind, wie der Name bereits andeutet, Systeme, bei denen Informationsverarbeitung in eine Umgebung eingebettet ist und dort komplexe Regelungs-, Steuerungs- oder Datenverarbeitungsaufgaben übernimmt. Die Vorlesung beschäftigt sich mit grundlegenden Konzepten für Modellierung und Entwurf Eingebetteter Systeme. Sie behandelt u.a. Spezifikationssprachen und Methoden für Eingebettete Systeme (wie z.B. Statecharts, Petrinetze, VHDL), Abbildung von Spezifikationen auf Prozesse, Hardware Eingebetteter Systeme sowie Hardware-/Software-Codesign. Es wird auf die Bauelemente eines Eingebetteten Systems eingegangen (z.B. Prozessoren, AD-/DA-Wandler, Sensoren, Sensorschnittstellen, Speicher) und es werden Methoden zum Entwurf und zur Optimierung der zugehörigen Schaltungen bezüglich Geschwindigkeit, Energieverbrauch und Testbarkeit vorgestellt.

Zu erbringende Prüfungsleistung / *Examination result*
schriftliche oder mündliche Abschlussprüfung

Benotung / *Grading*
Die Modulnote errechnet sich zu 100% aus der schriftlichen oder mündlichen Abschlussprüfung.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Bachelor of Science im Fach Embedded Systems Engineering, Prüfungsordnungsversion 2009: Die Modulnote wird nach ECTS-Punkten dreifach gewichtet in die Gesamtnote eingerechnet. • Bachelor of Science im Fach Embedded Systems Engineering Prüfungsordnungsversion 2011: Die Modulnote wird nach ECTS-Punkten dreifach gewichtet in die Gesamtnote eingerechnet. • Master of Science im Fach Embedded Systems Engineering Prüfungsordnungsversion 2012: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.

- Master of Science im Fach Informatik, Prüfungsordnungsversion 2005: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Master of Science im Fach Informatik, Prüfungsordnungsversion 2011: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Master of Science in Sustainable Systems Engineering, Prüfungsordnungsversion 2016: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.

Literatur / *Literature*

- Marwedel, P.: Embedded System Design. Springer-Verlag New York, Inc., 2006.
- Marwedel, P. ; Wehmayer, L.: Eingebettete Systeme. Springer-Verlag Berlin, 2007.
- Ritter, J. ; Molitor, P.: VHDL - Eine Einführung. Pearson Studium, 2004.
- Chang, K. C.: Digital Design and Modeling with VHDL and Synthesis. IEEE Computer Society Press, 1996.
- Teich, J. ; Haubelt, C.: Digitale Hardware/Software-Systeme. Berlin : Springer-Verlag Berlin, 2007.
- Baker, R. J.; Li, H. W.; Boyce, D. E.: CMOS Circuit Design, Layout, and Simulation. IEEE Press Series on Microelectronic Systems, 1998.
- Rabaey, J. M.; Chandrakasan, A. P.; Nikolic, B.: Digital Integrated Circuits. Prentice-Hall, 2003.
- Tietze, U.; Schenk, C.: Halbleiter Schaltungstechnik. Springer-Verlag, 2002.
- Weste, N.; Eshraghian, K.: Principles of CMOS VLSI Design; A Systems Perspective. Addison-Wesley, 1993.

Modul / *Module*
23. Einführung in die allgemeine Ethik (Proseminar)

Nummer: *Number*	06LE32S-16145PS		
Modulverantwortlicher: *Responsible person*	Prof. Dr. Reiner Marquard	**Einrichtung:** *Organisational unit*	Institut für Philosphie
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Seminar	**Sprache:** *Language*	German

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Seminar	**Angebotsfrequenz:** *Regular cycle*	Each term
Arbeitsaufwand: *Workload*	90 hours (28 or 32 hours Full-time attendance course of study + 58 or 62 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Interdisciplinary Profile

Lernziele / *Learning target*

Inhalte Seminar / *Content of the seminar*

Das Seminar beschäftigt sich mit der Aufgabe der Ethik anhand von Begriffsdefinitionen, mit unterschiedlichen Ethikansätzen (deskriptiv – normativ) und mit Grundfragen der Ethik (Autonomie, Gender). Die theoretischen Erwägungen werden anhand von Beispielen aus der Medizinethik (PND/PID, Gesundheit/Krankheit, Organspende, Sterbehilfe) erschlossen

Kommentar:
„Eine Gesellschaft Stachelschweine drängte sich an einem kalten Wintertage recht nahe zusammen, um durch die gegenseitige Wärme sich vor dem Erfrieren zu schützen. Jedoch empfanden sie die gegenseitigen Stacheln; welches sie dann wieder voneinander entfernte. Wann nun das Bedürfnis der Erwärmung sie wieder näher zusammenbrachte, wiederholte sich jenes zweite Übel, so dass sie zwischen beiden Leiden hin- und hergeworfen wurden. Bis sie eine mäßige Entfernung voneinander herausgefunden hatten, in der sie es am besten aushalten konnten. – Und diese Entfernung nannten sie Höflichkeit und feine Sitte“ (Arthur Schopenhauer).

Die ‚abendländische’ Ethik beginnt in Griechenland [Aristoteles (384-322 v.Chr.) ta êthika].

Aristoteles versteht unter ‚ethisch' die Beschäftigung mit dem Problem der Legitimation von Sitte und Institutionen einer Stadt. Indem Ethik bei Aristoteles nach den gelingenden Regelwerken einer Einwohnerschaft fragt, entzieht sie die Regeln des (Zusammen-)Lebens allein der Legitimation durch das Überkommene wie der Willkür einzelner.

Das Seminar beschäftigt sich mit der Aufgabe der Ethik anhand von Begriffsdefinitionen (Ethik/Moral), mit unterschiedlichen Ethikansätzen (deskriptiv – normativ) und der Frage der ethischen Urteilsbildung sowie mit Grundfragen der Ethik (Autonomie, Gender). Die theoretischen Erwägungen werden anhand von Beispielen aus der Medizinethik (PND/PID, Gesundheit/Krankheit, Organspende, Sterbehilfe) erschlossen.

Zu erbringende Studienleistung / *Course Achievement*

Bemerkung (wenn nötig: zu Prüfungen, Termin, Zielgruppe, evtl. besondere Sprachkenntnisse; Besonderheiten der LV; Anmeldepflicht): Aktive Teilnahme, und Hausarbeit (10 S.)

Benotung / *Grading*

Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Literatur / *Literature*

Pflichtlektüre: Annemarie Pieper, Einführung in die Ethik, München 62007

Modul / *Module*

24. Elektrochemische Energieanwendungen / Electrochemical energy applications

Nummer: *Number*	11LE50MO-5119		
Modulverantwortlicher: *Responsible person*	S. Thiele	**Einrichtung:** *Organisational unit*	IMTEK
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	German
Empfohlene Voraussetzungen: *Recommended preconditions*			

Empfohlenes Fachsemester:: *Recommended term of study*	2 - 4	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	
Arbeitsaufwand: *Workload*	90 hours (32 hours Full-time attendance course of study + 58 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

Lernziele / *Learning target*

The students have acquired an understanding of the relevance of electrochemical systems for the global energy transition. They are able to transfer basic electrochemical effects to different electrochemical systems.

They understand the connections between electrochemical analysis methods and properties of the considered electrochemical systems. They are able to propose simple strategies for the improvement of electrochemical systems.

Inhalte Vorlesung / *Content of the lecture*
Electrochemical systems such as fuel cells, batteries or electrolysis cells are promising approaches for the global energy transition. Based on these examplaric electrochemical systems key electrochemical effects are taught in this course. Additionally partial thematic topics of the global energy transition such as electromobility or energy storage are discussed. Limitations and novel developments of the mentioned electrochemical systems are covered. Finally all important electrochemical characterisations methods are discussed and explained.

Zu erbringende Prüfungsleistung / *Examination result*
written examination

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

Literatur / *Literature*
Will be provided within the lecture.

Modul / *Module*
25. Elektromobilität / Electromobility

Nummer: *Number*	11LE68MO-4111		
Modulverantwortlicher: *Responsible person*	M. Vetter	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English
Voraussetzungen zwingend / *Preconditions mandatory*	Lecture and exam in energy storage		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	75h		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

Lernziele / *Learning target*

- Know-how in various aspects and concepts of electro-mobility for automotive applications (light electric vehicles LEV, electric vehicles EV, plug-in hybrid electric vehicles PHEV), public transport, light and heavy load transport, marine sector as well as aerospace sector.
- Know-how in electrical storage technologies for mobile applications.
- Know-how in system design for mobile applications including peripheral components.
- Know-how in infrastructure concepts and challenges (e.g. fast charging stations).

Inhalte Vorlesung / *Content of the lecture*

- Electromobility in various sectors: Automotive, public transport, marine sector, aerospace, etc.
  - System concepts
  - Typical system designs
  - Infrastructure challenges and solutions
- Overview on relevant electric storage technologies for electromobility
- Storage system design for various mobile applications: module design, electrical,

thermal and mechanical interconnections, thermal management, storage management, integration of peripheral components
- Safety aspects and criteria
- Environmental issues

Zu erbringende Prüfungsleistung / *Examination result*
oral examination

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
• STATUS ELECTROMOBILITY 2016: OR HOW TESLA WILL NOT WIN, Prof. Dr.-Ing. Markus Lienkamp. • G. Pistoia: Lithium-Ion Batteries Advances and Applications.

Modul / *Module*

26. Eingebettete Regelungssysteme Praktikum / Embedded Control Laboratory

Nummer: *Number*	11LE50MO-5251		
Modulverantwortlicher: *Responsible person*	M. Diehl	**Einrichtung:** *Organisational unit*	IMTEK
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	German or English (alternating)
Empfohlene Voraussetzungen: *Recommended preconditions*	Systemtheorie und Regelungstechnik 1 / Systems and Control 1, Systemtheorie und Regelungstechnik 2 / Systems and Control 2, Modellierung und Systemidentifikation / Modelling and System Identification		

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2	**Angebotsfrequenz:** *Regular cycle*	Irregularly in summer term
Arbeitsaufwand: *Workload*	90 hours (28h attendance + 62h self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technologies

Lernziele / *Learning target*

Students are able to model and to simulate a mechatronic system and to design a feedback controller. In particular, they learn how to perform model based controller design and to use a rapid control prototyping approach.

Die Teilnehmenden erlernen für die industrielle Praxis wichtige Fähigkeiten in der Modellierung und der Entwicklung eingebetteter Regelungssysteme. Sie sind in der Lage ein mechatronisches System zu modellieren sowie eine Regelung für das entwickelte System zu entwerfen. Insbesondere lernen die Studierenden den modellbasierten "Rapid Control Prototyping"-Entwicklungsansatz anzuwenden und verschiedene regelungstechnische Verfahren in der Praxis anzuwenden und zu beurteilen.

Inhalte Vorlesung / *Content of the lecture*

Students model an existing mechatronic system. The control is realized via a „Rapid

Control Prototyping“ (RCP) system. The physical system will first be modelled, and the controller will be designed, tested, and tuned with help of computer simulations, until a desired specificatin is met. The control algorithm will then be directly deployed to a an existing control hardware of the RCP system, without the need of further programming.

Die Studierenden modellieren ein existierendes mechatronisches Regelungssystem. Die Regelung wird mittels eines „Rapid Control Prototyping“-Ansatzes (RCP) realisiert. Dazu wird das zu regelnde System modelliert und darauf aufbauend der Regler mit Hilfe von Computersimulationen entworfen, getestet und verfeinert bis eine hinreichende Regelungsgüte in der Simulation erreicht ist. Der gefundene Regelungsalgorithmus wird zum Einsatz im realen Aufbau direkt aus der Simulationsumgebung auf eine existierende Steuerungshardware geladen, die zur echtzeitfähigen Realisierung in der Zielhardware keiner weiteren Programmierung bedarf.

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Zu erbringende Studienleistung / *Course Achievement*
written or oral examination

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
Will be made available to participants at the start of the project.

Modul / *Module*
27. Energy

Nummer: *Number*	00LE62S-LAS-EE0002		
Modulverantwortlicher: *Responsible person*	Dr. Sabine Sané, Johannes Erben	**Einrichtung:** *Organisational unit*	University College Freiburg (UCF)
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	17.04. until 02.06.2017
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Introduction to Earth and Environmental Sciences; an affinity to mathematics and physics is required		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Semester week hours*	4 Seminar & practical work	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*			

Verwendbarkeit der Veranstaltung / *Usability of the module*
Elective Module for students of the study program • Master of Science in Sustainable Systems Engineering   ○ Interdisciplinary Profile

Lernziele / *Learning target*
After this course students will be able to recognize and understand the types and differences between current energy technologies and fuels. Students will be able to evaluate and compare these technologies, and furthermore, to apply their knowledge in current discussions about the benefits and limitations of prospect energy technologies.

Inhalte Vorlesung / *Content of the lecture*
One big challenge of the 21st century is the provision of a growing energy demand due to an increase in population and living standards without destroying the planet. In this respect, the benefits and limitations of traditional sources like coal, gas and oil vs. types of renewable energies like biomass, wind and solar power are often discussed. This course introduces students to the current energy technologies. We will identify potential applications, advantages and limitations of different energy technologies and fuels that drive them by getting to know the sciences behind them.

Students will focus on three main topics:
(1) electrochemical technologies which comprise batteries and fuel cells
(2) heat engines, which include motors, gas turbines, cooling processes and alike and
(3) other (supporting) technologies such as generators, electric motors, nuclear power, wind turbines, solar cells and hydro power.

The theoretical part of the course will be supported by practical work.

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Benotung / *Grading*
Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*
Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Literatur / *Literature*

Modul / *Module*

28. Energiewirtschaft und Energiepolitik / Energy Economics and Energy Policy

Nummer: *Number*	11LE68MO-5555		
Modulverantwortlicher: *Responsible person*	A. Weidlich, J. C. Goldschmidt	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Mandatory modules: Control and Integration of Grids, Solar Energy		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*	2 Lecture + 1 Seminar	**Angebotsfrequenz:** *Regular cycle*	Summer term; once in winter 2017/18
Arbeitsaufwand: *Workload*	150 hours		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Interdisciplinary Profile
  - Energy systems

Lernziele / *Learning target*

The students know and understand the structure of an energy sector for the example of Germany, and are able to systematically assess the structures of other energy markets. They can name different energy policy instruments and explain their working mechanism. They understand the impact of current developments in regulation and policy on the energy sector. They understand the role of non-technical aspects such as belief-systems, vested interests and informal networks in shaping these regulations. The students are able to perform economic calculations that help to assess the profitability of investments in the energy sector. They are able to critically assess energy scenarios. They know about the functioning of different energy markets and their possible future developments with rising shares of renewable energy.

Die Studierenden kennen und verstehen die Struktur eines Energiesystems am Beispiel von Deutschland und sind in der Lage, die Strukturen von Energiemärkten systematisch zu bewerten. Sie können verschiedene Politikinstrumente benennen und ihre Wirkungsweise

erklären. Sie verstehen den Einfluss aktueller Entwicklungen auf Regulierung und Politikmaßnahmen im Energiesystem. Sie verstehen die Rolle, die nicht-technische Aspekte wie Glaubenssysteme, Interessengruppen und informelle Netzwerke bei der Gestaltung der Regulierung spielen. Sie sind in der Lage, Energieszenarien kritisch zu bewerten. Sie verstehen die Funktionsweise verschiedener Energiemärkte und deren mögliche Weiterentwicklung bei steigenden Anteilen erneuerbarer Energien.

Inhalte Vorlesung / *Content of the lecture*

- *Structure of the energy sector and terminology (national energy balances; regulation principles; market roles; specifics of grid-bound energy sectors)*
- *Cost calculations; learning curves; investment appraisal methods*
- *Energy demand and supply (residual load and load curves; balance responsible party; electricity markets; cogeneration; flexibility requirements; marketing of renewable energy; sector coupling)*
- *Energy policy and environment protection instruments*
- *Non-technical aspects shaping energy systems: belief-systems, vested interests and informal networks*

- Struktur von Energiesystemen und Terminologie (nationale Energiebilanzen; Regulierungsprinzipien; Marktrollen; Besonderheiten leitungsgebundener Energiesysteme)
- Kostenberechnungen; Lernkurven; Investitionsrechnungen
- Energienachfrage und Energieversorgung (Residuallast und Lastkurven; Bilanzkreisverantwortung; Strommärkte; Kraft-Wärme-Kopplung; Flexibilitätsbedarfe; Vermarktung erneuerbarer Stromerzeugung; Sektorenkopplung)
- Energiepolitik- und Umweltschutzinstrumente
- Nichttechnische Aspekte, die Energiesysteme beeinflussen: Glaubenssysteme, Interessengruppen und informelle Netzwerke

Inhalte Übung / *Content of the exercise*

- *International comparison of energy systems*
- *Energy scenarios*
- *New developments in an energy system with high shares of renewable energy*
- *Future developments of energy markets*
- *Decentralised energy supply; virtual power plants*
- *Smart metering*

- Internationaler Vergleich von Energiesystemen
- Energieszenarien
- Neue Entwicklungen in Energiesystemen mit hohen Anteilen erneuerbarer Energien
- Zukünftige Entwicklung von Energiemärkten
- Dezentrale Energieversorgung; virtuelle Kraftwerke
- Smart Metering

Zu erbringende Prüfungsleistung / *Examination result*

written or oral examination

Zu erbringende Studienleistung / *Course Achievement*
• Referat, Vortrag / Presentation • schriftliche Ausarbeitung/Protokoll

Benotung / *Grading*
If technical concentration: The module grade is calculated from the result of the final examination. If interdisciplinary profile: Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*
If technical concentration: Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. If interdisciplinary profile: Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Literatur / *Literature*
P. A. Narbel, J. P. Hansen and J. R. Lien: Energy Technologies and Economics, Springer International Publishing Switzerland, 2014. W. Ströbele, W. Pfaffenberger, M. Heuterkes: Energiewirtschaft – Einführung in Theorie und Politik, 3rd edition, Oldenbourg, Munich, 2012.

