Faculty of Engineering

Module description

Master of Science (M.Sc.) in the subject Embedded Systems Engineering - Major Field
(Examination regulations version 2021)

universität freiburg

Table of Contents

Prolog

https://www.tf.uni-freiburg.de/en/study-programs/embedded-systems-engineering/m-sc-embedded-systems-engineeringThis module handbook is based on the examination regulations for the Master of Science degree program in the 2021 version, subject-specific provisions for the major in Embedded Systems Engineering. These provisions define the course content structured in the modules and the curriculum structured in terms of semesters and areas.

Modules consist of different elements: Courses (e.g. lectures, exercises, seminars, etc.) and coursework (pass/fail assessments) or examinations (graded assessments). The module descriptions explain in more detail both the course elements and the required coursework and examinations to demonstrate the acquisition of competencies.
In each case, the regular course and examination assessments are described; should it become necessary to deviate from the described assessments at short notice due to unforeseen circumstances, the substitute assessments will be announced in the first week of the lecture period at the latest.

For successfully completed modules, credit points are awarded, the so-called ECTS credit points according to the "European Credit Transfer and Accumulation System". These credits indicate the weighting of a course in a module as well as the workload associated with the course. One credit point corresponds to an effort of approx. 30 working hours per semester for an average student. A student should collect approx. 30 ECTS credits per semester.

The standard period of study is four semesters. A total of 120 ECTS points must be acquired in the Master of Science Embedded Systems Engineering.

Regulations regarding attendance:
Attendance is not mandatory in lectures.
Seminars and lab courses require regular attendance as part of the Studienleistung (pass/fail assessment) because it is essential for reaching the learning targets of these courses. Exercises may require regular attendance as well, in which case this fact will be stated in the description of the specific module.

While there are generally no admission requirements for examinations within a module, in the case of elective modules, it happens in very rare cases that two modules build directly on each other in terms of content and the corresponding advanced module can therefore only be completed if the introductory module has been successfully completed beforehand. This is indicated accordingly in the module descriptions.

Further information on the program (e.g. the examination regulations, the model study plan, entry requirements, etc.) can soon be found at
https://www.tf.uni-freiburg.de/en/study-programs/embedded-systems-engineering/m-sc-embedded-systems-engineering

---

B. Overview of Study program and teaching unit

Subject	Embedded Systems Engineering
Degree	Master of Science (M.Sc.)

Scope of ECTS credit points	120
Study duration	4 Semesters / 2 years
Study format	Full-time
Type of study program	Consecutive and research oriented
Regular study duration	4 Semesters
University	University of Freiburg (Albert-Ludwigs-Universität Freiburg)
Faculty	Faculty of Engineering
Department(s)	Department of Microsystems Engineering / Institut für Mikrosystemtechnik, IMTEK Department of Computer Science / Institut für Informatik, IIF Department of Sustainable Systems Engineering, INATECH
Homepage	https://www.tf.uni-freiburg.de/en/study-programs/embedded-systems-engineering/m-sc-embedded-systems-engineering
Short profile	The Master of Science program ESE is research-oriented and consecutive. It is designed for highly qualified national and international graduate students holding a bachelor‘s degree in engineering or science. The English-taught master’s program provides in-depth knowledge on design, development, fabrication and application of embedded systems. In detail, it provides knowledge about the design of microelectronic, micromechanic and software-based components as well as their integration into complete systems. Engineering optimization targets will be functionality, speed, costs, energy efficiency and reliability. According to their individual study profile, students will gain and deepen special knowledge in these areas. Furthermore, one of the concentration areas Artificial Intelligence, Cyber-Physical Systems, Circuits and Systems, Materials and Fabrication, Biomedical Engineering or Photonics can be chosen as a specialization. Students have the choice between a broader, cross-sectional training on computer science and microsystems engineering or a specialisation on one of the fields described above that is documented in the diploma documents.
Educational Goals / Qualification	M.Sc. ESE students will have the opportunity to

	• be involved in state-of-the-art research with internationally renowned professors, • benefit from state-of-the-art equipment on a modern campus and pioneering laboratories at partner institutes, • benefit from a European campus (www.eucor-uni.org), • live in one of Germany's most appealing and green cities. Successful students will be enabled to explore, design and apply technical solutions for combined software-hardware based systems during their subsequent employment as engineers. The accomplishment of the Master's degree qualifies for an academic career in research and development as well as for an occupation as an engineer or a software developer in industry, in scientific or research organizations or in a state authority.
Language(s)	English (no German skills necessary; however, some elective modules are offered in German)
Admission requirements	• A bachelor's degree in engineering or in computer science with a total of 180 ECTS and a duration of at least 3 years • An average grade of 2.9 or better on the German grading scale • Advanced English language skills at the level of C1 on the Common European Framework of Reference for Languages (CEFR)
Intake	can be started either in the winter semester or the summer semester
Date/Version	As of April 2025 / exam regulations 2021

C. Profile of the degree program with qualification goals (technical and interdisciplinary)

The Master program in Embedded Systems Engineering is research oriented and consecutive. In the Embedded Systems Engineering Master program it is the overall educational goal to bring graduate students to a postgraduate level where they can perform engineering tasks and develop software and hardware systems on a high scientific level. To that purpose they will gain expertise in subject areas that will be described in the further chapters. On the path from an idea to a product the required professional skills will enable first for problem definition and then for subsequent solutions finding and evaluation, be it in the physical world or in IT. While the development of micro-devices and hardware systems will require methods of design, construction and simulation in mechanical, electrical, materials and physical domains, the approach to IT developtments and data analysis will require firm foundations in algorithm design, software engineering and other computer science skills. Also, characterization and testing is important in order to optimize on all levels of systems' architecture.