Modul / *Module*

29. Ringvorlesung "Entrepreneurship" – Fachliche Grundlagen für die Realisierung eigener Geschäftsideen

Nummer: *Number*	---		
Modulverantwortlicher: *Responsible person*	ZfS	**Einrichtung:** *Organisational unit*	ZfS, BOK
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	German only

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	4
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Irregularly in summer term (summer 2017)
Arbeitsaufwand: *Workload*			

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Interdisciplinary Profile

Lernziele / *Learning target*

Inhalte Vorlesung / *Content of the lecture*

Die Teilnehmenden bekommen anhand von Beispielen aus der Praxis einen Einblick in die unternehmerische Welt. Sie lernen, wie aus einer Idee eine Dienstleistung oder ein Produkt wird und entwickeln ausgewählte Geschäftsideen. Expertinnen und Experten aus der Praxis vermitteln in den jeweils eineinhalbstündigen Vorlesungen wesentliche Grundlagen für das Gründen, die dem roten Faden eines Businessplan-Konzepts und des sogenannten Business Model Canvas folgen: Ideen-Beschreibung und Ausarbeitung, Zielgruppen-Ansprache, Marketing und Rechtsformen für den Einstieg in die Selbstständigkeit. Darüber hinaus berichten erfolgreiche selbständige Alumnae und Alumni der Uni Freiburg von ihren Geschäftsideen und von ihrem Weg in die Selbstständigkeit - sei es von ihrer Suche nach Kapital, Unterstützungsmöglichkeiten und Fördermitteln oder der Entwicklung des eigenen Angebots.

Die Teilnehmenden erarbeiten ihr Geschäftsmodell mithilfe des Business Model Canvas. Sie definieren für ihre Produkt- oder Dienstleistungsidee das Alleinstellungsmerkmal, schätzen den Finanzierungsbedarf ab und beschreiben die potenziellen Kundinnen und Kunden sowie Marketing- und Vertriebswege. Zum Ende der Reihe erhalten sie Tipps für

die mündliche Präsentation ihrer ausgearbeiteten Idee.

Zu erbringende Studienleistung / *Course Achievement*
Studierende, die ECTS-Punkte im BOK-Bereich am Zentrum für Schlüsselqualifikationen (ZfS) erwerben wollen, müssen für die Ringvorlesung über das elektronische VVZ einen Belegwunsch abgeben. Folgende Leistungen sind zum Erwerb der Studienleistung (BOK) oder für Teilnehmende, die eine Teilnahmebescheinigung erhalten wollen, erforderlich: Regelmäßige Teilnahme an allen Terminen der Ringvorlesung, Ausarbeitung einer Idee, Business Model Canvas, 4-6-seitiges schriftliches Geschäftskonzept, mündliche Präsentation. Infos dazu unter www.zfs.uni-freiburg.de. Schedule and videos of the lecture: http://www.gruenden.uni-freiburg.de/ausbildung/ringvorlesung-2017/

Benotung / *Grading*
Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Literatur / *Literature*
More information: http://www.gruenden.uni-freiburg.de/ausbildung/ringvorlesung-2017/

Modul / *Module*
30. Environmental Planning

Nummer: *Number*	00LE62S-LAS-GOEE0007		
Modulverantwortlicher: *Responsible person*	M. Gaede	**Einrichtung:** *Organisational unit*	UCF
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	UCF teaching block II: **11.12.17-16.02.18**
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Introduction to Earth and Environmental Sciences; Governance basics		

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Semester week hours*	4 Seminar	**Angebotsfrequenz:** *Regular cycle*	Irregularly in winter term
Arbeitsaufwand: *Workload*			

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Interdisciplinary Profile

Lernziele / *Learning target*

Upon successful completion of this module, you
- understand the key issues affecting contemporary society from the perspective of both the natural and built environment
- should be able to analyse environmental problems effectively and choose suitable assessment tools, methods and technique
- know how to collect, analyse and report environmental information and data in EIA
- improve your skills in analysis, synthesis, reasoned argument and communication considering the background of conflicting stakeholder interests
- present/discuss a selected topic and write a short paper.

Inhalte Vorlesung / *Content of the lecture*

Human beings and nature depend on intact ecosystems. Thus a crucial point seems to be how we can organize ways of using the environment in such a way that a landscape's functions and natural resources are used sustainably. Environmental and spatial planning are among the most important instruments available today for ensuring

sustainable development. The consequences of global change for humanity, flora and fauna, for ecological and economic systems are becoming increasingly apparent and call for specific projects and strategies at both local and regional levels as well as further exploration of the interdependence of systems within our environment. This course will introduce the basic elements of environmental planning, gaining importance to problem-solving at the interface between society and nature and thus comprising both scientific and social-scientific skills.

The first part of the course will provide an introduction to basic features of the planning system in Germany and Europe. In order to understand landscapes in their complexity some of the topics that will be discussed are: What do we understand by environment? What does environmental evaluation mean? What is the difference between evaluation and assessment? What is the function of evaluation in environmental planning? How can scientists or planners choose from different appropriate assessment tools and methods?

In the second part, students will become familiar with selected concepts, theories and instruments of spatial planning and environmental planning, in particular Environmental Impact Assessment (EIA) as a key instrument of European Union environmental policy, Natura 2000 Impact Assessment (Habitats Directive assessments), Interventions in nature and landscape according to Article 14 of the German Act on Nature Conservation and Landscape Management and other instruments. In addition, practical project work in small groups will help the students to transfer new knowledge into their own small surveys and interventions. In the tutorials, selected topics will be presented by the students and further discussed.

The third part will be concerned with linking theory and practice by providing a case study on renewable energy / wind energy.

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Zu erbringende Studienleistung / *Course Achievement*
written or oral examination

Benotung / *Grading*
Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Literatur / *Literature*

Modul / *Module*
31. Environment, Risks, and Us

Nummer: *Number*	00LE62S-LAS-LSEE0002		
Modulverantwortlicher: *Responsible person*	D. Bunke	**Einrichtung:** *Organisational unit*	UCF
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Introduction to Earth and Environmental Sciences or Introduction to Life Sciences		

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Semester week hours*		**Angebotsfrequenz:** *Regular cycle*	Irregularly in winter term
Arbeitsaufwand: *Workload*			

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Interdisciplinary Profile

Lernziele / *Learning target*

In this course students explore the complex relationships between human activities, the environment and resulting risks – for human health as well as for the environment.

Inhalte Vorlesung / *Content of the lecture*

The course deeply engages with different impacts on the environment and with the physical, chemical and biological properties of specific environmental hazards. For several groups of pollutants, their sources are described, their mechanisms of release into the environment, major environmental pathways and fates, and their effect on human health. In addition, students develop basic skills in environmental risk assessment and management strategies. The course will include topics such as properties of eco-labels, assessment of chemicals e.g. chemicals in products from your everyday life, ecotoxicology, assessment of contaminants in surface/drinking waters and their effects on human health, environmental pollutants and their effect on animals, their regulation and their substitution.

Zu erbringende Prüfungsleistung / *Examination result*

written or oral examination

Zu erbringende Studienleistung / *Course Achievement*
written or oral examination

Benotung / *Grading*
Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Literatur / *Literature*

Modul / *Module*
32. Environmental Psychology

Nummer: *Number*	00LE62S-LAS-GOEE0005		
Modulverantwortlicher: *Responsible person*	Sebastian Gölz	**Einrichtung:** *Organisational unit*	University College Freiburg (UCF)
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*			

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Semester week hours*	4	**Angebotsfrequenz:** *Regular cycle*	Irregularly
Arbeitsaufwand: *Workload*			

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Interdisciplinary Profile

Lernziele / *Learning target*

Upon successful completion of this module, students should be able to:
(1) Orient themselves among existing theories of environmental psychology.
(2) Apply psychology theories and models to real-world settings.
(3) Elaborate basic designs for environmental interventions.
(4) Use environmental methodologies in complex transformation settings.
(5) Present/discuss a selected topic and write a paper (short publication).

Inhalte Vorlesung / *Content of the lecture*

Human behaviour is a key factor for current global economic and ecological challenges. On the other hand, it is also a crucial resource which can be used to cope with these challenges. Environmental Psychology is an interdisciplinary field focusing on how human behavior and the physical environment interrelate. It is, for example, not sufficient to simply propose ways to solve global economic and ecological challenges. Substantial changes in people's behavior are also needed. This course will introduce the basic elements of Environmental psychology.
In the first part of the course, students will study psychological theories and modelling (unit

1) along the topics of environmental awareness, climate change and sustainability. In the second part, students will become familiar with typical issues in applied fields of environmental psychology (unit 2) such as the attitudes-behavior gap, behavior in social dilemmas, and interventions and behavioral changes. As different technological innovations (e.g. e-mobility and renewable energies) promise improvement for ecological risks, the third part will focus on ways to combine environmental psychology with the domain of technology usage, acceptance and usability (unit 3). Practical will help the students to transfer new knowledge into their own small surveys and interventions. In the tutorials, selected topics will be presented by the students and discussed in depth.

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Benotung / *Grading*
Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*
Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Literatur / *Literature*

Modul / *Module*

33. Environmental Psychology for Engineers

Nummer: *Number*	11LE68MO-5556		
Modulverantwortlicher: *Responsible person*	S. Gölz	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*	2	**Angebotsfrequenz:** *Regular cycle*	Irregularly in winter term
Arbeitsaufwand: *Workload*	150 hours		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Interdisciplinary Profile

Lernziele / *Learning target*

Upon successful completion of this module, students should be able to:
(1) Orient themselves among existing theories of environmental psychology.
(2) Apply psychology theories and models to real-world settings.
(3) Elaborate basic designs for environmental interventions.
(4) Use environmental psychology methodologies in complex transformation settings.
(5) Present/discuss a selected topic / paper.

Inhalte Vorlesung / *Content of the lecture*

Human behaviour is a key factor for current global economic and ecological challenges. On the other hand, it is also a crucial resource which can be used to cope with these challenges. Environmental Psychology is an interdisciplinary field focusing on how human behavior and the physical environment interrelate. It is, for example, not sufficient to simply propose ways to solve global economic and ecological challenges. Substantial changes in people's behavior are also needed. This course will introduce the basic elements of Environmental psychology.

In the first part of the course, students will study psychological theories and modelling (unit 1) along the topics of environmental awareness, climate change and sustainability.
In the second part, students will become familiar with typical issues in applied fields of environmental psychology (unit 2) such as the attitudes-behavior gap, behavior in social

dilemmas, and interventions and behavioral changes.
As different technological innovations (e.g. e-mobility and renewable energies) promise improvement for ecological risks, the third part will focus on ways to combine environmental psychology with the domain of technology usage, acceptance and usability (unit 3).

Course units in detail (may be subject to change):

- What is environmental behavior / Models explaining environmental behavior
- Qualitative and quantitative research in psychology
- Factors influencing environmental behavior I – Values & Social norms
- Factors influencing environmental behavior II – Symbolic and affective aspects
- Changing behavior
- Encouraging pro-environmental behavior I – Informational strategies
- Encouraging pro-environmental behavior II – Rewards and penalties
- Encouraging pro-environmental behavior III – Persuasive technology
- Nasty challenges I – Habits

Selected topics/papers will be presented by the students and discussed in depth.

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Benotung / *Grading*
Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*
Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Literatur / *Literature*
Will be presented during seminar.

Modul / *Module*

34. Ergebnisse wissenschaftlich präsentieren / Scientific writing and presentation

Nummer: *Number*	11LE50MO-5801SL		
Modulverantwortlicher: *Responsible person*	Prof. Dr. T. Hanemann	**Einrichtung:** *Organisational unit*	Chair Werkstoffprozess-technologien
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Seminar	**Sprache:** *Language*	German or English

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Seminar	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	90 hours (28 hours Full-time attendance course of study + 58 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Interdisziplinäres Profil / Interdisciplinary Profile

Lernziele / *Learning target*

Die Studierenden werden
- über die Bedeutung der Einhaltung der guten wissenschaftlichen Praxis informiert
- in die Lage versetzt, ein Labortagebuch (Laborjournal) und einfache wissenschaftliche Berichte zu schreiben
- über das Erstellen einer Master- bzw. Promotionsarbeit informiert
- in die Lage versetzt, einen wissenschaftlichen Vortrag (15 min), einen Kurzvortrag (3 min), ein wissenschaftliches Poster sowie ein Werbeposter zu erstellen und zu präsentieren.

Inhalte Vorlesung / *Content of the lecture*

The following topics will be covered during the course:
- Ancient and current scientific malpractice
- Rules for safeguarding good scientific practice
- Laboratory journal, Scientific reports (from project reports to dissertation thesis)
- Lecture presentation
- Oral poster presentation (3 minutes lecture)

- Scientic poster presentation, "Advertisement" poster

Zu erbringende Studienleistung / *Course Achievement*
Written or oral examination

Benotung / *Grading*
Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded, but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Modul / *Module*

35. Funktionale Sicherheit: Aktive Resilienz / Functional Safety: Active Resilience

Nummer: *Number*	11LE50MO-5120	**Gültig seid:** *Valid since*	2017
Modulverantwortlicher: *Responsible person*	I. Häring	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Grundlagen in den Bereichen Systemmodellierung, Systemanalyse, Zuverlässigkeitsbewertung oder Sicherheitsbewertung für eine ausgewählte technische Fachdisziplin wären hilfreich, insbes. Elektrotechnik oder Informatik. Any basics in the areas of system modelling, system analysis, reliability or safety assessment for a selected technical discipline would be appreciated, in particular electronics and informatics.		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	90 h (28 Anwesenheit / attendance + 62 Selbststudium / self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering
- Master of Science in Mikrosystemtechnik & Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
- Master of Embedded Systems Engineering
  - Zuverlässige eingebettete Systeme
  - Design and Smulation

Lernziele / *Learning target*

Lernziele umfassen die anwendbare Kenntnis des Konzepts Sicherheit und Resilienz von Systemen mit Hilfe von ausreichend zuverlässigen aktiven Systemfunktionen aufrechtzuerhalten bzw. herzustellen, sowie entsprechender grundlegender Vorgehens-, Entwicklungs- und Nachweisprozesse. Ferner wie diese Prozesse mit Hilfe von Techniken und Maßnahmen und ihrer effizienten Kombination unterstützt werden sowie welche Kennzahlen hierfür grundsätzlich eingesetzt werden können. Weitere Lernziele sind

Überblickswissen zu den häufigsten in der Praxis verwendeten Techniken und Maßnahmen sowie modernere Erweiterungen und neuere Methoden. Im Bereich der fachspezifischen Methoden, im Gegensatz zu allgemein auf Systeme anwendbaren Methoden, liegt der Schwerpunkt auf Systemen, die auch Elektronikhardware und Software verwenden. Ferner soll begleitend ein Überblick über aktuellere Anwendungsbeispiele (z. B. autonome Fahrfunktionen, Mensch-Roboter Kollaboration) sowie die sich entwickelnde Normenlandschaft erworben werden.

Learning objectives include the applicable knowledge of the concept of maintaining or generating safety, security and resilience of systems by means of sufficiently reliable active system functions as well as the corresponding basic procedure, development and verification and validation processes. Furthermore, how these processes are supported by techniques and measures and their efficient tailoring and combination as well as which technical quantities are typically used. Other learning objectives are to know the most practically used techniques and measures as well as modern extensions and newer methods. In the area of disciplinary specific methods, as opposed to generally on systems applicable methods, the focus is on methods that also use electronic hardware and software. Accompanying the students gain an overview on more recent application domains and examples (e. g. autonomous driving functions) as well as the developing standardization landscape.

Inhalte Vorlesung / *Content of the lecture*

Hauptinhalte umfassen:
1. Grundlagen und Definition der funktionalen Sicherheit
2. Zusammenhang Funktionale Sicherheit, Resilienz, Safety und Security: Definition Resilienzfunktion
3. Sicherheitslebenszyklusmodelle, allgemeine Anforderungen und Anforderungen an die Phasen
4. Analysemethoden und ihre Kombination zur Identifikation und Festlegung von Sicherheits- und Resilienzfunktionen, insbes. induktive (z. B. HL, HA, ETA, DFM), deduktive (z. B. FTA) analytische Methoden, graphische, algebraische und semi-formale sowie ihre geeignete Kombination
5. Methoden zur Allokation der Funktionen bzw. zur Festlegung von funktionalen Sicherheits- und Resilienzdesigns
6. Quantitative Kenngrößen (z. B. SIL, HFT, DC, DD, DU)
7. Überblick Methoden für Hardware und Software
8. Überblick neuere und neue Methoden (z. B. TFTA, Markovmodelle und –prozesse)
9. Anwendungsbereiche und -beispiele
10. Normenlandschaft

Main contents comprise:
1. Fundamentals and definition of functional safety
2. Relation of functional safety to resilience, safety and security: definition of resilience functions
3. Safety lifecycle models, general and phase-specific requirements
4. Analytical methods and their combination for the identification and determination of safety and security resilience functions, especially inductive (e.g. HL, HA, FMEDCA, ETA, DFM), deductive (e.g. FTA) analytical methods, graphical, algebraic and semi-formal
5. Methods for the allocation of safety functions and generation of functional safety and resilience designs
6. Quantities for functional safety (e.g. HR, SIL, DC, DD, DU)
7. Methods for hardware and software

8. Method extensions and emerging methods (e.g. TDFT, Markov models and processes)
9. Application domains and examples
10. Standardization landscape

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science im Fach Sustainable Systems Engineering, Prüfungsordnungsversion 2016: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet. • Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
Example literature/ Sample literature: Satisfying safety goals by probabilistic risk analysis, Hiromitsu Kumamoto, Springer 2007 Modern statistical and mathematical methods in reliability, Alyson Wilson et. al. (eds.), World Scientific, 2005 Mathematical and statistical methods in reliability, Bo H Lindqvist and Kyell A Doksum, World Scientific, 2003 Elektronische Sicherheitssysteme, Josef Börcsök, Hüthig, 2004 Funktionale Sicherheit: Grundzüge sicherheitstechnischer Systeme, Hüthig, 2014 Zuverlässigkeitstechnik, Arno Meyna and Bernhard Pauli, Hanser, 2010 The safety critical systems handbook, David J. Smith, Butterworth-Heinemann, 2010 Funktionale Sicherheit im Automobil, Hans-Leo Ross, Hanser, 2014 FRAM: the functional resonance analysis method, Erik Holnagel, Ashgate, 2012 Control systems safety evaluation and reliability, William M. Gobe, 2010 Further information: http://www.iec.ch/about/brochures/pdf/technology/functional_safety.pdf

Modul / *Module*

36. Höchstleistungsrechnen mit Python / High-Performance Computing with Python

Nummer: *Number*	11LE50MO-5253		
Modulverantwortlicher: *Responsible person*	L. Pastewska, A. Greiner	**Einrichtung:** *Organisational unit*	IMTEK
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English or German
Zwingende Voraussetzungen: *Mandatory requirements*	Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)		

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Semester week hours*	2 lecture + 2 project	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	180 Hours (64 full-time attendance course of study + 116 self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technologies

Lernziele / *Learning target*

The student
- can use Python for solving numerical problems using the numpy and scipy libraries and know strategies for writing efficient code
- can apply the Message Passing Interface (MPI) libraries to parallelize specific numerical problems
- can use job submission systems on parallel computers to run their Python codes.