The applications of embedded systems are manifold:

In medicine there are trends towards, minimally-invasive surgery, advanced diagnostics or intelligent prostheses. Modern communications systems rely on optics or on radio frequencies like mobile phones. Networks and sensors become more and more ubiquitous for consumers. The same holds for industrial applications, process management and instrumentation. In automobiles modern by-wire controls, safety features or even autonomous functions are based on optical microsystems and micro-sensors. It appears impossible to provide the deepest knowledge in all related fields. Therefore, the program was designed in a way that engineers from related fields will be elevated to a postgraduate level on a standard knowledge platform of Embedded Systems Engineering. Starting from this basis a specialization in the mentioned fields will be possible.

C.1 Qualification goals of graduates of the program Master of Science ESE

ESE master graduates will be capable of using engineering techniques as well as practical and methodological computer science approaches, and use them effectively and efficiently on the way from research to the market. Besides technical expertise graduates also need non-technical skills like the ability to work in a team, social competence, creativity and openness to new ideas, communication skills. The program also promotes entrepreneurial thinking and the ability to motivate oneself.

C2. Technical qualification goals

Students

- are able to analyse technical questions and to develop, design, test, optimize and manufacture embedded (micro-)systems
- acquire an overview of the most important methods, models, processes and technologies for realizing embedded systems; they are able to select, apply and combine the processes and methods that are suitable for a given problem
- can analyse and develop software and program code for embedded systems on different levels
- are able to assess the safety, security and efficiency features required for embedded systems
- learn strategies for identifying and evaluating new applications of embedded systems
- are able to prepare, plan, carry out and document experiments independently
- have an applicable overview of the most common design, fabrication and test techniques used in practice as well as their extensions and new methods
- are proficient in using the usual IT tools, like programming, software development, system design, optimization procedures, testing etc.
- acquire in-depth knowledge in a special field of embedded system engineering in the area of concentration or specialization they have chosen
- know how to address technical problems that require knowledge beyond the learning content of their studies

C3. General and interdisciplinary qualification goals

Students

- have general, interdisciplinary problem-solving skills
- can work on a given technical question largely independently and document the result in a scientific paper
- are able to team up in project groups, which can be made up of students from different master’s courses in the specialization modules, to promote social and intercultural competences
- are able to draw up a laboratory diary, write scientific reports, give a scientific lecture and create a scientific poster
- can assess themselves and their performance to the point, that they are capable of planning and implementing a wide variety of projects
- have the ability to work in a team and can take responsibility for themselves and others

D. Special features of the program (regarding stays abroad and internships)

In addition to the ERASMUS-Partnerships of the University, the Department of Microsystems Engineering has concluded a cooperation contracts with the following international Universities and institutes:

- ESIEE – Ecole Supérieure d'Ingénieurs en Electronique et Electotechnique, Noisy-le-Grand, Frankreich
- Technical University of Denmark (DTU), Lyngby, Dänemark
- College of Engineering, University of Michigan, USA
- Tohoku University, Graduate School of Engineering, Sendai, Japan
- University of Tokyo, Graduate School of Engineering, Tokyo, Japan
- Ritsumeikan University, Kusatsu, Japan
- Kyoto University, Graduate School of Engineering, Kyoto, Japan

Within this framework, Students have the opportunity to complete foreign semesters, in most cases without additional tuition fees. Students who would like to broaden their cultural horizons by spending a semester abroad will find information and support from various offices, such as the University's International Office and the Faculty's Erasmus coordinator for planning and coordination, and from the student advisor for useful adjustments to the individual personal study plan.
There is no mandatory internship requested. We have observed, that international students select to have elective internships in industry or to perform the work of their Master Thesis there. Most find such positions on their own initiative. Some seek professors' advice in order to get contacts and to improve their applications.

E. Module descriptions and model study plan

E.1 Course structure

The Master program in Embedded Systems Engineering is research oriented and consecutive.
The program addresses international graduates from bachelor programs in computer science and in engineering, especially in electrical engineering, electronics, mechatronics and information technology. The program provides in-depth knowledge on design, development, fabrication and application of embedded systems. In detail, it provides knowledge about the design of microelectronic, micro-mechanic and software-based components as well as their integration into complete systems. Engineering optimization targets will be functionality, speed, costs, energy efficiency and reliability. According to their individual study profile, students will gain and deepen special knowledge in these areas. Furthermore, one of the areas Artificial Intelligence, Cyber-Physical Systems, Circuits and Systems, Materials and Fabrication, Biomedical Engineering or Photonics can be chosen as a specialization. Students have the choice between a broader, cross-sectional training on computer science and microsystems engineering or a specialisation on one of the fields described above that is documented in the diploma documents. Successful students will be able to explore, design and apply combined hardware-software-based technical solutions during their subsequent employment as engineers. The accomplishment of the respective Master's degree qualifies for an academic career, a position in research and development as well as an engineering or scientific occupation in industry, in research organizations or in a state authority.