Inhalte Vorlesung / *Content of the lecture*

This lecture teaches Python basics and fast array operations with the numpy library for numerical problems. Parallelization strategies using the Message Passing Interface will be discussed.

1. Python basics: Containers, flow controls, functions
2. Python numerics: numpy arrays, numpy operations, scipy
3. Parallelization and scalability

4. The Message Passing Interface
5. Parallelization strategies for numerical simulations: Loop-level parallelization, domain decomposition
6. Interfacing Python with other languages
7. Practical aspects of working with High-Performance clusters

The students will implement their own parallel simulation code in the accompanying project.

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Zu erbringende Studienleistung / *Course Achievement*
Review/demonstration of simulation code from project

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
A. Scopatz, K.D. Huff, "Effective Computation in Physics" (O'Reilly 2015)

Modul / *Module*

37. Inelastisches Materialverhalten: Viskoelastizität und Plastizität / Inelastic Material Behaviour: Viscoelasticity and Plasticity

Nummer: *Number*	11LE68MO-4203		
Modulverantwortlicher: *Responsible person*	I. Schmidt	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Basic knowledge in engineering mechanics		

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture + 1 exercises	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	90 hours (48 hours full-time attendance course of study + 42 hours self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / *Learning target*

The module shall acquaint the students with the phenomenological description of viscoelastic and plastic material behaviour. The students get to know the manifestation of inelastic material behaviour as well as its mathematical description. They are able to interpret experimental findings and to assess which aspect of the material behaviour is relevant under which conditions. They are able to deal with stress analysis problems in simple engineering structures.

Inhalte Vorlesung / *Content of the lecture*

- Fundamentals: Stress and strain tensor, equilibrium conditions, linear elasticity, linear viscous behavior
- Viscoelasticity: Phenomenology, rheological models, constitutive law in rate- and integralform, Correspondence principle

- Plasticity: Phenomenology, incremental plasticity formulation, yield condition, flow rule, hardening

Inhalte Übung / *Content of the exercises*

Application of constitutive laws to simple engineering structures, determination of stress distributions

Zu erbringende Prüfungsleistung / *Examination result*

written or oral examination

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Master of Science im Fach Sustainable Systems Engineering, Prüfungsordnungsversion 2016: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*

- Gross, Hauger, Wriggers: Technische Mechanik 4, Springer
- Christensen: Theory of Viscoelasticity: An Introduction, Academic Press
- Lubliner: Plasticity Theory, McMillan

Modul / *Module*
38. Introduction to Earth and Environmental Sciences

Nummer: *Number*	00LE62V-LAS-EE0001; 00LE62S-LAS-EE0001		
Modulverantwortlicher: *Responsible person*	Dr. Sabine Sané	**Einrichtung:** *Organisational unit*	University College Freiburg (UCF)
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	12.06. until 29.07.2017
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*			

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Semester week hours*		**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*			

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Interdisciplinary Profile

Lernziele / *Learning target*

Inhalte Vorlesung / *Content of the lecture*

Many stores in Germany stopped selling plastic bags. But is it really better for the environment to use paper instead of plastic?
Questions like this are often discussed in everyday life. In this course we will analyze these questions in a scientific manner by exploring the broad field of the Earth and Environmental Sciences. Thereby, students will also get to know the basics behind this discipline. We will focus on sustainability by engaging with the environmental, social and economic dimensions of it. Students will be introduced to methods used to quantify the sustainability of products, activities and processes which will enable them to analyze decision-making processes towards more environmental sustainability in an academic manner.
Furthermore, students will discover research methods used in Earth and Environmental Sciences through practical work. This will introduce them further to the great variety of fields the Earth and Environmental Sciences tackle.

You will get informed about the exact schedule latest on the 1st day of the course (e.g.

courses may not start each Wednesday at 8:15h). However, until then, do not plan anything throughout the timeframe indicated in the LAS course catalog (see UCF hompage).

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Benotung / *Grading*
Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*
Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Literatur / *Literature*

Modul / *Module*

39. Keramische Werkstoffe der Mikrotechnik / Ceramic Materials for Microsystems

Nummer: *Number*	11LE50MO-5102		
Modulverantwortlicher: *Responsible person*	Prof. Dr. T. Hanemann	**Einrichtung:** *Organisational unit*	Chair Werkstoff Process Technology
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	German
Empfohlene Voraussetzungen: *Recommended preconditions*	Kenntnisse der Werkstoffwissenschaft, z.B. Zustandsdiagramme, physikalische Eigenschaften verschiedener Materialklassen, Kristallsysteme, thermodynamische Eigenschaften und Kinetik kristalliner und nichtkristalliner Festkörper		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	90 hours (28 hours full-time attendance course of study + 62 hours self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / *Learning target*

Ziel des Moduls ist es, die technologischen und physikalischen Grundlagen der keramischen Werkstoffe und die zugehörigen Prozessierungsmethoden zu vermitteln. Mikrosystemtechnisch relevante Aspekte der keramischen Werkstoffe und ihrer

Prozessierungsmethoden sollen aufgezeigt werden.

Inhalte Vorlesung / *Content of the lecture*
Im ersten Teil werden die allgemeinen Aspekte keramischer Werkstoffe mit den Schwerpunkten Oxid- und Nichtoxidkeramiken sowie Magnetkeramiken behandelt. Weitere Kapitel betreffen die Herstellung keramischer Pulver, die Charakterisierung von Pulvern und Keramiken und die Herstellung und Beschreibung von Pulversuspensionen. Anschließend wird die Herstellung keramischer Komponenten für die Mikrotechnik nach unterschiedlichen Verfahren (Trockenpressen, Schlickergießen, elektrophoretische Abscheidung, Foliengießen, pulverkeramisches Spritzgießen) vorgestellt. Die Lecture schließt mit einer Einführung in Sinterprozesse. Es besteht die Möglichkeit, im Anschluss an die Lecture ein ca. 2-wöchiges BlockLaboratory zu absolvieren. Dieses dient dazu die in der Lecture theoretisch behandelten Themen praktisch umzusetzen.

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Sustainable Systems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
Begleitend zur Lecture wird ein Skriptum und werden Handzettel der Lecturesfolien zur Verfügung gestellt.

Modul / *Module*

40. Konstitutive Gleichungen und Diskretisierungsverfahren zur Versagensmodellierung / Physics of Failure

Nummer: *Number*	11LE50MO-5121		
Modulverantwortlicher: *Responsible person*	S. Hiermaier	**Einrichtung:** *Organisational unit*	Chair Nachhaltige Ingenieurssysteme
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	90 hours (32 hours Full-time attendance course of study + 58 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
  - Master of Science in Microsystems Engineering Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

Lernziele / *Learning target*

With this module Students are able to distinguish between damage and failure as two distinct process types in materials as other thermo-mechanic behaviors. Basic differences between phenomenological and physics based modeling approaches become evident. Specifically, the multi-scale character of the process is recognized. The resulting dimension of related resources for computations as well as the necessity for scale-bridging methodologies is learnt. Furthermore, a variety of experimental and numerical methods for characterizing and modeling the processes is investigated.

Inhalte Vorlesung / *Content of the lecture*

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science im Fach Sustainable Systems Engineering, Prüfungsordnungsversion 2016: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet. • Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Modul / *Module*

41. Kontinuumsmechanik I / Continuum mechanics I

Nummer: *Number*	11LE68MO-4301	**Gültig seid:** *Valid since*	01.10.2016
Modulverantwortlicher: *Responsible person*	D. Helm	**Einrichtung:** *Organisational unit*	Institut für Nachhaltige Technische Systeme
Modultyp: *Module Type*	Elective module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Advanced mathematics; engineering mechanics		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	90 hours (32 hours Full-time attendance course of study + 58 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering
  - Nachhaltige Materialien / Sustainable Materials
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering Engineering
  - Design and simulation
  - Materials
  - Personal Profile

Lernziele / *Learning target*

The objective of the module is to master the mathematical foundations of continuum mechanics in form of tensor algebra and tensor analysis as well as the knowledge of the basic structure of continuum mechanics.

Inhalte Vorlesung / *Content of the lecture*

- Mathematical foundations of continuum mechanics (specialized to orthonormal base systems) consisting of tensor algebra and tensor analysis
- Introduction to the basic strucutre of continuum mechanics (kinematics, balance equations, constitutive relations).

The focus lies on the treatment of small deformations and simplified examples with reference to engineering mechanics.

Zu erbringende Prüfungsleistung / *Examination result*

Written or oral examination

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Master of Science in Sustainable Systems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*

- M. Itskov, Tensor Algebra and Tensor Analysis for Engineers, Springer, 2013

Modul / *Module*

42. Kontinuumsmechanik I mit Übung / Continuum mechanics I with exercises

Nummer: *Number*	11LE68MO-4302	**Gültig seid:** *Valid since*	2018
Modulverantwortlicher: *Responsible person*	D. Helm	**Einrichtung:** *Organisational unit*	Institut für Nachhaltige Technische Systeme
Modultyp: *Module Type*	Elective module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Advanced mathematics; engineering mechanics		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Semester week hours*	2 Lecture + 2 exercises	**Angebotsfrequenz:** *Regular cycle*	Summer term (starting from 2018)
Arbeitsaufwand: *Workload*	180 hours (64 hours Full-time attendance course of study + 116 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering
  - Nachhaltige Materialien / Sustainable Materials
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering Engineering
  - Design and simulation
  - Materials
  - Personal Profile

Lernziele / *Learning target*

The objective of the module is to master the mathematical foundations of continuum mechanics in form of tensor algebra and tensor analysis as well as the knowledge of the basic structure of continuum mechanics.
The content of the topics of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.

Inhalte Vorlesung / *Content of the lecture*
• Mathematical foundations of continuum mechanics (specialized to orthonormal base systems) consisting of tensor algebra and tensor analysis • Introduction to the basic strucutre of continuum mechanics (kinematics, balance equations, constitutive relations). The focus lies on the treatment of small deformations and simplified examples with reference to engineering mechanics.

Inhalte Übung / *Content of the exercises*
The content of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.

Zu erbringende Prüfungsleistung / *Examination result*
Written or oral examination

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Sustainable Systems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
• M. Itskov, Tensor Algebra and Tensor Analysis for Engineers, Springer, 2013

Modul / *Module*

43. Kontinuumsmechanik II / Continuum mechanics II

Nummer: *Number*	11LE68MO-4303	**Gültig seid:** *Valid since*	01.10.2016
Modulverantwortlicher: *Responsible person*	D. Helm	**Einrichtung:** *Organisational unit*	Institut für Nachhaltige Technische Systeme
Modultyp: *Module Type*	Elective module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	• Kontinuumsmechanik I / Continuum mechanics I • Kontinuumsmechanik I mit Übung / Continuum mechanics I with exercises		

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	90 hours (32 hours Full-time attendance course of study + 58 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering
  - Nachhaltige Materialien / Sustainable Materials
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering Engineering
  - Design and simulation
  - Materials
  - Personal Profile

Lernziele / *Learning target*

The objective of the course is the knowledge of nonlinear continuum mechanics and its applications in solid state and fluid mechanics.

Inhalte Vorlesung / *Content of the lecture*

- Kinematics for finite deformations: representation of motion, strain tensors etc. at large deformations, geometric linearization
- Balance relations of mechanics and thermomechanics
- Principles of mechanics: principle of D'Alembert, principle of virtual displacements
- Constitutive relations for fluids and solids (e.g. lienar-elastic fluid, finite elasticity, viscoelasticity, plasticity, viscoplasticity, heat conduction, ...)
- Extension of the mathematical foundations of tensor algebra and tensor analysis to general base systems and curved coordinates

Zu erbringende Prüfungsleistung / *Examination result*

Written or oral examination

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Master of Science in Sustainable Systems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*

- P. Haupt, Continuum Mechanics and Theory of Materials, Springer Verlag, 2002

Modul / *Module*

44. Kontinuumsmechanik II mit Übung / Continuum mechanics II with exercises

Nummer: *Number*	11LE68MO-4304	**Gültig seid:** *Valid since*	2018
Modulverantwortlicher: *Responsible person*	D. Helm	**Einrichtung:** *Organisational unit*	Institut für Nachhaltige Technische Systeme
Modultyp: *Module Type*	Elective module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	• Kontinuumsmechanik I / Continuum mechanics I • Kontinuumsmechanik I mit Übung / Continuum mechanics I with exercises		

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Winter term (starting from 2018)
Arbeitsaufwand: *Workload*	90 hours (32 hours Full-time attendance course of study + 58 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering Engineering
  - Design and simulation
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / *Learning target*

The objective of the course is the knowledge of nonlinear continuum mechanics and its applications in solid state and fluid mechanics. The content of the topics of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.

Inhalte Vorlesung / *Content of the lecture*
• Kinematics for finite deformations: representation of motion, strain tensors etc. at large deformations, geometric linearization • Balance relations of mechanics and thermomechanics • Principles of mechanics: principle of D'Alembert, principle of virtual displacements • Constitutive relations for fluids and solids (e.g. lienar-elastic fluid, finite elasticity, viscoelasticity, plasticity, viscoplasticity, heat conduction, ...) • Extension of the mathematical foundations of tensor algebra and tensor analysis to general base systems and curved coordinates

Inhalte Übung / *Content of the exercises*
The content of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.

Zu erbringende Prüfungsleistung / *Examination result*
Written or oral examination

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Sustainable Systems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
• P. Haupt, Continuum Mechanics and Theory of Materials, Springer Verlag, 2002

Modul / *Module*

45. Kristalline Silicium-Photovoltaik / Crystalline silicon photovoltaics

Nummer: *Number*	11LE68MO-4102		
Modulverantwortlicher: *Responsible person*	S. Glunz	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Solar energy (mandatory module); Basic knowledge of semiconductor physics		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Irregular
Arbeitsaufwand: *Workload*	90 hours (28 hours Full-time attendance course of study + 62 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

Lernziele / *Learning target*

The aim of this module is to get a detailed understanding of the physics and technology of crystalline silicon cell and modules. The module will cover the whole value chain from silicon feedstock via cell technology up to module technology. It will give a deep insight into the actual industrial technology and also into advanced concepts.

Inhalte Vorlesung / *Content of the lecture*

- Principle structure and components of a silicon solar cell
- Definition of conversion efficiency
- Physics of silicon solar cells
- Production of crystalline silicon for solar cells (From quartz to silicon wafers)
- Characterization of silicon material and wafers
- Production process of silicon solar cells (From wafers to cells)
- Characterization of silicon solar cells
- Electrical optimization of solar cells (incl. modelling exercises)

- Optical optimization of solar cells (incl. modelling exercises)
- Module technology (From cells to modules)
- Advanced silicon solar cells

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

Literatur / *Literature*
- P. Würfel, Physics of Solar Cells. From Principles to New Concepts, Wiley-VCH, 2005 - A. Goetzberger, B. Voß und J. Knobloch, Sonnenenergie: Photovoltaik, Teubner, 1997 - M.A. Green, Solar Cells, University of New South Wales, 1982

Modul / *Module*

46. Laser Scanning for Mapping Large Structures

Nummer: *Number*	11LE68MO-4205		
Modulverantwortlicher: *Responsible person*	A. Reiterer	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Grundverständnis für optische Messtechnik *Basic understanding of optical measurement techniques*		
Zwingende Voraussetzungen: *Mandatory requirements*	Grundlagen in Optik und Physik *Basics of Optics and Physics*		

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	90 hours		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

Lernziele / *Learning target*

Vermittlung des Verständnisses für den Aufbau und Einsatz von Laser Scanning für die Erfassung, Dokumentation und Überwachung von Großstrukturen. Einordnung von Spezifikationen kommerziell erhältlicher Systeme und Lösungen. Vor- und Nachteile von Laser Scannern für ausgewählte Anwendungen.

The lecture provides an understanding of the design and use of laser scanning for documentation and monitoring of large structures. Classification of specifications for commercially available systems and solutions. Advantages and disadvantages of laser scanners for selected applications.

Inhalte Vorlesung / *Content of the lecture*

- Grundlagen der messtechnischen Begriffe (Genauigkeit, Präzision, Auflösung, etc.)
- Komponenten eines Laser Scanners
- Herausforderungen beim mobilen Laser Scanning
- Registrierung von Punktwolken
- Geo-Referenzierung von Punktwolken
- Projektbeispiele
- Übung: Lösung konkreter Projektbeispiele (Konzipierung von Messsystemen, Vor- und Nachteile verschiedener Ansätze)

- *Basics of measurement terminology (accuracy, precision, resolution etc.)*
- *Components of a laser scanner*
- *Challenges of mobile laser scanning*
- *Registration of point clouds*
- *Georeferencing of point clouds*
- *Project examples*
- *Exercise: Solution of concrete project examples (design of measurement systems, advantages and disadvantages of different approaches)*

Zu erbringende Prüfungsleistung / *Examination result*

written or oral examination

Zu erbringende Studienleistung / *Course Achievement*

Um zur Abschlussprüfung zugelassen zu werden, muss an 8 von 10 Terminen teilgenommen werden.

The students have to attend the lecture at 8 out of 10 dates in order to be admitted to the final module exam.

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*

Modul / *Module*

47. Lattice Gas Methoden / Lattice Gas Methods

Nummer: *Number*	11LE50MO-5504a		
Modulverantwortlicher: *Responsible person*	A. Greiner	**Einrichtung:** *Organisational unit*	Chair Simulation
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture and exercises	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	It is advantageous but not necessary to be familiar with the basic topics of the course "Simulation".		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Semester week hours*	2 lecture + 2 exercises	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	180 hours (56 hours Full-time attendance course of study + 124 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / *Learning target*

Lecture:
The students will learn the basic theoretical descriptions of the Lattice Gas and of the Lattice Boltzmann method and their derivation from
kinetic theory. The students will understand the application of these two methods to the computational tasks for the simulation of fluid flow.

Practical exercises:
The students will learn to apply the Lattice Gas method as well as Lattice Boltzmann method to special problems in fluid dynamics. They
will be assigned to implement the methods into an algorithm, estimate the computational cost for a given problem, and they will learn to elaborate
the result obtained by the simulation and give a detailed interpretation of the fluid flow phenomena under investigation.

Inhalte Vorlesung / *Content of the lecture*

The lectures will cover the following topics:

- From classical mechanics to statistical mechanics
- Concepts of thermodynamics
- Formal classical transport theory
- The Boltzmann transport equation (BTE)
- Methods for solving the BTE
- Simple Lattice Gas Method
- Lattice Boltzmann Method

Inhalte Übung / *Content of the exercises*

This exercise will accompany the topics given in the course on Advanced Topics in Simulation: Lattice Gas Methods. The exercises will focus on problems to be solved with the software tool Mathematica.
The students will be assigned with a project to be solved by Mathematica.
To pass the exercises, students have to pass minimum 50 % of the exercises sheets.

Zu erbringende Prüfungsleistung / *Examination result*

Written or oral examination

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the

calculation of the overall grade.

- Master of Science in Sustainable Systems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Modul / *Module*

48. Leistungselektronik für die Elektromobilität / Power Electronics for E-Mobility

Nummer: *Number*	11LE68MO-4106		
Modulverantwortlicher: *Responsible person*	S. Reichert	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English
Zwingende Voraussetzungen: *Mandatory requirements*	Power Electronic Circuits and Devices (elective module)		

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	90 hours (28 hours full-time attendance course of study + 62 hours self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

Lernziele / *Learning target*

It is the aim of this module to get a fundamental understanding of power electronic circuits used in E-Mobility applications like traction inverters, bidirectional chargers and onboard energy management.
The students will learn different circuit topologies and basic control structures for power electronic circuits. The interaction between the power grid and electric vehicles will be discussed.

Inhalte Vorlesung / *Content of the lecture*

Power Electronics for E-Mobility applications:

- Conductive and inductive chargers for electric vehicles
- Traction inverters and electric motors
- DC/DC converters for onboard energy management
- Control of grid connected inverters
- E-Mobility as an instrument for a better grid integration of renewable energies

Exercises/Tutorials are included in the lecture.

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
default

Literatur / *Literature*
Teodorescu R., Liserre M., Rodriguez P.; Grid Converters for Photovoltaic and Wind Power Systems, Wiley-IEEE, 2011

Modul / *Module*

49. Leistungselektronik für Photovoltaik und Windenergie / Power Electronics for Photovoltaics and Wind Energy

Nummer: *Number*	11LE68MO-4107		
Modulverantwortlicher: *Responsible person*	B. Burger	**Einrichtung:** *Organisational unit*	Energy Systems
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English
Zwingende Voraussetzungen: *Mandatory requirements*	Power Electronics Circuits and Devices (elective module)		
Empfohlene Voraussetzungen: *Recommended preconditions*	Knowledge in Electrical Components (Semiconductors, Inductors, Capacitors)		

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	90 hours (28 hours full-time attendance course of study + 62 hours self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

Lernziele / *Learning target*

Power electronics circuits convert the DC power of PV modules to grid compatible AC power. Wind turbines produce AC power with variable frequency, which has to be converted to AC with grid frequency. The commonly used hardware topologies of power electronic converters for renewable energies are shown and explained in detail. Additional aspects like MPP-tracking, supply of reactive power, low voltage ride through (LVRT) etc. are discussed.

Inhalte Vorlesung / *Content of the lecture*

- Solar Module Integrated Electronics
- Single Phase String Inverters
- Three Phase String Inverters
- Battery Chargers and Off-Grid Inverters

- PV System Technology
- Frequency converters for Wind Energy

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
default

Literatur / *Literature*
Robert W. Erickson, Dragan Marksimovic: Fundamentals of Power Electronics Mohan, Undeland, Robbins: Power Electronics http://nptel.ac.in/courses/Webcourse-contents/IIT%20Kharagpur/Power%20Electronics/New_index1.html https://en.wikipedia.org/wiki/DC-to-DC_converter https://en.wikipedia.org/wiki/Power_inverter https://en.wikipedia.org/wiki/Variable-frequency_drive

Modul / *Module*

50. Mechanische Eigenschaften und Degradationsmechanismen / Mechanical Properties and Degradation Mechanisms

Nummer: *Number*	11LE50MO-5115		
Modulverantwortlicher: *Responsible person*	Prof. Dr. C. Eberl	**Einrichtung:** *Organisational unit*	Chair Mikro- und Werkstoffmechanik
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	90 hours (28 hours Full-time attendance course of study + 62 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials
  - Resilienz / Resilience Engineering

Lernziele / *Learning target*

The goal is to learn how materials properties can be understood and evaluated and how they impact functionality and performance of materials and micro systems. You will learn about the physical mechanisms in structural and functional materials as well as damage evolution during the applications lifetime. Based on the physical understanding you will be able to evaluate materials and microsystem designs, improve their lifetime and performance.

This allows specifying materials and systems closer to their performance limit.

Inhalte Vorlesung / *Content of the lecture*

Introduction: physical mechanisms
Fundamentals in stress and strain as well as anisotropic properties
Fundamentals in mechanics of beams and membranes explained in examples
Micro- and nanostructured materials in micro systems
Small scale characterization of mechanical properties
Intrinsic stresses
Elastic and plastic behavior
Adhesion properties
Physical principles and loading conditions in functional materials for actors and sensors.

Zu erbringende Prüfungsleistung / *Examination result*

written or oral examination

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*

- M. Ohring: „The Materials Science of Thin Films“, Academic Press, 1992
- L.B. Freund and S. Suresh: „Thin Film Materials“
- T.H. Courtney: „Mechanical Behaviour of Materials“, Mc-Graw-Hill, 1990
- M. Madou: Fundamentals of Microfabrication“, CRC Press 1997

- W. Menz und P. Bley: „Mikrosystemtechnik für Ingenieure“, VCH Publishers, 1993
- Chang Liu: Foundations of MEMS, Illinois ECE Series, 2006

Modul / *Module*
51. Mikroelektronik / Micro-electronics

Nummer: *Number*	11LE50MO-7050/672		
Modulverantwortlicher: *Responsible person*	Prof. Dr. Y. Manoli	**Einrichtung:** *Organisational unit*	Fritz-Hüttinger Professur für Mikroelektronik
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture and exercises	**Sprache:** *Language*	German or English
Empfohlene Voraussetzungen: *Recommended preconditions*	Basiswissen in Elektrotechnik und gute Kenntnisse in Elektronik, insbesondere in folgenden Themenbereichen: • Halbleiterdiode • Bipolar Transistor • MOS Transistor • Operationsverstärker • Einführung in die Digitaltechnik • Grundgatter & Schaltungsfamilien • Digitale elektrische Systeme • Sequentielle Schaltungen		

Empfohlenes Fachsemester:: *Recommended term of study*	1	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*	2 Lecture + 2 Exercisesg	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	150 hours (64 hours full-time attendance course of study + 86 hours self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technology

Lernziele / *Learning target*

Modulteil Mikroelektronik:
Nach Teilnahme an diesem Modul sind Studierende in der Lage, elementare analoge integrierte Schaltkreise wie Stromspiegel und Differenzverstärker zu verstehen und zu entwerfen. Die Studierenden beherrschen die physikalischen Grundlagen des MOS-Transistors und können mit diesem Wissen einfache analoge integrierte Schaltungen entwerfen. Darüber hinaus können mikroelektronische Systeme auf Block- und Transistorebene analysiert werden.

Modulteil Micro-electronics:

Having attended the module, the students will be able to understand and to design widely used basic analog integrated circuits like current mirrors and differential amplifiers. The students understand the physical principles and the use of MOS transistors in circuits and are able to build simple circuits. Furthermore, they will be able to analyze microelectronic systems on block and on transistor level.

Inhalte Vorlesung / *Content of the lecture*

This course covers the fundamentals of microelectronics for analog circuits. It starts with a review of the CMOS process and the available components. Then, current sources, single stage amplifiers and differential amplifiers are discussed in time and frequency domain. The presentation of basic circuit concepts and their enhancements is completed with an introduction into analog circuit layout and a discussion of electronic noise in circuits.
At last, applications of the presented circuits are shown, with a special focus on MEMS sensor readout.

List of contents:
1. Introduction and review of CMOS technology and available components
2. Small signal equivalent circuit
3. Current sources
4. Single stage amplifier and its frequency behaviour
5. Differential amplifiers
6. Noise in electronic circuits
7. Analog layout
8. MEMS Applications

Inhalte Übung / *Content of the exercises*

A weekly exercise is offered. Four short tests (quizzes) during the semester will be written at the beginning of the exercise class. Approximately 40 % of the maximum points have to be achieved in order to be allowed to write the final examination.

Zu erbringende Prüfungsleistung / *Examination result*

Written or oral examination

Zu erbringende Studienleistung / *Course Achievement*

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science im Fach Sustainable Systems Engineering, Prüfungsordnungsversion 2016: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet. • Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
• Allen, Holberg: CMOS Analog Circuit Design, Oxford University Press • Sedra, Smith: Microelectronic Circuits, Oxford University Press • Razavi: Design of Analog CMOS Integrated Circuits, McGraw-Hill Higher Education.

Modul / *Module*
52. Nanomaterialien / Nanomaterials - Lecture

Nummer: *Number*	11LE50MO-5104		
Modulverantwortlicher: *Responsible person*	Prof. Dr. Zacharias, Dr. Hiller	**Einrichtung:** *Organisational unit*	IMTEK
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Laboratory	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	90 hours (28 hours Full-time attendance course of study + 62 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - MEMS Processing
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / *Learning target*

Inhalte Vorlesung / *Content of the lecture*

After a short introduction on basics of bottom-up growth the lecture will summarize the state of the art knowledge in nanomaterials growth. Highly relevant examples from research will be discussed in detail developing the knowledge of material growth as well as basic understanding in selected growth techniques. The bottom-up growth will be discussed on selected examples which include: carbon nanotubes, Si nanoclusters and nanocrystals, Si

nanowires, ZnO nanowires, colloidal methods for II-VI nanoclusters, nanobiological systems. The lecture will also include some basic knowledge on size effects and high resolution characterization methods. At the end methods of functionalizing nanomaterials and surfaces will be taught.

Zu erbringende Prüfungsleistung / *Examination result*

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Sustainable Systems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
Script

Modul / *Module*
53. Nanomaterialien / Nanomaterials - Laboratory

Nummer: *Number*	11LE50P-5105		
Modulverantwortlicher: *Responsible person*	Prof. Dr. Zacharias, Dr. Hiller	**Einrichtung:** *Organisational unit*	IMTEK
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	Deutsch

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Laboratory	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	90 hours (28 hours Full-time attendance course of study + 62 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - MEMS Processing
  - Personal Profile
  - Master of Science in Microsystems Engineering Life Sciences: Biomedical Engineering
  - MEMS Processing
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / *Learning target*

Inhalte Vorlesung / *Content of the lecture*

Fabrication of size-controlled silicon quantum dots
Atomic layer deposition (ALD) of ZnO thin films
Gold nanodots/lines via phase shift nanolithography
ZnO nanowire growth via vapor-solid (VS) method

SnO2 nanowire growth via ionic-liquid assisted vapor-liquid-solid method (VLS)
Photoluminescence spectroscopy of Si and ZnO nanostructures
Imaging and elemental analysis of nanostructures using scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDX)

Zu erbringende Prüfungsleistung / *Examination result*

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Sustainable Systems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
Script

Modul / *Module*

54. Netzfreie Methoden in technischen Anwendungen / Particle Methods in Engineering

Nummer: *Number*	11LE50MO-5122		
Modulverantwortlicher: *Responsible person*	S. Hiermaier G. Ganzenmüller	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Semester week hours*	2 Lecture + 2 Exercises	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	180 hours (56 hours Full-time attendance course of study + 124 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Wahlpflichtmodul für Studierende folgender Studiengänge /
Elective Module for students of the study program

- Master of Science in Mikrosystemtechnik / *Microsystems Engineering*
  - Materials
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / *Sustainable Materials*
  - Resilienz / *Resilience Engineering*

Lernziele / *Learning target*

Netzfreie Methoden sind ein alternatives Diskretisierungsverfahren für die partiellen Differentialgleichungen der Kontinuumsmechanik. Im Vergleich zu den etablierten netzbasierten Verfahren, z.B. Finite Elemente oder Euler-CFD, besitzen netzfreie Methoden Vorteile wenn große Deformationen abgebildet werden sollen. So sind typische Einsatzgebiete für netzfreie Methoden der Automobilcrash, Meteoritenimpakt, Bird-Strike auf Flugzeuge, aber auch zerspanende Vorgänge in der Fertigung.

Lernziele:

- Verstehen der prinzipiellen Vorgehensweisen bei der Diskretisierung von gekoppelten Differentialgleichungen in Zeit und Raum.
- Erfahrung im Programmieren eines C++-Programms für dynamische Simulationen
- Verstehen von explizite Zeitintegrationsalgorithmen
- Erwerben von grundlegenden Kenntnissen der Kontinuumsmechanik und der

Materialmodellierung

Meshfree Methods are alternative approaches for discretizing the partial differential equations of continuum mechanics. In comparison with the established mesh-based methods for this purpose, i.e., Finite Elements or Euler-CFD, meshfree methods offer advantages when large deformations are to be modelled. Typical applications of meshfree methods include automotive crash, meteorite impact analysis, bird-strike in aviation, and machining processes such as drilling.

Learning targets:

- *Understanding of the principal steps involved in discretizing coupled differential equations in space and time*
- *Acquiring practice in programming C++-code for dynamic simulations*
- *Understanding explicit methods for time integration*
- *Acquiring fundamental knowledge in continuum mechanics and numerical modelling of material behaviour.*

Inhalte Vorlesung / *Content of the lecture*

Inhalte der Vorlesung:

- Systeme von interagierenden Teilchen – Newtonsche Dynamik und Grundlagen der Moleküldynamik
- Zeitintegrationsalgorithmen
- Kontinuumsmechanik und das gekoppelte System von partiellen Differentialgleichungen, welche den Erhalt von Masse, Impuls und Energie beschreiben
- Übergang von diskreten Körpern (so wie in der Moleküldynamik) hin zu Volumenelementen, welche die Domäne beschreiben, innerhalb der die partiellen Differentialgleichungen definiert sind.
- SPH – Smooth Particle Hydrodynamics als die prototypische netzfreie Methode
- Kernelfunktionen, Näherungswerte für Felder und Divergenzen
- SPH für Festkörper und Fluide
- Gekoppelte Fluid-Festkörper Simulationen

Content of the Lecture

- *Systems of interacting particles – Newtonian Dynamics and basic Molecular Dynamics*
- *Time integration algorithms*
- *Continuum mechanics and the set of partial differential equations which describe conservation of mass, energy, and momentum*
- *Transition from discrete bodies (as in Molecular Dynamics) to volume elements which represent the domain on which the partial differential equations are defined.*
- *SPH – Smooth Particle Hydrodynamics as the prototypical meshfree method*
- *Kernel functions, field and divergence estimators*
- *SPH for fluids and solids*
- *Coupled fluid and solid simulations*

Zu erbringende Prüfungsleistung / *Examination result*

Mündliche oder schriftliche Prüfung

written or oral exam

Benotung / *Grading*

Die Modulnote errechnet sich zu 100% aus der schriftlichen oder mündlichen Abschlussprüfung.

The module grade is entirely calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Master of Science in Sustainable Systems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*

- William Graham Hoover, *Smooth Particle Applied Mechanics, The State of the Art*, Advanced Series in Nonlinear Dynamics: Volume 25, World Scientific Publishing, 2006
- D. C. Rapaport, *The Art of Molecular Dynamics Simulation*, Cambridge University Press, 2004
  see also: http://www.ph.biu.ac.il/~rapaport/mdbook/index.html
- Daniel V. Schroeder, *Interactive molecular dynamics*, American Journal of Physics 83, 210 (2015); doi: 10.1119/1.4901185
  see also: http://physics.weber.edu/schroeder/md/InteractiveMD.html

Modul / *Module*

55. Neurowissenschaften für Ingenieure / Neuroscience for Engineers

Nummer: *Number*	11LE50MO-5319		
Modulverantwortlicher: *Responsible person*	U. Egert	**Einrichtung:** *Organisational unit*	IMTEK
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English or German (English if necessary; all slides and texts used are in English)
Empfohlene Voraussetzungen: *Recommended preconditions*	Prior lectures on biology will be helpful but are not mandatory.		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 lecture + 1 exercise	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	90 hours (42 attendance + 48 self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Interdisciplinary profile

Lernziele / *Learning target*

The aim of this module is to convey an understanding of fundamental neuroscientific concepts, methods, processes and structures that define or influence the function of technical components in biomedical applications.