The Master of Science program in Embedded Systems Engineering can be started both in the summer term and the winter term. Courses and exams of the Master program Microsystems Engineering generally will be taught in English. Several of the elective modules and courses as well as the corresponding exams can be performed partly or completely in German language.
The Master of Science program in Embedded Systems Engineering encompasses 120 ECTS credits and cover manily into two fields: Computer Science and Microsystems Engineering. The Master Thesis encompasses 30 ECTS credit points. The remaining 90 ECTS credits are structured in 5 parts with a scope of 18 ECTS credits each. Four of these parts are compulsory:

- Essential Lectures in Computer Science
- Advanced Microsystems Engineering
- Elective Courses in Computer Science
- Microsystems Engineering Concentration Areas

Students are expected to choose modules/courses inside each of these areas with a scope of 18 credits.
The last part (with also 18 ECTS credits) is elective and students can choose modules/course

- either in one or more of the four areas mentioned above
- by completing courses from the facultative area of Customized Course Selection

The overall structure of the curriculum is shown in a diagram in the Curriculum section under
https://www.tf.uni-freiburg.de/en/study-programs/embedded-systems-engineering/m-sc-embedded-systems-engineering

When certain conditions have been met, a **specialization** can be certified in the diploma. The affiliation of a course with one of the specialization areas is mentioned in the module description. An overview of the lectures and courses that are assigned to the respective area CPS or AI is provided as an overview via PDF documents in the Curriculum section on the program website mentioned above; for the four MSE specializations, available modules correspond with the respective concentration area itself.

The contributions of the individual modules to the Master program structure are stated in the Epilog.

E.2 Example for study plan

Since all of the modules in this study program are compulsory elective modules with a large selection of courses to select from, or individual work without a fixed reference to the lecture period, presenting a study schedule is only useful to a limited extent, as the specific plan is different for each student.
An exemplary study plan/curriculum for M.Sc. Embedded Systems Engineering in the Curriculum section of the program website gives an example of what such an individual study plan might look like when startin in winter semester.

F. Teaching and Learning Methods

Lectures and related exercises make up the majority of the different courses in the Master program. Lectures convey fundamental and advanced subject-relevant knowledge on specific topics as well as methodological knowledge in a coherent manner. Lectures are an integral part of teaching in technical subjects, as they summarize facts, structures and interdependencies of a subject area and convey general knowledge.
In accompanying **exercises**, the acquired technical and methodological knowledge as well as scientific working techniques are applied and practiced independently. Usually, exercises are held as follows: in a first part, students work on subject-specific questions methodically and independently. In a second part, the work results are discussed under the guidance of a tutor. The students improve their problem-solving skills through qualified feedback on their own performance and discovering common sources of error.

A **seminar** as a type of course introduces and develops the ability to independent scientific work - alone and in groups - and intensive discussion in regards to a given topic. In seminars, content on a specific subject area is not prepared and presented by the lecturers alone; instead, the students work through provided literature largely independently and present the acquired knowledge to their fellow students. Following the presentations, there is generally a discussion between the supervising lecturer and the participating students, which offers room for reflection and constructive criticism. In addition, a written version of the results in the form of a scientific poster or a term paper, is often expected as part of the coursework. The interdisciplinary skills usually learned in seminars - e.g. B. analyzing, reflecting, discussing and presenting – are achieved in a group is a supervised setting. Therefore, a group-related compulsory attendance is required in these events.

Lab courses and **practical exercises** provide subject-related practical and methodical skills. Students are required to work largely independently and often in a special setting, e.g. in appropriately equipped laboratories or (possibly in small groups) with special tool kits provided. Accordingly, compulsory attendance can be required here. In most cases, the performance for lab courses is assessed through written reports, exercise sheets, supervised experiments and / or a presentation.

In **projects**, students learn to critically analyze complex problems in groups or alone and to work out solutions. In line this work, theoretical knowledge and methodological skills are applied in practical settings. A self-chosen or specified task from a real-life situation is tackled alone or in a team. Problem-solving skills relevant to the specific topic of the task are developed and professional qualifications like communication, team work and self-management skills are deepened. Projects are usually evaluated on the basis of a written draft, a demonstrator and / or a presentation.

The university library (especially with the faculty's own branch) provides literature necessary for self-study that supplements the lectures and for background research required for project work.

G. Explanation of the examination system

Evaluation of the successful achievement of the qualification goals is done during the study program at the end of the module in each semester. Most modules in this program are completed with a graded assessment (“Prüfungsleistung”); details depend on the chosen courses. Courses can include additional coursework, depending on the qualification goals. Details are given in the examination regulations and in the individual module descriptions. Lecturer provide further specifications at the beginning of the respective course.

Courses in the Customized Course Selection are completed with pass/fail assessments. For courses outside of the Faculty of Engineering ("fachfremde Wahlmodule"), the regulations and deadlines of the respective offering faculty/department apply; the organization of these courses regarding booking and registration procedures in the Campus Management System (HISinOne) is subject to constant further development, and it requires students to actively inform themselves. For questions the program coordinator or the study advisor can be contacted.

The Master program is completed by writing a Master thesis and presenting it during the Master colloquium. With the thesis students show, that they are able to work on a computer science topic independently within a given period of time using scientific methods and to present the results appropriately. If a specialization area is chosen, the topic of the master thesis must be chosen from within that specialization area.

G.1 Graded assessments / Exams („Prüfungsleistungen“)

Usually, modules are completed with a graded examination. The type and scope of the examinations are specified in the subject-specific examination regulations as well as in the module handbook and are also announced to the students at the beginning of the respective course.

Written course-based graded assessments include supervised written examinations (Klausuren) and written term papers or essays. Graded assessments can also be administered orally, in the form of oral examinations (exam interviews) and presentations. Practical examinations include conducting experiments and creating and demonstrating software or demonstrators. Examinations (as well as pass/fail assessments) can also be taken as online exams, in accordance with the current examination regulations and framework regulations of the University of Freiburg.

The duration of written exams lies between a minimum of 60 and a maximum of 240 minutes. Students will be notified about the dates for exams and information about permitted aids in a suitable manner in good time. The duration of an oral examination (which can be carried out as an individual or as a group examination) is at least 10 and a maximum of 30 minutes (per examinee); if the oral exam is a final module exam, the maximum duration per examinee is 45 minutes. Presentations usually have a duration of 10-20 minutes (depending on the topic and purpose; details are announced by the lecturers in the respective course. The scope (number of pages) of homework/papers varies depending on the topic and format and is therefore specified by the lecturer in the course.

Timely registration for exams via the HISinOne administration system is required for course-related examinations. The exact dates and information about the procedure can be found on the homepage of the examination office of the Faculty of Engineering (https://www.tf.uni-freiburg.de/en/studies-and-teaching/a-to-z-study-faq/examinations). It is important to note that for elective modules and courses from other subjects, the regulations of the respective offering faculty/department apply!

Unless otherwise specified in the examination regulations or in the module descriptions, the grade for the module is calculated purely from the stated graded assessment. The overall grade is calculated as the arithmetic average of the module grades weighted by ECTS points. More details are given in the examination regulations.

G.2 Pass/fail assessments / Coursework („Studienleistungen“)

Pass/fail assessments or coursework are individual written, oral or practical achievements that are provided by students in connection with courses, but which only have to be passed. These assessments can be repeated as often as necessary until they are passed. They can be graded, but do not have to be, and are not included in the respective final grade (i.e. the final grade of the module as well as the final grade of the course). The scope and type of them are specified in the module descriptions and are announced to the students at the beginning of the respective course.

Coursework may consist, for example, of

- regular attendance in a course
- written tests or examinations (i.e. written supervisory work, possibly also online, or as an open-book exam)
- Written elaborations such as reports, case studies, wikis, websites or posters
- oral tests or exams
- the completion of exercises or worksheets
- presentations
- doing experiments
- the creation and presentation of software or demonstrators

Examination prerequisites (i.e. admission requirements for examinations within a module) do not exist in the Master of Science Embedded Systems Engineering program, as these could have the adverse effect of extending the study duration considerably. If a module requires the completion of coursework as well as graded examination, these can, if necessary, be completed independently of each other. This means that completion of the coursework is not a mandatory requirement for participation in the graded examination, although in most cases it makes more sense from a didactic point of view to complete the coursework before the taking the exam.

Since for the calculation of the final grade all relevant module grades (i.e. from modules completed by a graded assessment) are weighted by ECTS credits, this is not specifically mentioned in each individual module description. Please refer to the examination regulations.

Name of module	**Number of module**
Mastermodul / Master Module	11LE50K-T-9991-MSc-787-2021-MM
Responsible	
Prof. Dr. Hannah Bast Prof. Dr.-Ing. Bastian Rapp	
Faculty	
Faculty of Engineering	

ECTS-Points	30.0
Workload	900 Stunden | hours
Hours of week	
Recommended semester	4
Duration	1 semester / 6 months
Compulsory/Elective (C/E)	Compulsory
Frequency	each term

Compulsory requirement
Successful completion of modules with a scope of at least 72 ECTS credits.
Recommended requirement
In-depth knowledge of mathematical fundamentals, engineering methods and applications, practical and theoretical IT areas and especially in the subject area in which the thesis will be written

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload

Contents
The topic of the master thesis is given by a professor from the Faculty of Engineering in consultation with the student. The topic may originate outside of the Faculty of Engineering, as long as one of the professors at the Department of Computer Science agrees to the assessment and evaluation of the work as the official supervisor. The student is assigned a supervisor with a university-level qualification. The technical content is task-specific and is predominantly acquired in self-study through independent research. If a specialization (Circuits and Systems, Specialization Materials and Fabrication, Biomedical Engineering or Photonics in the Microsystems Engineering area, or Artificial Intelligence or Cyber-Physical Systems in the Computer Science area) is chosen, the topic of the master thesis must be chosen from within the relevant specialization.
Qualification
In the master thesis, the students work independently on a computer science topic. For the given questions, they carry out background research in literature for scientific sources. The students select suitable scientific procedures and methods and apply them on their topic, adapt them or develop them. The results obtained are critically compared with the current state of research and evaluated. The students present their results clearly and in an academically appropriate form in their written thesis, as well in its presentation during the colloquium. They are able to discuss their work on a suitable academic level.