Inhalte Vorlesung / *Content of the lecture*

The lecture series conveys the foundations of various neuroscientific processes, structures and measuring techniques. We emphasize processes that
- influence the generation and properties of signals measurable with neuronal systems,
- influence the usability of MST components, such as sensors and implants,
- are relevant for typical fields of application of MST components, e.g. implantable sensors, prostheses, neurotechnology, etc..

In the course of the lectures we will present and overview of central neuroscientific concepts, tools and applications. Main topics are:

- Structure of the nervous systems
- Biophysics of electrical potentials
- Neuronal networks and their signals
- Sensory systems
- Foundations of learning and memory
- Interaction with neuronal networks

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Zu erbringende Studienleistung / *Course Achievement*
written or oral examination

Benotung / *Grading*
Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Literatur / *Literature*
Literature will be presented during the lecture

Modul / *Module*

56. Numerical Optimal Control in Science and Engineering

Nummer: *Number*	11LE50MO-5249		
Modulverantwortlicher: *Responsible person*	M. Diehl	**Einrichtung:** *Organisational unit*	IMTEK
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Project *Numerical Optimal Control in Engineering*	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Numerical Optimization (NUMOPT), Modelling and System Identification (MSI), Systems and Control Bachelor or Master lectures		
Zwingende Voraussetzungen: *Mandatory requirements*	Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses		

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Semester week hours*	4 Lecture & Exercise	**Angebotsfrequenz:** *Regular cycle*	Irregularly in winter term
Arbeitsaufwand: *Workload*	180 hours		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Information Processing Technologies

Lernziele / *Learning target*

Die Studierenden verstehen wichtige in der Praxis verwendete numerische Methoden für die Lösung von Optimalsteuerungsproblemen und sind in der Lage, diese selbstständig anzuwenden.

Inhalte Vorlesung / *Content of the lecture*

- Introduction: Dynamic Systems and Optimization
- Rehearsal of Numerical Optimization
- Rehearsal of Parameter Estimation
- Discrete Time Optimal Control
- Dynamic Programming
- Continuous Time Optimal Control
- Numerical Simulation Methods

- Hamilton-Jacobi-Bellmann Equation
- Pontryagin and the Indirect Approach
- Direct Optimal Control
- Differential lgebraic Equations
- Periodic Optimal Control
- Real-Time Optimization for Model Predictive Control

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Zu erbringende Studienleistung / *Course Achievement*
Precondition to be admitted to the final module examination is the succesful completion of the associated exercise. Details about the exercise will be given at the start of the course and in HISINONE.

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
• Manuscript "Numerical Optimal Control" by M. Diehl and S. Gros • Biegler, L.T., Nonlinear Programming, SIAM, 2010

Modul / *Module*
57. Numerical Optimal Control in Engineering - Project

Nummer: *Number*	11LE50MO-5250		
Modulverantwortlicher: *Responsible person*	M. Diehl	**Einrichtung:** *Organisational unit*	IMTEK
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture *Numerical Optimal Control in Science and Engineering*	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*			
Zwingende Voraussetzungen: *Mandatory requirements*	Participation in the project is only possible for participants of the lecture *Numerical Optimal Control in Science and Engineering* which takes place in the same semester.		

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	1	**Angebotsfrequenz:** *Regular cycle*	Irregularly
Arbeitsaufwand: *Workload*	90 hours		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Information Processing Technologies

Lernziele / *Learning target*

Die Studierenden sind in der Lage, numerische Methoden der optimalen Steuerung selbstständig zu programmieren, zu analysieren und anzuwenden.

Students can independently program, analyse and apply numerical methods for optimal control problems.

Inhalte Vorlesung / *Content of the lecture*

Das Projekt besteht in der Implementierung einer oder mehrerer selbstgewählter Optimalsteuerungsmethoden auf dem Computer und ihrer Anwendung auf ein oder mehrere selbstgewählte Anwendungsprobleme. Der Fokus kann eher auf Algorithmen und Performancevergleichen oder auf der Modellierung eines spezifischen Problems liegen.

Resultat des Projektes ist ein dokumentierter Computer Code, ein Report, sowie eine öffentliche Präsentation.

The project work consists of a computer implementation of one ore more self-chosen optimal control methods and the application to one or more application problems. The focus could be more on the algorithmic side, e.g. on comparing different algorithm variants, or more on the modelling side, e.g. formulating and solving on interesting optimization problem. The project results are a documented computer code, a project report, and a public presentation.

Zu erbringende Prüfungsleistung / *Examination result*

written or oral examination: for details see HISINONE

Zu erbringende Studienleistung / *Course Achievement*

Um zur Abschlussprüfung zugelassen zu werden, muss die zu diesem Modul gehörige Lehrveranstaltung "Numerical Optimal Control in Science and Engineering" erfolgreich absolviert werden.

Successful participation in the lecture "numerical optimal control"

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*

http://syscop.de/teaching/

Modul / *Module*

58. Oberflächenanalyse / Surface Analysis

Nummer: *Number*	11LE50MO-5606-1		
Modulverantwortlicher: *Responsible person*	Prof. Dr. J. Rühe	**Einrichtung:** *Organisational unit*	Chair Chemie und Physik von Grenzflächen
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	90 hours (28 hours Full-time attendance course of study + 62 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - MEMS Processing
  - Personal Profile
  - Master of Science in Microsystems Engineering Life Sciences: Biomedical Engineering
  - MEMS Processing
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / *Learning target*

XPS, TEM, FTIR, UPS, SEM, AFM, SPR, GIR, ATR, STM?? Got it?
The performance of Sustainable Systems is often dominated by the nature of the surfaces involved. This course honours the great importance of surfaces and interfaces in Sustainable Systems engineering by introducing the most common techniques for surface analysis. Examples will be presented which are typical to various fields of Sustainable Systems engineering.

Inhalte Vorlesung / *Content of the lecture*

The techniques presented are grouped into three general topics which are imaging of surfaces (electron microscopy, scanning probe techniques), chemical analysis (XPS, SIMS, FTIR) of the composition of surfaces and methods for the determination of thicknesses (Ellipsometry, XRR, Surface Plasmon Spectroscopy) of layers. General topics from the surface sciences such as adhesion, wetting, and adsorption processes are also presented together with the techniques.

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Sustainable Systems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
Various materials are available on the website.

Modul / *Module*

59. Oberflächenanalyse Praktikum / Surface Analysis Lab

Nummer: *Number*	11LE50P-5311		
Modulverantwortlicher: *Responsible person*	Prof. Dr. J. Rühe	**Einrichtung:** *Organisational unit*	Chair Chemie und Physik von Grenzflächn
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Laboratory	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	90 hours (28 hours Full-time attendance course of study + 62 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - MEMS Processing
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / *Learning target*

Bei Mikrosystemen, speziell bei solchen für die Mikrofluidik, können aufgrund des geringen Volumens Oberflächeneffekte nicht mehr vernachlässigt werden. In vielen Fällen dominieren die Eigenschaften der Oberfläche gar das Verhalten des Gesamtsystems. Ähnliches lässt sich für Bauteile sagen, die z.B. als Sensor mit biologischen Flüssigkeiten in Kontakt gebracht werden. Deshalb kommt der Oberflächenanalytik bei vielen in der Mikrosystemtechnik relevanten Fragestellungen eine zentrale Bedeutung zu. Im Praktikum sollen ausgewählte oberflächenanalytische Techniken vorgestellt und deren jeweilige Stärken und Limitierungen anhand von Beispielen aufgezeigt werden. Als Beispiele werden Fragestellungen gewählt, wie sie in den "Life Sciences" häufig auftreten.

Inhalte Vorlesung / *Content of the lecture*
Topic 1: **Determination of the layer thickness and roughness of biocompatible coatings** Experiment 1: Using ellipsometry and x-ray reflectometry to determine the thickness of hydrogel coatings Topic 2: **Wetting of surfaces – Surface free energies** Experiment 2: Measurement of the contact angles of test liquids in various surfaces; Determination of the surface free energy using the Zisman method Experiment 3: Generation and characterization of microarrays on various surfaces Topic 3: **Proteins / peptides on surfaces** Experiment 4: Measurement of the adsorption of blood proteins on surfaces using Surface Plasmon Resonance Experiment 5: Characterization of the structure of protein layers using Fourier Transform Infrared Spectroscopy Topic 4: **DNA at surfaces** Experiment 6: Visualisation of DNA on mica using the Atomic Force Microscope

Zu erbringende Prüfungsleistung / *Examination result*
Before each experiment there will be an oral examination and for each experiment the student has to submit a written laboratory report.

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Sustainable Systems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
Script

Modul / *Module*
60. Operations Research für Energiesysteme / Operations Research for Energy Systems

Nummer: *Number*	11LE68MO-5558		
Modulverantwortlicher: *Responsible person*	A. Weidlich	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*	3 lecture, exercise & seminar	**Angebotsfrequenz:** *Regular cycle*	This module will be offered for the first time in winter semester 2017/18. The regular cycle (frequency) will be defined later.
Arbeitsaufwand: *Workload*	150h		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
• Master of Science in Sustainable Systems Engineering
  ○ Energiesysteme / Energy Systems
  ○ Interdisciplinary Profile

Lernziele / *Learning target*
The students have an overview of different optimization problems in the energy sector and can choose an appropriate method for problem solving. They understand the mathematical background of linear programming, mixed-integer linear programming and other techniques that are widely applied in the energy economy. They are able to formulate mathematical models (objective functions, constraints) and are able to apply optimization methods with the help of computational tools. The students understand the background of different forecasting methods and can carry out forecasts based on time series and multiple linear regression. Die Studierenden haben einen Überblick über verschiedene Optimierungsprobleme im Energiesektor und können eine geeignete Methode zur Problemlösung auswählen. Sie verstehen den mathematischen Hintergrund von linearer und gemischt-ganzzahliger linearer Programmierung sowie weiteren in der Energiewirtschaft verbreiteten Methoden. Sie sie sind in der Lage, mathematische Modelle (Zielfunktionen, Nebenbedingungen) zu

formulieren und sie rechnergestützt zu lösen. Die Studierenden verstehen den Hintergrund verschiedener Prognosemethoden und können Prognosen basierend auf Zeitreihen und multipler linearer Regression durchführen.

Inhalte Vorlesung / *Content of the lecture*

- *Optimization problems in energy economics (e. g. unit commitment, resource scheduling)*
- *Linear and mixed-integer linear programming*
- *Dynamic programming*
- *Multi-criteria decision analysis*
- *Multiple linear regression*
- *Time series-based forecasting*

Associated exercise:
Computational tools for optimization

- Optimierungsprobleme in der Energiewirtschaft (z. B. Kraftwerkseinsatzplanung)
- Lineare und gemischt-ganzzahlige lineare Programmierung
- Dynamische Programmierung
- Multi-kriterielle Entscheidungsunterstützung
- Multiple lineare Regression
- Zeitreihenbasierte Prognosen

Associated exercise:
- Computational tools for optimization

Zu erbringende Prüfungsleistung / *Examination result*

written examination;
presentation

Zu erbringende Studienleistung / *Course Achievement*

Presentation

Benotung / *Grading*

If technical concentration:
The module grade is calculated from the result of the final examination.
If interdisciplinary profile:
Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*

If technical concentration:
Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

If interdisciplinary profile:
Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Literatur / *Literature*

- Suhl, L., Mellouli, T.: Optimierungssysteme : Modelle, Verfahren, Software, Anwendungen. 2. Auflage, Berlin : Springer, 2009.
- Poler, R., J. Mula, M. Díaz-Madronero: Operations Research Problems: Statements and Solutions, Springer, Berlin / Heidelberg, 2014.
- Williams, H. P.: Model Building in Mathematical Programming, 5th Edition, John Wiley & Sons, 2013.

Modul / *Module*
61. Optische Eigenschaften von Mikro- und Nanostrukturen / Optical Properties of Micro and Nano Structures - Vorlesung

Nummer: *Number*	11LE50MO-5211		
Modulverantwortlicher: *Responsible person*	PD Dr. Gombert, Andreas	**Einrichtung:** *Organisational unit*	Technische Fakultät (Verantwortlicher); Institut für Mikrosystemtechnik (Verantwortlicher)
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 Term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*			

Empfohlenes Fachterm:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Term week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	90 hours (32 Full-time attendance course of study + 58 Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Lehramt an Gymnasien in Informatik major subject
- Lehramt an Gymnasien in Informatik additional major subject
- Lehramt an Gymnasien in Informatik major subject in combination with Visual Arts or Music
- Master of Science in Embedded Systems Engineering
- Master of Science in Informatik
  - Cyber-Physical Systems
- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technologies

Lernziele / *Learning target*

Inhalte Vorlesung / *Content of the lecture*

Micro and nano structures have optical properties that differ from macroscopic bodies. The interaction between incident light or more generally incident electromagnetic radiation may lead to a modification of the propagation direction, the polarisation, and the spectral signature of absorption, reflection or transmission. In micro systems or similar technologies these phenonema can be used on purpose or need to be considered when manufacturing micro and nano structures. In this lecture we will work on the theoretical fundamentals as well as on selected applications.

Topics:

- Calculating with complex amplitudes
- Energy transfer at boundaries
- Two beam interference
- Huygens´ principle
- Fresnel´s zone construction
- Introduction into Fourier optics
- Kirchhoff-Fresnel diffraction integral
- Fresnel diffraction
- Fraunhofer diffraction
- Introduction into diffraction gratings
- Spectroscopic gratings
- Theory and applications of subwavelength gratings
- Photonic crystals
- Resonant structures in metalsProduction technologies for micro structures with optical functions

Zu erbringende Prüfungsleistung / *Examination result*

written or oral examination

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
• M. Klein, T. Furtak: Optics, Springer-Verlag 1988 • E. Hecht: Optics, Addison-Wesley, 1989 • J. W. Goodman, Introduction to Fourier Optics, Mc Graw-Hill 1988.

Modul / *Module*

62. Partikelsimulationsmethoden / Particle Simulation Methods

Nummer: *Number*	11LE50MO-5505a		
Modulverantwortlicher: *Responsible person*	A. Greiner	**Einrichtung:** *Organisational unit*	Chair Simulation
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture and exercises	**Sprache:** *Language*	English

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Semester week hours*	2 lecture + 2 exercises	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	180 hours (64 hours Full-time attendance course of study + 116 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering Engineering
  - Design and Simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / *Learning target*

Lecture:
The students will learn about alternative approaches to the simulation of hydrodynamic phenomena relevant for Sustainable Systems engineering. They will have a basic understanding of Molecular Dynamics, Dissipative Particle Dynamics and Smoothed Particle Hydrodynamics. They will understand the relation to continuum methods for fluid dynamics. The students will acquire the knowledge on how to apply particle methods to specific problems in microfluidics simulation.

Practical exercises:
The will be able to compile an adequate model for the description of the phenomenon under investigation. They will be able to decide which of the the respective particle methods detailed in the lecture to apply for the solution. The students will understand the meaning of particle simulation methods as an experimental tool to investigate materials behaviour through the usage of a particle simulation program and the solution of modeling and simulation assigment.

Inhalte Vorlesung / *Content of the lecture*

The lecture will cover the following topics:

- From classical mechanics to statistical mechanics
- Concepts of thermodynamics
- Molecular Dynamics (MD): Basics
- MD: Numerical Techniques
- Dissipative Particle Dynamics (DPD)
- Smothed Particle Hydrodynamics
- Energy conserving DPD
- Degrees of freedom internal to dissipative particles

Inhalte Übung / *Content of the exercises*

These exercises will accompany the topics given in the course on Advanced Topics in Simulation: Particle Methods. The exercises will focus on problems to be solved with the software tool SYMPLER, developed at IMTEK Simulation. SYMPLER is a software package published under the GPL (see http:sympler.org). It XML input language and provides a wide range of tools for the analysis of results. Direct graphical output can be followed on the computer screen. An interface to Paraview is included to observe different states of the simulation and to produce videos from the results. The students will be assigned with a project to be solved by SYMPLER. To this end, a detailed introduction on the usage of SYMPLER will be given.
To pass the exercises, students have to pass minimum 50 % of the exercises sheets.

Zu erbringende Prüfungsleistung / *Examination result*

Written or oral examination

Zu erbringende Studienleistung / *Course Achievement*

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*

- J. M. Haile, Molecular dynamics simulation: elementary methods, Wiley (1997)
- D. C. Rapaport, The art of molecular dynamics simulation, Cambridge Univ. Press (2004)
- Andrew R. Leach, Molecular modelling: principles and applications, Prentice Hall (2001)
- sympler.org

Modul / *Module*
63. Photovoltaik-Praktikum / Photovoltaic Laboratory

Nummer: *Number*	11LE68MO-4108		
Modulverantwortlicher: *Responsible person*	S. Glunz, N. Tucher	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English
Voraussetzungen zwingend / *Preconditions mandatory*	Mandatory module “solar energy”		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*	3	**Angebotsfrequenz:** *Regular cycle*	Summer term, Irregularly in winter term
Arbeitsaufwand: *Workload*	150 hours (35h attendance + 115h preparation and self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

Lernziele / *Learning target*

The Photovoltaic Laboratory provides an opportunity for hands-on experience with the PV-related topics introduced in the Solar Energy course. Students will get to know solar cells from a practical view and gain experience in interconnection and operation of solar cells, including evaluation of their performance. Students will understand the electrical properties of solar cells e.g. the IV-curve and related parameters; they will experience the influence of environmental conditions such as temperature, intensity of the incoming light and the angle of incidence. The examination of solar cells as a component part in electrical circuits will enable students to solve typical problems, e.g. how to connect a couple of single cells reasonably to build up a module or how to avoid problems caused by shading. Knowledge about the behavior and performance on load when used as power source is very important for the application of solar cells. Off-Grid systems will also be investigated as a practical application scenario for photovoltaic. This will bring students in contact with electrical components such as load-regulators, storage etc. These are elementary topics for solid knowledge of solar cells and crucial for ongoing research of a more application-oriented use of solar cells.

Inhalte Vorlesung / *Content of the lecture*

A broad variety of laboratory experiments will address the operating characteristics of solar cells and photovoltaic modules. Different experiments will be performed each week. These experiments include:

- Fundamental electric basics: series and parallel connection of solar cells
- Geometrical aspects and environmental conditions: Illumination, angle of incidence and temperature dependence of the solar cell power
- Solar cell characterization: IV-curve in the dark and under illumination, maximum power point and fill factor
- Building up PV modules: I-V-characteristics of different solar modules and partial shading
- Working principle of mpp-tracking: DC/DC inverter
- Solar cells as power supply: on-load power and internal resistance
- Components and operation of a solar off-grid system
- Comparison and operation of different charge controllers: shunt-, series- and PWM regulator
- Discharge protection and DC/AC inverter

Zu erbringende Prüfungsleistung / *Examination result*

- Presentation of experimental results
- Admission requirements for the exam; see under “Course Achievement”.

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Zu erbringende Studienleistung / *Course Achievement*

- Attendance of all laboratory sessions
- Protocols of performed laboratory experiments

Both are admission requirements for the exam.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Master of Science im Fach Sustainable Systems Engineering, Prüfungsordnungsversion 2016: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*

- Smets, Solar Energy, UIT Cambridge 2016
- P. Würfel, Physik der Solarzelle, Spektrum - Akademischer Verlag 2000

- A. Goetzberger, B. Voß und J. Knobloch, Sonnenenergie: Photovoltaik, Teubner 1997
- M.A. Green, Solar Cells, University of New South Wales 1982
- K. Mertens, Photovoltaik, Hanser 2011
- J. Nelson, The physics of solar cells, Imperial College Press 2008

Modul / *Module*

64. Projektmanagement für Ingenieure / Project management for engineers

Nummer: *Number*	11LE50MO-5803SL		
Modulverantwortlicher: *Responsible person*	Prof. Dr. U. Wallrabe	**Einrichtung:** *Organisational unit*	Chair Microactuators
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Seminar	**Sprache:** *Language*	English and German (alternating)

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Seminar	**Angebotsfrequenz:** *Regular cycle*	Each term (alternating language)
Arbeitsaufwand: *Workload*	90 hours (28 or 32 hours Full-time attendance course of study + 58 or 62 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Interdisciplinary Profile

Lernziele / *Learning target*

Students shall learn the basic ideas and techniques of project management and apply them to representative examples. They shall realize that planning tasks isn't always as clear-cut as in engineer courses. A project can be structured in different ways. One plan isn't necessarily better than the other. Instead, one approach might be more practical or provide a better overview than another. Additionally, the students shall gain insight into the soft skills of project management, i.e. how to deal with operating persons, namely the project team as a social system.

Inhalte Seminar / *Content of the seminar*
The course comprises a mixture of lecture and group work with short presentations of the obtained project plans. The different phases of a project and its respective project management, i.e. project assignment, planning, execution and completion of a project, is presented as an introduction into the field. The different roles of people coping with the project, i.e. initiator or customer, project manager and staff, and their duties are presented, and their responsibilities analysed. Various planning techniques and plans will be introduced: project environment analysis, risk analysis, work breakdown structure, Gantt chart and SWOT analysis. The financial budgeting of a project will be shown: existing cost factors, their estimation and what exactly has to be considered. In addition, the more technical aspect of project planning will be supplemented with soft skills, like how to lead a discussion, mediation, etc. MS Project will be used to make the project management simpler. With its help project plans for fictitious projects will be developed. The presented lecture content will be visualized with two fictitious projects. The students will have to implement the learning matter in individual and team work. The projects are a journey round the world with fellow students after graduation and a virtual Master thesis.

Zu erbringende Studienleistung / *Course Achievement*
written examination

Benotung / *Grading*
Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Literatur / *Literature*
Regularly updated lecture notes are available.

Modul / *Module*
65. Resilienzquantifizierung / Quantification of Resilience

Nummer: *Number*	11LE68MO-4110	**Gültig seid:** *Valid since*	2017
Modulverantwortlicher: *Responsible person*	I. Häring	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	• SSE Modul Grundlagen resilienter/stabiler Systeme • Grundlegendes Wissen in einem der nachfolgenden Bereiche wäre hilfreich, sind jedoch nicht zwingend erforderlich: Systemmodellierung und -simulation, Fehlermodelle, Statistik und Wahrscheinlichkeitsrechnung, ingenieurtechnische Modelle zur Bestimmung von Systemverhalten bei ungünstigen, disruptiven oder schädlichen Belastungen oder Ereignissen, Simulation von Versorgungsnetzen, Graphen- und Netzwerkmodelle, diskrete Modelle, gekoppelte physikalische Modelle, Modellierung und Simulation cyberphysikalischer und soziotechnischer Systeme. • SSE Module Fundamentals of resilience • Basic Knowledge in any of the following domains would be of avail without being mandatory: system modeling and simulation, failure modelling, statistics, probability theory, stochastic processes, engineering models for the determination of system behavior in case of adverse, damage or disruptive loads or events, supply network modeling, critical infrastructure models, graph and network models, discrete models, coupled physical models, modeling and simulation of cyber-physical and socio-technical systems.		

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	90 h (32 h Anwesenheit / Attendance, 58 h Selbststudium / Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*
Elective Module for students of the study program • Master of Science in Sustainable Systems Engineering   ○ Resilienz / Resilience Engineering

Lernziele / *Learning target*

Das erste Lernziel ist anwendbares Wissen der Ziele der Resilienzquantifizierung und der Optionen zu gewinnen, wenn Resilienzgrößen technischer und soziotechnischer Systeme zugänglich sind. Diese Ziele schließen ein: Systemversagen auch nach größeren Disruptionen voherzusagen und zu kontrollieren; Systemresilienz zu entwickeln, zu verbessern und zu optimieren; Systemdesigns relativ und absolut in Bezug auf ihre Resilienz zu vergleichen; klassische Begriffe wie Zuverlässigkeit, Wartbarkeit und Risikokontrolle zu erweitern; ausgewogenere Systemdesigns und Entwicklungen zu ermöglichen, die eine Vielzahl von Entwurfszielen berücksichtigen, welche von der Nachhaltigkeit bis hin zur innovativen Chancenmangement im Falle von Systemanpassungen bei Disruptionen reichen; alternative oder vereinigende Perspektiven bzgl. Nachweis Safety und Security zu ermöglichen; einen Weg zu eröffnen für intelligentere, ressourceneffizientere Risikokontrollkonzepte, z. B. durch die Vermeidung von Redundanz durch schnelle Systemadaption; und nicht zuletzt die Basis zu schaffen für anpassbare Resilienzmanagement- und analyseverfahren, die Resilienzquantifizierung und –entwicklung einschließen.

Das zweite Hauptlernziel ist einen anwendbareren Überblick über Resilienzquantifizierungsverfahren zu erlangen, der ausreicht um Methoden auszuwählen und zu kombinieren. Der Überblick umfasst qualitative Methoden, semi-formale Methoden, Reihenentwicklung von Wahrscheinlichkeiten nach Resilienzdimensionen, die Propagation von zahlreichen disruptiven Ereignissen in Form von Trajektorien durch Resilienzanalyselayer, Graphen- und Netz-basierte Ansätze sowie gekoppelte agentenunterstützte Simulation von mehreren ingenieurtechnischen Netzen (z. B. Strom-, Wasser- und Telekommunikationsnetze). Der Überblick soll ausreichen um die grundlegenden Annahmen der Methoden zu kennen, ihre Randbedingungen bzw. Voraussetzungen, typische Eingangs- und Ausgangsdaten sowie die wichtigsten Vor- und Nachteile. Die meisten der Methoden sind anwendbar auf soziotechnische cyberphysikalische Systeme und decken ein breites Spektrum an Anwendungen und Systemlösungen ab.

Das dritte Lernziel ist ein breites Wissen über Systemmodellierungen und -simulationsmethoden aus nachfolgender Liste zu vermitteln, die ausreichen um Resilienz von Systemen zu quantifizieren: heuristische Modellierung von Systemfunktionen, semi-formale Methoden, Zustandsmodelle, Eingabe/Ausgabe Modelle unter Berücksichtigung der Funktionsbedingungen der Komponenten, empirisch-analytische Methoden, historisch-statistische ereignisbasierte Methoden, probabilistische Methoden einschl. Wahrscheinlichkeitsnetzen, stochastische Prozesse, ingenieurtechnische Methoden, physikalische gekoppelte numerische Simulationsmethoden, gekoppelte Netzsimulationen (z. B. flussbasierte Berechnungen) unter Verwendung von Agenten für die technische Kopplung und die Modellierung von Personen. Dies umfasst auch die Kombination der Methoden, die Berücksichtigung ihrer Schnittstellen und die Herausforderung der Festlegung von realisierbaren und ausreichenden internen und externen Systemgrenzen. Darüber hinaus werden die Herausforderungen fehlender und unsicherer Systemdaten, Geheimhaltungsfragen und Fragen bzgl. proprietärem Wissen im Kontext der Modellauswahl adressiert.

Das vierte Hauptlernziel ist zu wissen, wie modell- und simulationsbasierte Resilienzgrößen definiert und vor allem berechnet werden. Es wird gezeigt, wie die Resilienzgrößen verschiedene Resilienzdimensionen abdecken, insbes. die Resilienzzyklusphasen (Betrachtung des zeitlichen Verlaufs), technische Resilienzfähigkeiten, Systemschichten und Resilienzkriterien. Vor allem werden Resilienzgrößen bereitgestellt, die die

Suszeptibilität bewerten (z. B. mittlere Zeit bis zum Eintritt von Disruptionen), die Vulnerabilität (z. B. die Schädigung im Falles des Eintretens eines Ereignisses), das unmittelbare Antwortverhalten (z. B. Systemstabilisierung nach einem Ereignis), und die Erholung bzw. Wiederherstellung einschl. der Anpassung und Transformation für ein gleiches oder auch besseres System nach der Disruption (z. B. durch Systemrekonfiguration verbessertes Design). In ähnlicher Weise werden Resilienzgrößen bereitgestellt, die auch ausgewählte Aspekte der anderen Resilienzdimensionen abdecken. Das Lernziel schließt ein, zeitabhängige und zeitunabhängige Systemperformanz- und Systemnichtperformanzmaße zu kennen, insbes. für die Quantifizierung des Resilienzdreiecks bzw. des Resilienzverlustes sowie die Effizienz der Überbrückung oder Durchtunnelung von Resilienzeinbrüchen bzw. Resilienzbarrieren. Weiterhin erfolgt ein Fokus auf die effiziente Kombination von Resilienzgrößen für die Gesamtbewertung und Optimierung der Resilienz eines technischen oder sozio-technischen Systems, z. B. gewichtete Kombinationen dimensionsloser Resilienzgrößen oder -funktionen. Schließlich werden auch unterschiedliche Unsicherheiten der Resilienzquantifizieung addressiert.

Learning targets:

The first learning goal is to gain an applicable knowledge on objectives of resilience quantification and on options if it is available. These include: to predict and control system behavior also after major disruptions; to design, develop, improve and optimize system resilience; to compare system designs relatively and absolutely with respect to their resilience; to extend classical notions of reliability, maintainability, technical risk control and chance management; to allow for balanced system designs and developments that take account of a multitude of design objectives ranging from sustainability to innovative system transformation post disruptive events; to allow for broadened and joint perspectives on the generation of safety and security; to path the way for smart risk control concepts which are resource efficient, e.g. by avoiding redundancy through fast system adaptation; and last but not least to provide the basis for a tailorable resilience management process comprising resilience quantification and development.

Second main objective is to gain an applicable overview on resilience quantification approaches sufficient to select and combine the approaches. The overview comprises qualitative methods, semi-formal methods, resilience dimensional probability series expansions, resilience trajectory propagation approaches of multiple disruptive events, graph and network based approaches, coupled multi-domain engineering (e.g. electricity, water and telecommunication grid) agent-supported simulation approaches. The overview will be sufficient to know the basic assumptions of each method, their boundary conditions, input and output data as well as most important advantages and disadvantages of each method. Most of the approaches are applicable to today’s socio-technical cyber-physical systems and cover a wide range of model applications and resolutions.

Third main learning objective is to know a broad variety of system modeling and simulation approaches sufficient for resilience quantification out of the following set: heuristic functional models, semi-formal models, discrete state models, input/output operability models, empirical-analytical models, statistical-historical event-based models, probabilistic models including net-based, stochastic processes, engineering models, multi-domain physical-simulative models, coupled multiple grid models (e.g. based on flow-simulation models) using agents for interface and person modelling. This also comprises their combinations and interfacing as well as the challenge of the definition of feasible and sufficient model internal and external boundaries. Furthermore the challenge of lack and uncertainty of system data, security and proprietary issues are addressed in the context of model selection.

The fourth main learning objective is to know how to define and compute model and

simulation based resilience quantities. It will be shown how the different quantities address the resilience dimensions, including the resilience response cycle phases (resilience timeline), technical resilience capabilities, system layers and resilience criteria. In particular, resilience quantities will be provided to assess the susceptibility (e.g. expected mean time till disruptions), the vulnerability (e.g. initial damage in case of event), the response (e.g. in terms of system stabilization after the shock), and recovery including adaption and transformation for bouncing back or bouncing back better after the disruption (e.g. in terms of system reconfiguration or new disruption-aware design). In a similar way, resilience quantities will be provided to cover selected aspects of the other resilience dimensions. This learning goal includes knowing system performance and nonperformance function based resilience quantifications, in particular the quantification of the resilience triangle or resilience performance loss and the efficiency of resilience bridging and tunneling. It also includes a focus on suitable combinations of resilience quantities for overall resilience assessment and optimization, e.g. weighted dimensionless functions as well as overall resilience performance functions. Finally, also the various uncertainties of the resilience quantification approaches are addressed.

Inhalte Vorlesung / *Content of the lecture*

Hauptinhalte sind:

- Kontext, grundlegende Definitionen, Ziele und Optionen der Resilienzquantifizierung: Resilienzmanagement und Resilienzentwicklungsprozess
- Überblick über Methoden zur Resilienzquantifizierung soziotechnischer cyberphysikalischer Systeme: Resilienzdimensionen und Taxonomie für Resilienzquantifizierungsmethoden
- Qualitative und semi-quantitative Resilienzabschätzung: Schemen, Vorgehensmodelle und Auswertung
- Graphische und semi-formale Ansätze: Heuristiken vs. Modelle
- Entwicklungen nach Resilienzdimensionen und resultierende Abschätzungsgrenzen
- Anwendung klassischer Systemanalyse- und modellierungsmethoden, z. B. deterministische flussbasierte Ansätze, Markovmodelle, stochastische Prozesse
- Graphen-basierte und topologische Ansätze: Systemdefinition, Identifikation von Disruptionsvektoren, Bestimmung des Antwort- und Erholungsverhaltens, Antwortstrategien, Optimierungsoptionen
- Resilienzquantifizierung basierend auf Ereignispropagation durch Resilienzanalyselayer unter Verwendung von Übergangsmatrizen und entsprechender statistisch-empirischer, probabilistischer und ingenieurtechnisch-physikalischer Methoden: induktive und deduktive Propagation
- Eingabe-Ausgabe Modelle und Modelle zur Funktionsfähigkeit: diskret und kontinuierlich
- Gekoppelte, agentenunterstützte Netzmodellierungen für die Gesamtsystemmodellierung, -simulation und -reslienzquantifizierung, insbes. auch für die Modellierung von Bedienpersonal und Bevölkerung, sowie den Einfluss von Organisationen, Richtlinien und Rahmenbedingungen
- Kombination von Resilienzgrößen und Optimierungsaufgaben der Resilienzforschung
- Für alle Resilienzquantifizierungsansätze: Modellannahmen, Anwendungsgebiete und –beispiele, typische Ein- und -Ausgaben
- Standards, entstehende Standards und fortlaufende Standardisierungsbemühungen

Main contents comprise:

- Context, basic definitions, objectives and options of resilience quantification: resilience management process, resilience quantification and development process
- Overview of methods for resilience quantification of socio technical cyber physical

systems: resilience dimensions, resilience method taxonomy
- Qualitative and semi-quantitative resilience assessments: ontologies, schemes and evaluation
- Graphical and semi-formal approaches: heuristics vs. models
- Resilience dimensional order expansions and resulting quantification bounds
- Application of classical system analysis approaches, e.g. deterministic flux-based approaches, Markov models, stochastic processes
- Graph-based and topological approaches: system definition, identification of disruption vector, response and recovery determination and response strategy optimization
- Resilience quantification based on event propagation through resilience analysis layers using resilience transition matrix elements and related statistical-empirical, probabilistic, engineering and physical-simulative methods: inductive and deductive propagation
- Input-output models, operability models: discrete and continuous
- Coupled agent-supported engineering grid-model approaches for overall system modelling, simulation and resilience determination, in particular also for modeling of operators, citizens as well as organizational, policy and framing influences
- Combinations of resilience quantification approaches and optimization problems in resilience engineering
- For all resilience quantification approaches: model assumptions, application domains and examples, typical input and output data
- Standards, emerging standards and ongoing standardization efforts

Zu erbringende Prüfungsleistung / *Examination result*

Written or oral examination

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

Master of Science in Sustainable Systems Engineering, academic regulations of 2016: The grade of this module is single-weighted according to the number of its ECTS credits in the calculation of the overall grade.

Literatur / *Literature*

- Vulnerable systems, Wolfgang Kröger and Enrico Zio, Springer, 2011
- Catalogue of risks: natural, technical, social and health risks, Dirk Proske, Springer, 2008
- Resilience engineering: models and analysis, Nii O. Attoh-Okine, Cambridge University Press, 2016
- Urban resilience for emergency response and recovery: fundamental concepts and applications, Gian Paolo Cimellaro, Springer, 2016
- Risk assessment and decision analysis with Bayesian networks, Norman Fenton and Martin Neil, CRC Press, 2013
- Risk analysis and management: engineering resilience, Ivo Häring, Springer 2015
- Principles of cyber-physical systems, Rajeev Alur, MIT Press, 2015
- Cyber-physical systems: from theory to practice, Danda B. Rawat, Joel J.P.C.