Examination achievement
Written Master thesis in German or English, must be completed within six months The master thesis is supplemented by an approximately 60-minute master colloquium, which may be held in German or English at the student's choice. The master colloquium is usually led and evaluated by the supervisor of the master thesis and consists of an approximately 20-minute presentation by the student on the results of the master thesis and a subsequent discussion. Admission to the master colloquium is granted only if the master thesis has been submitted. The master colloquium counts for 3 ECTS points and is usually open to the university public.
Course achievement
Regular attendance in meetings with the supervisor, self-organizing the given tasks, doing background research
Literature
Abhängig vom Thema | Depending on topic
Usability
Compulsory Module for students of the study pogram ■ M.Sc. in Embedded Systems Engineering (PO 2021)

↑

Name of node	**Number of node**
Informatik | Computer Science	11LE50KT-MSc-787-2021-CS
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Compulsory

Comment
Students have to choose courses with a scope of 36 ECTS credits in the two areas of Computer Science: ■ Essential Lectures in Computer Science ■ Elective Courses in Computer Science They can choose to do more courses, but the maximum number of credits must not surpass 54. Overall, the limit of ECTS credits is 90 for the areas of ■ Essential Lectures in Computer Science ■ Elective Courses in Computer Science ■ Advanced Microsystems Engineering ■ Microsystems Engineering Concentration Areas

↑

Name of node	Number of node
Essential Lectures in Computer Science	11LE50KT-MSc-787-2021-EssentialCS
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Compulsory

Comment
Students have to choose at least 18 ECTS credits (i.e. 3 courses) from the following selection of Computer Science lectures. They can take at most 36 ECTS credits (i.e. 6 courses/lectures). ■ Algorithm Theory ■ Cyber-Physical Systems – Discrete Models ■ Databases and Information Systems ■ Introduction to Embedded Systems ■ Machine Learning ■ Computer Architecture ■ Foundations of Artificial Intelligence ■ Image Processing and Computer Graphics ■ Software Engineering Together with the chosen courses in the Elective Courses in Computer Science area, the amount of ECTS credits must not surpass 54. Overall, the limit of ECTS credits is 90 for the areas of ■ Essential Lectures in Computer Science ■ Elective Courses in Computer Science ■ Advanced Microsystems Engineering ■ Microsystems Engineering Concentration Areas ■ (as well as the optional area of Customized Course Selection)

↑

Name of module	**Number of module**
Algorithms Theory	11LE13MO-2010 ESE PO 2021
Responsible	
Prof. Dr. Hannah Bast Prof. Dr. Fabian Kuhn	
Organizer	
Department of Computer Science, Algorithms and Complexity	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Basic algorithms and data structures knowledge, comparable to what is done in Algorithms and Data structures, is assumed.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Algorithms Theory	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Algorithms Theory - Exercises	excercise course	Core elective		1.0	

Qualification
The design and analysis of algorithms is fundamental to computer science. Students know important algorithmic techniques, are able to apply them and, if necessary, adapt them for new situations. Students have mastered the basic principles of algorithm design, and are able to use complex data structures to implement algorithms. They can assess the power of algorithmic design principles, such as randomization and dynamic programming, and are able to apply sophisticated approaches for the analysis of methods designed according to such principles.
Examination achievement
Written exam (usually 90 to 180 minutes)

Course achievement
Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points. To successfully complete the course work (Studienleistung), you need to have 50% of all exercise points.
Recommendation
Exercises should be done in groups of 2 students. Please team up with a colleague and send an email (including name and matriculation number of both students) to the lecturer.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Weiterführende Vorlesung | Advanced Lectures ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Essential Lectures in Computer Science Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	Number of module
Algorithms Theory	11LE13MO-2010 ESE PO 2021
course	
Algorithms Theory	
Event type	Number
lecture course	11LE13V-2010
Organizer	
Department of Computer Science, Algorithms and Data Structures Department of Computer Science, Algorithms and Complexity	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	47 Stunden | hours
Independent study	118 Stunden | hours
Hours of week	3.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

This course teaches fundamental algorithms and data structures, and a variety of fundamental techniques for their design and analysis. The focus is on material not already covered in the basic undergraduate course on algorithms and data structures, or on the enhancement of that material. Example techniques are: divide and conquer, randomization, amortized analysis, greedy algorithms, dynamic programming. Example algorithms and data structures are: fast Fourier transformation, randomized quicksort, Fibonacci heaps, minimum spanning trees, longest common subsequence, network flows.
The design and analysis of algorithms is fundamental to computer science. In this course, we will study efficient algorithms for a variety of basic problems and, more generally, investigate advanced design and analysis techniques. Central topics are algorithms and data structures that go beyond what has been considered in the undergraduate course Informatik II. Basic algorithms and data structures knowledge, comparable to what is done in Informatik II, or , is therefore assumed. The topics of the course include (but are not limited to):

- Divide and conquer: geometrical divide and conquer, fast fourier transformation
- Randomization: median, randomized quicksort, probabilistic primality testing, etc.
- Amortized analysis: binomial queues, Fibonacci heaps, union-find data structures
- Greedy algorithms: minimum spanning trees, bin packing problem, scheduling
- Dynamic programming: matrix chain product problem, edit distance, longest common subsequence problem
- Graph algorithms: network flows, combinatorial optimization problems on graphs

Examination achievement

Siehe Modulebene |
See module level

Course achievement
Siehe Modulebene | See module level
Literature
■ Jon Kleinberg and Éva Tardos: Algorithm Design, Addison Wesley ■ Thomas H. Cormen, Charles E. Leiserson, Robert L. Rivest, and Cliford Stein: Introduction to Algorithms, MIT Press ■ Thomas Ottmann and Peter Widmayer: Algorithmen und Datenstrukturen, Spektrum Akademischer Verlag
Compulsory requirement
keine | none
Recommended requirement
Grundkenntnisse in Algorithmen und Datenstrukturen | Basic algorithms and data structures knowledge

↑

Name of module	**Number of module**
Algorithms Theory	11LE13MO-2010 ESE PO 2021
course	
Algorithms Theory - Exercises	
Event type	Number
excercise course	11LE13Ü-2010
Organizer	
Department of Computer Science, Algorithms and Data Structures Department of Computer Science, Algorithms and Complexity	

ECTS-Points	
Attendance	15 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement
Recommendation
We might be able to offer German exercise tutorials (there will definitely be English tutorials). In case you'd prefer to have the exercise tutorials in German, please indicate this via email to the lecturer.

↑

Name of module	Number of module
Computer Architecture	11LE13MO-2020 ESE PO 2021
Responsible	
Prof. Dr. Armin Biere Prof. Dr. Christoph Scholl	
Organizer	
Department of Computer Science, Computer Architecture	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Grundlegendes Wissen und Kenntnisse aus dem Bereich der technischen Informatik (analog zum Modul Technische Informatik), Grundlagen binärer Mathematik; Grundlagen zu digitalen Schaltkreisen; Programmierkenntnisse in C / C ++ | Basic knowledge and in the area of technical informatics (analogous to the module Technische Informatik), fundamentals of binary mathematics; basic knowledge of digital circuits; programming skills in C / C ++

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Rechnerarchitektur / Computer Architecture - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Rechnerarchitektur / Computer Architecture - Exercises	excercise course	Core elective		1.0	

Qualification
Students will be introduced to methods of designing computers, which will cover the topics of testing and verification of digital circuits, processor data and control paths, pipelining and parallelism. They will learn about the RISC-V instruction set and related CPUs. Students will learn to maximize the performance of computing machinery and how to guarantee the correctness of circuits. Finally, they understand how the restric-

tions resulting from digital technology and the specific computer architectures affect higher levels of abstraction, especially those of software technology.
Examination achievement
Written exam (usually 90 to 180 minutes)
Course achievement
Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points. To successfully complete the course work (Studienleistung), you need to have reached at least 50% of points per exercise sheet.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Weiterführende Vorlesung | Advanced Lectures ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Essential Lectures in Computer Science Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Computer Architecture	11LE13MO-2020 ESE PO 2021
course	
Rechnerarchitektur / Computer Architecture - Lecture	
Event type	Number
lecture course	11LE13V-2020
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Operating Systems	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	45 Stunden | hours
Independent study	120 Stunden | hours
Hours of week	3.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

An introduction to fundamental questions, methods and techniques of computer design and computer architecture is given. The following topics are included:
Instructions, Logic Design, Digital Circuit Verification, Testing, Placement & Routing, Single-Cycle Datapath & Control, Pipelining and Pipelining Hazards, Parallelism, Exception and Interrupts

Examination achievement

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

Literature

Mainly:
- David A. Patterson, John L. Hennesey - "Computer Organization and Design - The Hardware Software Interface [RISC-V Edition]

Also helpful:
- J.Teich: Digitale Hardware/Software-Systeme, Springer Verlag, 1997.
- Becker, Bernd and Drechsler, Rolf and Molitor, Paul, „Technische Informatik – Eine Einführung“, Pearson Studium.

■ Tanenbaum: Structured Computer Organization, Prentice Hall, 3rd Edition, 1990.
Compulsory requirement
keine | none
Recommended requirement
Grundlegendes Wissen und Kenntnisse aus dem Bereich der technischen Informatik (analog zum Modul Technische Informatik), Grundlagen binärer Mathematik; Grundlagen zu digitalen Schaltkreisen; Programmierkenntnisse in C / C ++ | Basic knowledge and in the area of technical informatics (analogous to the module Technische Informatik), fundamentals of binary mathematics; basic knowledge of digital circuits; programming skills in C / C ++

↑

Name of module	**Number of module**
Computer Architecture	11LE13MO-2020 ESE PO 2021
course	
Rechnerarchitektur / Computer Architecture - Exercises	
Event type	Number
excercise course	11LE13Ü-2020
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Operating Systems	

ECTS-Points	
Attendance	15 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Die Übungen sollen den Studenten ein besseres Verständnis der wichtigsten Techniken vermitteln, die sie während der Vorlesungen lernen, indem sie die Prinzipien und Methoden anwenden. | The exercises are intended to give students a better understanding of the most important techniques they learn during lectures by applying the principles and methods.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	Number of module
Cyber-Physical Systems – Discrete Models	11LE13MO-2070 ESE PO 2021
Responsible	
Prof. Dr. Andreas Podelski	
Organizer	
Department of Computer Science, Software Engineering	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge in the areas of computer architecture and software engineering / software design

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Cyber-Physikalische Systeme – Diskrete Modelle / Cyber-Physical Systems – Discrete Models - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Cyber-Physikalische Systeme – Diskrete Modelle / Cyber-Physical Systems – Discrete Models - Exercises	excercise course	Core elective		1.0	

Qualification
The course provides an introduction to discrete models of cyber-physical 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. 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.