Rodrigues, and Ivan Stojmenovic (eds.), CRC Press, 2016
- Cyber-physical systems: integrated computing and engineering design, Fei Hu, CRC Press, 2013
- Agent-based modelling of socio-technical systems, Koen H. van Dam, Igor Nikolic and Zoifia Lukszo (eds.), 2012, Springer
- Introduction to agent-based modeling, Uri Wilenski, Springer, 2015

Zusätzliche Informationen / Additional information:
http://www.leistungszentrum-nachhaltigkeit.de/themen/resilience-engineering/
http://www.academy.fraunhofer.de/de/weiterbildung/energie-nachhaltigkeit/resilience-engineering.html
http://www.lrfoundation.org.uk/publications/resilience-engineering.aspx
http://www.lr.org/en/news-and-insight/news/lrf-res-eng.aspx
http://frs.ethz.ch/
https://www.irgc.org/irgc-resource-guide-on-resilience/
http://link.springer.com/article/10.1007/s41125-015-0001-x
http://www.din.de/de/; http://www.iso.org/iso/home.html; http://www.iec.ch/; https://ansi.org/
Suche nach / searched for “resilience”

Modul / *Module*
66. Resources and Sustainability

Nummer: *Number*	00LE62S-LAS-GOEE0006		
Modulverantwortlicher: *Responsible person*	Hoppe / Sané	**Einrichtung:** *Organisational unit*	UCF
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	UCF teaching block I: **16.10.17-08.12.17**
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Introduction to Earth and Environmental Sciences; Governance basics		

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	6
SWS: *Semester week hours*		**Angebotsfrequenz:** *Regular cycle*	Irregularly in winter term
Arbeitsaufwand: *Workload*			

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Interdisciplinary Profile

Lernziele / *Learning target*

After the course students should be able to:
1) Understand the productivity of various renewable and non-renewable resources and the new political frameworks according to them;
2) Analyze the resource usage according to its impact on the environment, society and economy;
3) Evaluate different aspects of resource usage in respect to a sustainable development.

Inhalte Vorlesung / *Content of the lecture*

The growing human footprint on our planet is clearly shown by the enormous consumption of renewable (e.g. biomass and water) and non-renewable resources (e.g. fossil fuel, metals, construction material). To sustain a high human development without destroying the environment, an equilibrium between economic viability, environmental tolerability and social fairness is required. This concept of sustainability is incorporated in many national constitutions, numerous regulations and is discussed in several summits.

The course will study geo- and bio-resources in respect to their extraction and use, their potential impact on the environment, their economic value and the legal situation necessary to fulfil the requirement of sustainable development. This includes topics such as the use of mass materials for construction and land use conflicts, as well as the use of renewable resources for electricity production and the energy policy and management that comes along with this. Small excursions to governmental and non-university organizations will illustrate the theoretical content in practical applications.
Finally, students will amplify important topics of resources and its governance during seminars.

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Zu erbringende Studienleistung / *Course Achievement*
written or oral examination

Benotung / *Grading*
Academic performance, which can be graded but usually is evaluated with pass or fail.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: Academic performance, which can be graded but usually is evaluated with pass or fail. If the module is graded, the grade is not included in the final grade.

Literatur / *Literature*

Modul / *Module*

67. RF- und Mikrowellen Bauelemente und Schaltungen / RF- and Microwave Devices and Circuits

Nummer: *Number*	11LE50MO-5215		
Modulverantwortlicher: *Responsible person*	R. Quay	**Einrichtung:** *Organisational unit*	Institut für Mikrosystemtechnik
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English

Empfohlenes Fachsemester:: *Recommended term of study*	5	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	90 hours (28 hours Full-time attendance course of study + 62 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Personal Profile
- Master of Science in Microsystems Engineering Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

Lernziele / *Learning target*

The students will be enabled to understand concepts, devices, design, and functioning of modern RF- and microwave transceiver subsystems. This includes the understanding of basic RF-concepts, passive and active devices, circuits, functionalities, their critical figures-of-merrit, and the inclusion into modules. The students will be competent to analyse passive and active RF-structures and circuits, which are relevant for any system with an RF-functionality. The competence includes the full understanding of a transmit/receive module

needed for today's communcation and sensing.

Inhalte Vorlesung / *Content of the lecture*

The lecture RF- and Microwave Devices and Circuits deals with the fundamentals of RF-devices and circuits. It comprises three parts: high-frequency/RF concepts and passive structures, active electronic RF-devices, and RF-circuits and modules. At the interface of modern electronics, dielectric wave propagation, circuit design, and advanced communication and sensing, advanced analysis and characterisation techniques are introduced in order to bridge the gap from modern electronics and modern passive RF-technology to the understanding of RF-communication and sensing systems. The methodologies of RF-analysis, design of devices and circuits, and their basic figures-of-merit, their modelling and characterisation are introduced along with the demonstration of their relevance to modern RF- components and Sustainable Systems. This also includes a discussion of the underlying technology and many examples supported by RF-design tools from the microwave oven to today's RF-applications in mobile communication in the iPod.

Zu erbringende Prüfungsleistung / *Examination result*

written or oral examination

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in µSystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*

RF- and Microwave passives

- Zinke/Brunswig, Hochfrequenztechnik, Band 1, Springer, 1999

RF-Devices

- U.K. Mishra, J. Singh, Semiconductor Device Physics And Design, Springer, 2007

Modul / *Module*

68. RF- und Mikrowellen Design Kurs / RF- and Microwave Design Course

Nummer: *Number*	11LE50MO-5244		
Modulverantwortlicher: *Responsible person*	R. Quay	**Einrichtung:** *Organisational unit*	Institut für Mikrosystemtechnik
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Laboratory	**Sprache:** *Language*	English
Zwingende Voraussetzungen: *Mandatory preconditions*	The prior or parallel participation in either module "RF- and microwave devices and circuits" or "RF- and microwave circuits and systems" is required. No prior knowledge of the software is required.		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Laboratory	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	90 hours (28 hours Full-time attendance course of study + 62 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Personal Profile
- Master of Science in Microsystems Engineering Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

Lernziele / *Learning target*

The students will be enabled to understand, design and layout modern RF- and microwave components and systems by means of the electronic design environment Agilent Advanced Design System including the two- and three-dimensional electromagnetic simulators

Momentum and EMPro 3D. The detailed use of a complex RF-software environment is a dedicated target of this course. This includes the numerical analysis of complex passive and active devices, the design and layout of hybrid and integrated circuits, and their packaging and signal flow. The students will be competent to design and layout passive and active RF-structures including packages and interconnects and circuits of relevance to everydays communication and sensing. The competence includes in-depth understanding and treatment of complex microwave systems and of general system design including the treatment of complex modulated signal flows.

Inhalte Praktikum / *Content of the laboratory*

The Design Course: RF- and Microwave Systems deals with the analysis and creation of RF-devices, circuits and systems. It comprises three aspects: the detailed electromagnetic design of high-frequency/RF passive and active structures, the modelling and layout and verification of active electronic RF-devices in circuit environments based on various semiconductor technologies, and the high-level combination of more complex microwave systems. This includes the simulation of printed circuit boards, of integrated circuits and of devices in package including RF-interconnects, and of behavioural system simulation. Advanced analysis of RF-problems, characterisation, modelling and linear and nonlinear simulation techniques are introduced in order to combine knowledge from modern electronics (from various technologies such as silicon complementary MOS and GaAs), from component analysis, RF-circuit design principles, and system engineering. The examples include simple printed circuits boards, integrated circuits, advanced communication transceivers in mobile communication based on UMTS and LTE and modern radar.

Zu erbringende Prüfungsleistung / *Examination result*

written or oral examination

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in µSystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
ADS Agilent Design System User Manual 2013 www.agilent.com search: ADS Skript: Design Course: RF- and Microwave Systems, R. Quay, 2014 (will be provided at the beginning of the lecture)

Modul / *Module*

69. Solarzellcharakterisierung: Vom Rohmaterial bis zur Zelleffizienz / Characterization of solar cells: From feedstock quality to final cell efficiency

Nummer: *Number*	11LE68MO-4104		
Modulverantwortlicher: *Responsible person*	M. Schubert	**Einrichtung:** *Organisational unit*	
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Solar Energy		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	90 hours (28 hours Full-time attendance course of study + 62 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

Lernziele / *Learning target*

It is the aim of this module to get solid insight into characterization techniques for solar materials and solar cells with a strong focus on silicon technology. Both, industrially used as well as lab-type methods are adressed in order to provide a solid background in loss analysis possibilities for solar cells.
This course is ideal to learn about typical real-life limitations of material and solar cells and a very useful basis for anybody interested in the application, fabrication and improvement of solar cells.

Inhalte Vorlesung / *Content of the lecture*

- State-of-the-art measurement techniques for
- silicon material analysis: feedstock, blocks, wafers, cells
- Cell characterization: local and global loss analyses

- Identifying efficiency losses
- Quantifying efficiency limitations
- Lab type and industrial applications
- Approaches for non-silicon cells

Exercises are included in the lecture which shall deepen the understanding of the discussed characterisation techniques.

Zu erbringende Prüfungsleistung / *Examination result*
written examination

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

Literatur / *Literature*
Schroder, Dieter K. Semiconductor material and device characterization. John Wiley & Sons, 2006. Würfel, Peter, and Uli Würfel. Physics of solar cells: from basic principles to advanced concepts. John Wiley & Sons, 2009.

Modul / *Module*

70. Sicherheit und Privatheit in der Informationsgesellschaft - Security and Privacy in the Information Society

Nummer: *Number*	11LE68MO-4401		
Modulverantwortlicher: *Responsible person*	G. Müller	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*	2 seminar	**Angebotsfrequenz:** *Regular cycle*	Irregularly in the winter term
Arbeitsaufwand: *Workload*	150 hours (56 hours full-time attendance course of study + 94 hours self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Sustainable Systems Engineering
  - Informationstechnik / Information Processing Technologies

Lernziele / *Learning target*

Goal of the module *Security and Privacy in the Information Society* is to give participants insights into the research areas Security in Energy, Big Data and in Business Process Management and Internet Privacy. Additionally, the module aims at giving the opportunity to practice the systematic analysis of scientific texts.

Inhalte Seminar / *Content of the seminar*

Participants of the seminar have to read a scientific paper and provide a summary and evaluation of its content in form of a written report. The report has to be presented in a 15-minute presentation during the final seminar meeting.
In the evaluation of the papers, the approach and the results presented in the papers are challenged and discussed. Additionally, the paper relevance to the field is evaluated. To that end, literature based on the paper results as well as literature referenced by the papers can and should be studied (Tip: Google Scholar). In the evaluation, it is important to present a subjective and reasoned opinion on the papers.

Zu erbringende Prüfungsleistung / *Examination result*
Written documentation

Zu erbringende Studienleistung / *Course Achievement*
Oral presentation

Benotung / *Grading*
The module grade is calculated from the evaluation of the written report.

Gewichtung der Prüfungsleistung / *Weight of examination result*
Master of Science in Sustainable Systems Engineering, academic regulations of 2016: The grade of this module is single-weighted according to the number of its ECTS credits in the calculation of the overall grade.

Modul / *Module*

71. Sicherheit und Privatheit in resilienten Systemen / Security and Privacy in Resilient Systems

Nummer: *Number*	11LE68MO-9030		
Modulverantwortlicher: *Responsible person*	G. Müller	**Einrichtung:** *Organisational unit*	Institut für Informatik und Gesellschaft
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture and exercises	**Sprache:** *Language*	English

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*	2 lectures + 2 exercises	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	150 hours (56 hours full-time attendance course of study + 94 hours self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering

Lernziele / *Learning target*

Students should learn limits of technical concepts and models which enable privacy protection and how they differ from the security viewpoint. Further privacy protection is considered as issue between economics and social interaction. Students should learn how to apply models on the problem of privacy protection. The lecture will handle security vs. privacy as well as the application of privacy enhancing and transparancy enhancing techniques. Additionally the "right to be forgotten" will be discussed.

Inhalte Vorlesung / *Content of the lecture*

Topics discussed are:
- Privacy and transparency enhancing mechanisms
- Privacy vs. security
- Privacy engineering & assessment
- Security in Business Processes

Zu erbringende Prüfungsleistung / *Examination result*

written or oral examination, exercises and volunteer presentations

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
Master of Science in Sustainable Systems Engineering, academic regulations of 2016: The grade of this module is single-weighted according to the number of its ECTS credits in the calculation of the overall grade.

Literatur / *Literature*
• Müller, G. and Rannenberg, K. “Multilateral Security”, in: Addison-Wesley, 1999 • Berendt, B., Günther, O., Spiekermann, S., "Privacy in E-Commerce: Stated Preferences vs. Actual Behavior”, Communications of the ACM (CACM), Vol. 48, Nr.3, 2005

Modul / *Module*

72. Strukturelle Robustheit: Resiliente Entwurfsprinzipien / Structural Robustness: Resilient Designs

Nummer: *Number*	11LE68MO-4109	**Gültig seid:** *Valid since*	
Modulverantwortlicher: *Responsible person*	A. Stolz	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	SSE Modul Fundamentals of resilience SSE Modul Design of large urban infrastructures		

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	90 hours (32 Full-time attendance course of study + 58 Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

Lernziele / *Learning target*

Es besteht ein starkes Bedürfnis, die Menschen, die gesellschaftliche Gemeinschaft und kritische Infrastrukturen und Versorger vor schädigenden Naturereignissen oder von Menschen herbeigeführten außergewöhnlichen Ereignissen zu schützen. Lösungen müssen abgeleitet werden, um eine ausreichende Robustheit und Resilienz der städtischen Infrastruktur für diese außergewöhnlichen Ereignisse mit minimaler Wirkung auf die Normalität zu realisieren. Bisher berücksichtigen normale Regularien und Baurichtlinien diese außergewöhnlichen Ereignisse nicht im Detail. Das erforderliche Fachwissen steht aber zur Verfügung.
Daher sollten die Grundlagen dieses Wissens, welche erforderlich sind um Lösungen abzuleiten, in diesem Kurs beleuchtet werden.

There is strong need to protect people, the societal community and critical infrastructures and utilities against being damaged, destroyed or disrupted by natural disasters or deliberate acts of terrorism. Solutions have to be derived to realize sufficient resilience of the urban infrastructure for rare occasions with minimum effect on normality. Hitherto, normal

regulations and building guidelines do not take into account such extraordinary events in detail. But the required specialist knowledge is available.

Hence the basics of this knowledge to derive the required solutions will be explored within this course.

Inhalte Vorlesung / *Content of the lecture*

Vorlesung und Übung

Im Detail sollen die Studierenden folgendes lernen:
• Ingenieurverfahren zur Grenztragfähigkeit von Strukturen
• Druck-Impulsdiagramme zur Schadensbewertung
• Schädigungsmodelle
• Grundlagen der Verwendung numerischer Simulation zur Schadensbewertung
• Überblick numerische Methoden
• Beispiele zum Einsatz numerischer Simulation, Anwendung der Verfahren auf vorhandene Bausubstanz
• Redundanzen, Resttragfähigkeit
• Verfahren und Methoden zur Risikominderung durch Schutzmaßnahmen
• Umsetzungsbeispiele zu Schutzmaßnahmen
• Retrofit: Konzepte, Planungsdesign

Lecture and exercise

In detail students will learn about
- Engineering methods for the assessment of the ultimate bearing capacity of structures
- Pressure-Impulse diagrams for the damage assessment
- Damage models in general
- Fundamentals of numerical simulations for damage assessment
- Overview of numerical methods
- Use cases of numerical Simulations on build infrastructures
- Redundancy and Residual bearing capacity
- Processes and methods for risk reductions
- Examples for effective countermeasures
- Retrofit: Concepts and plan design

Zu erbringende Prüfungsleistung / *Examination result*

Schriftliche Prüfungsleistung / written examination;
Referat, Vortrag / presentation

Benotung / *Grading*

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Master of Science im Fach Sustainable Systems Engineering, Prüfungsordnungsversion 2016: Die Modulnote wird nach ECTS-Punkten einfach

gewichtet in die Gesamtnote eingerechnet.

- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*

Modul / *Module*

Modul / *Module*

73. Systemtheorie und Regelungstechnik II / Systems theory and automatic control II

Nummer: *Number*	11LE50MO-5234		
Modulverantwortlicher: *Responsible person*	Prof. Dr. M. Diehl	**Einrichtung:** *Organisational unit*	Chair Systemtheorie
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture and exercises	**Sprache:** *Language*	English

Empfohlenes Fachsemester:: *Recommended term of study*	3	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*	2 lecture + 1 exercises	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	150 hours (48 hours Full-time attendance course of study + 102 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Design and simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering Engineering
  - Circuits and systems
  - Design and simulation
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

Lernziele / *Learning target*

Students understand important structures used in practice and can independently apply the aquired knowledge. In addition, they master fundamental methods to describe, analyse and control discrete-time systems and multivariable systems. Furthermore, students can design model-based controllers and understand important concepts of nonlinear control.

Inhalte Vorlesung / *Content of the lecture*
Based on the Bachelor module "Systemtheorie und Regelungstechnik", advanced methods are discussed to describe, analyze, and control dynamic systems. The course consists of four parts: The first part focuses on linear single-input single-output (SISO) systems. The methods derived in "systems theory and automatic control I" for continuous-time systems are transferred to discrete-time systems. In particular, the structure of digital control systems using analog-to-digital and digital-to-analog converter are discussed. Furthermore, methods to characterize discrete-time systems are introduced such as difference equations, z-transformation, and z-transfer function. The bilinear transformation is introduced in context of controller design. In the second part, different control structures and design methods for linear SISO systems are discussed which go beyond the standard control loop presented in the course "systems theory and automatic control I". Concepts for feedforward control and disturbance rejection are presented and the basic structure of a cascade controller is discussed. In addtion, the internal model controller, the compensation controller and the Smith predictor are treated. In the third part of the lecture, linear multi-input multi-output (MIMO) systems are treated. The Kalman decomposition is introduced in state space as an important principle to describe the observability and controllability of a MIMO system. Controller design for directly observable systems using pole placement and LQR (Linear Quadratic Regulator) are discussed. Addressing not directly observable systems, the Luenberger observer and the Kalman filter are introduced for state estimation. The fourth part of the lecture provides an introduction to the control of nonlinear systems. In particular, the concept of Lyapunov stabilty is treated and used to characterize non-linear systems.

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Sustainable Systems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade

of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*

- Lunze, J.: Regelungstechnik 1 - Systemtheoretische Grundlagen, Analyse und Entwurf einschleifiger Regelungen, Springer
- Lunze, J.: Regelungstechnik 2 - Mehrgrößensysteme, Digitale Regelung, Springer
- Unbehauen, H.: Regelungstechnik I - Klassische Verfahren zur Analyse und Synthese linearer kontinuierlicher Regelsysteme, Fuzzy-Regelsysteme, Vieweg + Teubner Verlag
- Unbehauen, H.: Regelungstechnik II - Zustandsregelungen, digitale und nichtlineare Regelsysteme, Vieweg + Teubner Verlag
- Föllinger, O.: Regelungstechnik: Einführung in die Methoden und ihre Anwendung, Hüthig Verlag

Modul / *Module*

74. Technologische Optionen für die Zukunft der Photovoltaik / Emerging and Future Photovoltaic Technology Options

Nummer: *Number*	11LE68MO-4105		
Modulverantwortlicher: *Responsible person*	J. C. Goldschmidt	**Einrichtung:** *Organisational unit*	Energy Systems
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Mandatory module: Solar Energy		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	90 hours (28 hours Full-time attendance course of study + 62 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

Lernziele / *Learning target*

The overarching goal of this module is to enable the students to participate in research & development of advanced photovoltaic technologies, as well as to critically assess the potential benefit of new PV technologies for a sustainable energy system in an industrial or political context.

Participants of this module will be able to explain how efficiency limitations of the current silicon solar cell technology and the current cost structure of PV electricity motivate the ongoing efforts to develop alternative PV technologies.

The students will be able to name the relevant PV technology options that are currently being investigated, describe their working principles as well as the limitations and challenges these options face.

The students will be able to list critical key indicators for the perfomance, potential, market

readiness and relevance of a PV technology and to use those to critically assess emerging PV technologies.

Inhalte Vorlesung / *Content of the lecture*

- Historic development of PV technology and past misconception of alternative PV technologies
- Challenges for the dominant silicon technology: Approaching efficiency limits and system cost structure
- Dye Sensitized-, Organic-, and Perovskite Solar Cells
- Quantum Dots and Nanowire Solar Cells
- Tandem Approaches
- Spectral Management
- The role of Nanophotonics
- Hot Carrier Solar Cells and Thermophotovoltaics
- Thermodynamic limits to future developments
- Disruptive vs. Evolutionary Change
- The importance of efficiency and stability
- Resource limitations
- Exercises are included in the lecture which shall deepen the understanding of the discussed topics.

Zu erbringende Prüfungsleistung / *Examination result*

written examination

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

default

Literatur / *Literature*

M. Green, Third Generation Photovoltaics

J. Nelson, The Physics of Solar Cells

Würfel, Peter, and Uli Würfel. Physics of solar cells: from basic principles to advanced concepts. John Wiley & Sons, 2009.

Modul / *Module*

75. Technologien für Mehrfachsolarzellen und Konzentratorphotovoltaik / Multi-junction solar cell technology and concentrator PV

Nummer: *Number*	11LE68MO-4103		
Modulverantwortlicher: *Responsible person*	A. Bett	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Basic knowledge of semiconductor physics; Solar energy (mandatory module)		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Irregular
Arbeitsaufwand: *Workload*	90 hours (28 hours Full-time attendance course of study + 62 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

Lernziele / *Learning target*

Die Anforderungen für Solarzellen mit Wirkungsgraden jenseits des klassischen Shockley-Queisser-Limits zu verstehen; Materialien und Technologien zu Herstellung von Mehrfachsolarzellen zu kennen; Kenntnisse erwerben zu den spezifische Materialanforderungen und zur Charakterisierung von Mehrfachsolarzellen; Anwendungsfelder von Mehrfachsolarzellen techno-ökonomisch zu bewerten können; Verständnis entwickeln um systemische Optimierungsansätze für Konzentratorsysteme durchzuführen

Understanding of challenges for solar cells with efficiencies beyond the classical Shockley-Queisser limits; knowledge about materials and technologies to fabricate multi-junction solar cells; generate understanding on the specific needs in respect to material quality and characterisation techniques for multi-junction solar cells; techno-economic evalution of multi-junction solar cells in concentrating photovoltaic systems; Understanding how to optimize holistically a concentrator system.

Inhalte Vorlesung / *Content of the lecture*
• Konzepte für Mehrfachsolarzellen um die Wirkungsgrade zu erhöhen; unterschiedliche Solarzellenarchitekturen • Einführung der III-V-Verbindungshalbleiter, Mischkristalle zur Einstellung der Bandlücke, Wachstumstechnologien • Charakterisierungstechniken für Materialien, Mehrfachsolarzellen und Konzentratormodule • Einführung in die Konzentratortechnologie: hoch- und niedrig-konzentrierende Systeme • Komponeten eines Konzentratorsystems: Optik, Zelle, Herstellung • Konzentratorsystemanalyse mit ökonomischer Bewertung • Multi-junction solar cell approach to increase the sunlight conversion efficiency, different solar cell architectures • introduction III-V materials, adjustment of band-gap, growth techniques • methods for charaterisation of III-V materials, multi-junction solar cells and concentratormodules • PV concentrator technology: low and high concentration • componentes of CPV systems: optics, cells, manufacturing • CPV system analysis including an economical evalution

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
default

Literatur / *Literature*
"Solar Cells and Their Applications", L. Fraas, L.Partain, Wiley, 2010; "Advanced Concepts in Photovoltaics", AJ Nozik, G. Conibeer, MC Beard, Royal Society of Chemistry, 2014; "Next Generation Photovoltaics", AB Cristobal Lopez, A. Marti Vega, A. Luque Lopez, Springer Series in Optical Sciences 165, 2012, "Concentrator Phtovoltaics", A Luque, V. Andreev, Springer Verlag, Series in Optical Sciences, 2011 http://www.III-V.de

Modul / *Module*
76. Theory and Modeling of Materials

Nummer: *Number*	07LE33V-MODMAT		
Modulverantwortlicher: *Responsible person*	C. Elsässer	**Einrichtung:** *Organisational unit*	Physikalisches Institut
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*		**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Theoretical physics and solid-state physics on the level of a BSc in Physics		

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*	2 lecture + 1 exercise	**Angebotsfrequenz:** *Regular cycle*	Irregularily in summer and winter term
Arbeitsaufwand: *Workload*	150 hours		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials

Lernziele / *Learning target*

- Students become able to develop and apply theoretical models to investigate practical problems of the physics of materials
- Students become familiar with theoretical condensed-matter physics and computational modelling and simulation of materials

Inhalte Vorlesung / *Content of the lecture*

The content of each course will be given in the announcement for each semester. The series of one- or two-semester elective-subject lectures introduces theoretical models and computational methods of solid-state physics for the description of many-electron systems, by means of which cohesion and structure, physical, chemical, or mechanical properties of perfect crystals and real materials can be understood qualitatively and calculated quantitatively on a microscopic fundament. The lecture series comprises courses on, e.g., these topics:

- Electronic-structure theory of condensed matter I + II

- Superconductivity I (phenomenology) + II (microscopic theory)
- Theoretical models for magnetic properties of materials
- Theory of atomistic and electronic structures at interfaces in crystals
- etc.

Zu erbringende Prüfungsleistung / *Examination result*
written or oral examination

Zu erbringende Studienleistung / *Course Achievement*
written or oral examination

Benotung / *Grading*
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
Recommended literature will be announced in each lecture

Modul / *Module*

77. Thermoelektrik / Thermoelectric

Nummer: *Number*	11LE50MO-5715		
Modulverantwortlicher: *Responsible person*	Prof. Dr. J. Wöllenstein	**Einrichtung:** *Organisational unit*	Chair Dünnschicht-Gassensorik
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	German
Empfohlene Voraussetzungen: *Recommended preconditions*	Basic knowledge physics, electrical engineering, microsystem technology and sensor technology		

Empfohlenes Fachsemester:: *Recommended term of study*	5	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	2 Lecture	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	90 hours (32 hours Full-time attendance course of study + 58 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Energiesysteme / Energy Systems

Lernziele / *Learning target*

Das Ziel des Moduls ist die Vermittlung der physikalischen, chemischen, elektrischen Funktionsweise thermoelektrischer Bauelemente und Systeme. Dabei werden aufbauend auf den vermittelten Grundlagen typische Materialsysteme, Modultechnologien und Anwendungen vorgestellt. Die Studierenden sollen den Zusammenhang zwischen der Wirkungsweise, Modul- und Systemdesign, Fertigungsprozessen und dem Einsatz

thermoelektrischer Systeme wie Thermogeneratoren, Peltier-Elemente und Thermocouples erlernen.

Inhalte Vorlesung / *Content of the lecture*

Thermoelektrische Anwendungen finden sich in der Temperaturmesstechnik, der Kalorimetrie, der Detektion von Strahlung, der Kühl- und Heiztechnik und der direkten Konversion von Wärmeenergie in elektrischer Energie, den Thermogeneratoren. In der Lecture wird ein grundlegendes Verständnis thermoelektrischer Effekte vermittelt und deren Abhängigkeit von verschiedenen Materialeigenschaften wie zum Beispiel Seebeck- und Peltier-Koeffizient, elektrische Leitfähigkeit und Wärmeleitfähigkeit abgeleitet. Es werden verschiedene Materialsysteme, die sich für die Thermoelektrik besonders eignen, vorgestellt und im Hinblick auf typische Anwendungen bewertet. Der Stand der Technik in der Umsetzung dieser verschiedenen thermoelektrischen Materialien in Module und Systeme wird vorgestellt. Anhand typischer Anwendungsbeispiele werden Modellierung und Entwurf thermoelektrischer Module erörtert.

Zu erbringende Prüfungsleistung / *Examination result*

written or oral examination

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*

- Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
- Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*

Begleitend zur Lecture werden die verwendeten Folien zur Verfügung gestellt.

Modul / *Module*

78. Werkstoffdynamik / Dynamics of Materials: Material Characterization

Nummer: *Number*	11LE50MO-5118		
Modulverantwortlicher: *Responsible person*	S. Hiermaier M. May	**Einrichtung:** *Organisational unit*	INATECH
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture	**Sprache:** *Language*	English

Empfohlenes Fachsemester:: *Recommended term of study*	2	**ECTS-Punkte:** *ECTS-points*	5
SWS: *Semester week hours*	2 lecture + 2 exercises	**Angebotsfrequenz:** *Regular cycle*	Summer term
Arbeitsaufwand: *Workload*	150 hours (56 hours Full-time attendance course of study + 94 hours Self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of these study programs

- Master of Science in Embedded Systems Engineering
  - Personal Profile
  - Design and Simulation
- Master of Science in Mikrosystemtechnik / *Microsystems Engineering*
  - Life Sciences: Biomedical Engineering
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering Life Sciences: Biomedical Engineering
  - MEMS Processing
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Nachhaltige Materialien / Sustainable Materials
  - Resilienz / Resilience Engineering

Lernziele / *Learning target*

Lernziel des Moduls ist die Kenntnis experimenteller und numerischer Grundlagen zum

mechanischen Verhalten von Werkstoffen bei dynamischer Belastung. Mit den erarbeiteten Methoden können die Studierenden Spannungs-Verzerrungs-
Beziehungen in Abhängigkeit von der Belastungsgeschwindigkeit bestimmen und in numerischen Verfahren als Materialmodell implementieren. Übergeordnetes Lernziel der Lehrveranstaltung ist die Beherrschung der Grundfähigkeiten zur experimentellen Charakterisierung und numerischen Model lierung dynamischen Materialverhaltens.

Aim of the course is the knowledge of experimental and numerical basics on the mechanical behaviour of materials under dynamic loading conditions. It enables the students in deriving strain-rate dependent stress-strain relations and in implementing the resulting constitutive models into numerical codes. General aim is the basic ability for experimental characterization and numerical modelling of dynamic material behaviour.

Inhalte Vorlesung / *Content of the lecture*

Werkstoffcharakterisierung:

- Statische und dynamische Werkstoffprüfung
- Die Verzerrungsrate als Maß für die Materialdynamik
- Nutzung von Wellenausbreitung zur Materialprüfung
- Verzerrungsratenabhängige Elastizität, Plastizität und Versagen
- Mathematische Modellierung des Materialverhaltens
- Auftreten von Stoßwellen in Festkörpern
- Zustandsgleichung als Komponente des Spannungstensors
- Nichtlineare Zustandsgleichungen

Numerik dynamischer Deformationsprozesse:

- Räumliche und zeitliche Diskretisierung dynamischer Prozesse in Festkörpern
- Finite Differenzen Verfahren in Raum und Zeit
- Finite Element Verfahren
- Implizite und explizite Zeitintegration
- Netzfreie Diskretisierungsverfahren

Materials Characterisation:

- *Static and dynamic testing of materials*
- *Strain rate as a measure for dynamic material behaviour*
- *Use of elastic waves for materials testing*
- *Strain-rate dependent elasticity, plasticity, and failure*
- *Mathematical modelling of material failure*
- *Shock waves in solids*
- *Equations of state and the total stress tensor*
- *Nonlinear Equations of state*

Numerical modelling of dynamic deformation

- *Spatial and Time Discretization of dynamic deformation of solids*
- *Finite differences for space and time*

- *Basics of the Finite Element method*
- *Implicit and explicit time integration*
- *Basics of meshfree discretization methods*

Zu erbringende Prüfungsleistung / *Examination result*
Written or oral exam

Benotung / *Grading*
Die Modulnote errechnet sich zu 100% aus der schriftlichen oder mündlichen Abschlussprüfung. *The module grade is entirely calculated from the result of the final examination.*

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Sustainable Systems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
• S. Hiermaier, "Structures under Crash and Impact", Springer, 2008

Modul / *Module*

79. Zuverlässigkeitstechnik / Reliability Engineering

Nummer: *Number*	11LE50MO-5214		
Modulverantwortlicher: *Responsible person*	Prof. Dr. J. Wilde	**Einrichtung:** *Organisational unit*	Chair Aufbau- und Verbindungstechnik
Modultyp: *Module Type*	Elective Module	**Moduldauer** *Module duration*	1 term
Zugehörige Lehrveranstaltungen: *Connected events*	Lecture and exercises	**Sprache:** *Language*	English
Empfohlene Voraussetzungen: *Recommended preconditions*	Basic understanding in mathematics (statistics) as well as materials sciences		

Empfohlenes Fachsemester:: *Recommended term of study*	5	**ECTS-Punkte:** *ECTS-points*	3
SWS: *Semester week hours*	1 Lecture + 1 Exercises	**Angebotsfrequenz:** *Regular cycle*	Winter term
Arbeitsaufwand: *Workload*	90 hours (32 hours full-time attendance course of study + 58 hours self-study)		

Verwendbarkeit der Veranstaltung / *Usability of the module*

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Sustainable Systems Engineering
  - Resilienz / Resilience Engineering

Lernziele / *Learning target*

It is the aim, that after this module, the student will:

- have elementary capabilities to solve praxis-relevant.
- know how experiments can be replaced by simulation and what the necessary input data are.
- be able to evaluate Sustainable Systems and more complex electronic and

mechatronic systems including software.
- Furthermore it is expected that the student will have improved capabilities in the risk analysis of hazardous applications.
- Also the students will be able to report the corresponding results.

Inhalte Vorlesung / *Content of the lecture*

1. Definitions
   - 1.1 Quality, dependability, reliability and safety
   - 1.2 Benchmarks for dependability, availability und lifetime
   - 1.3 Statistical description of reliability
2. Dependability of mechanical systems
   - 2.1 Example 1: The ICE-crash at Eschede
   - 2.2 Loads on mechanical components
   - 2.3 Risk factors: notches and cracks
   - 2.4 Fatigue - Woehler's S-N-curve concept
   - 2.5 Computation of operational strength
3. Reliability of electronic hardware
   - 3.1 Automotive electronics: architecture, requirements and quality level
   - 3.2 Reliability of electronic devices, data
4. Reliability data-bases
5. Reliability of systems
   - 5.1 Reliability block-diagram (failure-rate analysis)
   - 5.2 Overview of failure mode analyses
   - 5.3 Fault tree analysis (FTA)
   - 5.4 State-Space: A general method to compute Rs(t) and Fs(t)
6. Reliability of repairable systems
   - 6.1 Definitions
   - 6.2 Repair rate
   - 6.3 Availability
   - 6.4 Markov-Chains and Markov-Processes
7. Software reliability
   - 7.1 Examples of software-induced accidents
   - 7.2 Probability of software faults
   - 7.3 Reliability models for software
   - 7.4 Misjudgements concerning software use
8. Human factors
9. Pre-requisites for development processes
10. Standards and legislation for medical devices

Zu erbringende Prüfungsleistung / *Examination result*

written or oral examination

Benotung / *Grading*

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / *Weight of examination result*
• Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in µSystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. • Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / *Literature*
• Reliability Engineering, Alessandro Birolini, 4th ed., Springer, 2004, ISBN: 3-540-40287-X • Fehlerbaumanalyse in Theorie und Praxis, Frank Edler, Michael Soden, René Hankammer, 1. Aufl., Springer Vieweg, 2015, ISBN: 978-3-662-48166-0

Third Edition, July 2017

Publisher:

Issued by:
The Dean of Academic Affairs,
Sustainable Systems Engineering
Faculty of Engineering
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