Examination achievement
Written exam (usually 90 to 180 minutes) If the number of participants is small (< 15), an oral examination may be held instead. The students will be informed in good time.
Course achievement
Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points. To pass the course work (Studienleistung), you must obtain at least 50% of the exercise points. Also, every student must present his/her solution to an exercise in an exercise group at least once in the semester.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Essential Lectures in Computer Science Part of the specialization Cyber-Physical Systems in Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)

↑

Name of module	Number of module
Cyber-Physical Systems – Discrete Models	11LE13MO-2070 ESE PO 2021

course	
Cyber-Physikalische Systeme – Diskrete Modelle / Cyber-Physical Systems – Discrete Models - Lecture	
Event type	Number
lecture course	11LE13V-2070

Organizer
Department of Computer Science, Computer Architecture Department of Computer Science, Programming Languages Department of Computer Science, Software Engineering Department of Computer Science, Operating Systems

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	45 Stunden | hours
Independent study	120 Stunden | hours
Hours of week	3.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

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.

Examination achievement

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

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
Compulsory requirement
keine | none
Recommended requirement
Grundlegende Kenntnisse in den Themenbereichen Rechnerarchitektur und Softwaretechnik / Softwareentwurf | Basic knowledge in the areas of computer architecture and software engineering / software design

↑

Name of module	**Number of module**
Cyber-Physical Systems – Discrete Models	11LE13MO-2070 ESE PO 2021
course	
Cyber-Physikalische Systeme – Diskrete Modelle / Cyber-Physical Systems – Discrete Models - Exercises	
Event type	Number
excercise course	11LE13Ü-2070
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Programming Languages Department of Computer Science, Software Engineering Department of Computer Science, Operating Systems	

ECTS-Points	
Attendance	15 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The lecture is accompanied by exercises. Students train themselves to write down things in a formally correct way.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	Number of module
Datenbanken und Informationssysteme / Data Bases and Information Systems	11LE13MO-2060 ESE PO 2021
Responsible	
Prof. Dr. Hannah Bast Prof. Dr. Joschka Bödecker	
Organizer	
Department of Computer Science, Algorithms and Data Structures Department of Computer Science, Databases and Information Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge of practical computer science, algorithms and data structures as well as basic programming skills; Basic knowledge of operating systems and their use, fundamental knowledge about networks and protocols

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Datenbanken und Informationssysteme / Data Bases and Information Systems - Lecture	lecture course	Compulsory	6.0	2.0	180 Stunden | hours
Datenbanken und Informationssysteme / Data Bases and Information Systems - Exercises	excercise course	Compulsory		2.0	

Qualification
Students understand the basic concepts of databases. They are able to think on different levels of abstraction and have methodical skills in designing a database. They know essential concepts of the SQL standard. Students gained practical experience in using a declarative, set-oriented language for databases. They are able to estimate the processing effort of a request and are able to deal with access rights.

Examination achievement
Written exam (usually 90 to 180 minutes)
Course achievement
The exercise sheets will be assessed. To pass the course, at least 50% of the points you can get by working on the exercise sheets must be achieved.
Recommendation
The exercises deepen the subject matter dealt with in the lecture in theory and practice. The exercise sheets also contain tasks to be solved on the computer. Familiarization with the required software is required for this. While the course is usually offered in German, there are English recordings available; at least one exercise group will be held in English. You are allowed to do the coursework and the written exam in English.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (PO 2020) in Weiterführende Vorlesung | Advanced Lectures ■ M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Essential Lectures in Computer Science Pflichtmodul für Studierende des Studiengangs ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021) Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018)

↑

Name of module	**Number of module**
Datenbanken und Informationssysteme / Data Bases and Information Systems	11LE13MO-2060 ESE PO 2021
course	
Datenbanken und Informationssysteme / Data Bases and Information Systems - Lecture	
Event type	Number
lecture course	11LE13V-2060
Organizer	
Department of Computer Science, Algorithms and Data Structures Department of Computer Science, Databases and Information Systems	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	32 Stunden | hours
Independent study	118 Stunden | hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Languages	german, english

Contents

Aufgabe von Datenbanken ist die Verwaltung großer, dauerhafter Datenbestände in der Weise, dass eine Menge von Benutzern diese Daten unabhängig voneinander, effizient, bequem und sicher verarbeiten können.
Der Stoff der Vorlesung wird in Übungen und einem parallel laufenden Praktikum anhand verschiedener Datenbanksysteme konkretisiert.
Es werden im einzelnen die folgenden Aspekte behandelt:

- Einführung in Datenbanken
- Datenbankentwurf und Datenmodelle
- Datenmanipulationssprachen
- Entwurfstheorie
- Datenintegrität
- Transaktionsverwaltung
- Physische Datenorganisation und aktuelle Entwicklungen.

|
The function of databases is to manage large, permanent data sets in such a way that a large number of users can process this data independently, efficiently, comfortably and securely.
The material of the lecture is concretized in theoretiscal and practical exercises using various database systems.
The following aspects are dealt with in detail:

- Introduction to databases
- Database design and data models
- Data manipulation languages
- Design theory
- Data integrity

- Transaction management
- Physical data organization and current developments.

Examination achievement
Siehe Modulebene | See module level

Course achievement
Siehe Modulebene | See module level

Literature
■ G. Lausen: Datenbanken - Grundlagen und XML-Technologien, Elsevier Spektrum Akademischer Verlag, 2005. ■ A. Heuer, G. Saake: Datenbanken - Konzepte und Sprachen, International Thomson Publishing, 2. Auflage, 2000. ■ A. Kemper, A. Eickler: Datenbanksysteme - Eine Einführung, Oldenbourg, 4. Auflage, 2001. ■ G. Vossen: Datenmodelle, Datenbanksprachen und Datenbank-Management-Systeme, Oldenbourg, 4. Auflage, 2000.

Compulsory requirement
keine | none

Recommended requirement
Grundkenntnisse in praktischer Informatik, zu Algorithmen und Datenstrukturen sowie grundlegende Programmierkenntnisse; Grundkenntnisse über Betriebssysteme und deren Einsatz, über Netzwerk und Protokolle | Basic knowledge of practical computer science, algorithms and data structures as well as basic programming skills; Basic knowledge of operating systems and their use, fundamental knowledge about networks and protocols

↑

Name of module	**Number of module**
Datenbanken und Informationssysteme / Data Bases and Information Systems	11LE13MO-2060 ESE PO 2021
course	
Datenbanken und Informationssysteme / Data Bases and Information Systems - Exercises	
Event type	Number
excercise course	11LE13Ü-2060
Organizer	
Department of Computer Science, Databases and Information Systems	

ECTS-Points	
Attendance	30 Stunden | hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Languages	german, english

Contents
Die Übungen vertiefen den in der Vorlesung behandelten Stoff in Theorie und Praxis. Die Übungsblätter enthalten auch am Computer zu lösende Aufgaben. Hierzu ist ein Vertrautmachen mit der benötigten Software erforderlich. | The exercises deepen the subject matter dealt with in the lecture in theory and practice. The exercise sheets also contain practical tasks to be solved on the computer. Familiarization with the required software is required for this.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Foundations of Artificial Intelligence	11LE13MO-2040 ESE PO 2021

Responsible
Prof. Dr. Joschka Bödecker Prof. Dr. Frank Roman Hutter
Organizer
Department of Computer Science, Computer Science, Foundations of Artificial Intelligence Department of Computer Science, Autonomous Intelligent Systems Department of Computer Science, Professorship in Neurorobotics Department of Computer Science, Professorship in Machine Learning
Faculty
Faculty of Engineering

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none Grundlagenkenntnisse in mathematischer Logik können hilfreich sein | Basic knowledge about formal logic can be helpful

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Foundations of Artificial Intelligence - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Foundations of Artificial Intelligence - Exercises	excercise course	Core elective		1.0	

Qualification
Students have basic knowledge of the various techniques of artificial intelligence. They understand the basic principles of artificial intelligence and apply the technical terms in the correct context. Students are able to interpret tasks in the area of problem solving and searching, and can apply the learned algorithms

to new situations. Students know the usual types of knowledge representation and are able to analyze the techniques presented and evaluate their use in new situations.
Examination achievement
Written exam (usually 90 to 180 minutes)
Course achievement
Working on the exercise sheets is voluntary, but strongly recommended. The exam will contain similar tasks.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Weiterführende Vorlesung | Advanced Lectures ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Essential Lectures in Computer Science Part of the specialization Artificial Intelligence in Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Foundations of Artificial Intelligence	11LE13MO-2040 ESE PO 2021
course	
Foundations of Artificial Intelligence - Lecture	
Event type	Number
lecture course	11LE13V-2040
Organizer	
Department of Computer Science, Computer Science, Foundations of Artificial Intelligence Department of Computer Science, Autonomous Intelligent Systems Department of Computer Science, Professorship in Neurorobotics Department of Computer Science, Professorship in Machine Learning	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	41 Stunden | hours
Independent study	126 Stunden | hours
Hours of week	3.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

This course will introduce the basic concepts and techniques used within the field of Artificial Intelligence. The following topics will be covered:

- Introduction to Artificial Intelligence, including a short history of Artificial Intelligence
- agents
- problem solving and search
- logic and knowledge representation
- action planning
- representation of and reasoning with uncertainty
- machine learning

Examination achievement

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

Literature

- Artificial Intelligence: A modern approach, Stuart Russel and Peter Norvig, Prentice Hall, 2009

Compulsory requirement

keine | none

Recommended requirement
keine | none Grundlagenkenntnisse in mathematischer Logik können hilfreich sein | Basic knowledge about formal logic can be helpful

↑

Name of module	Number of module
Foundations of Artificial Intelligence	11LE13MO-2040 ESE PO 2021
course	
Foundations of Artificial Intelligence - Exercises	
Event type	Number
excercise course	11LE13Ü-2040
Organizer	
Department of Computer Science, Computer Science, Foundations of Artificial Intelligence Department of Computer Science, Autonomous Intelligent Systems Department of Computer Science, Professorship in Neurorobotics Department of Computer Science, Professorship in Machine Learning	

ECTS-Points	
Attendance	13 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The exercises are intended to give students a better understanding of the most important techniques they learn during lectures by applying the principles and formal methods to real life tasks.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Image Processing and Computer Graphics	11LE13MO-2050 ESE PO 2021
Responsible	
Prof. Dr. Thomas Brox Prof. Dr.-Ing. Matthias Teschner	
Organizer	
Department of Computer Science, Computer Graphics Department of Computer Science, Pattern Recognition and Image Processing	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Fundamental mathematical knowledge and programming skills in C/C++

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Image Processing and Computer Graphics - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Image Processing and Computer Graphics - Exercise	excercise course	Core elective		1.0	

Qualification
Students have basic knowledge of the tasks and procedures in image processing and computer graphics. They are able to classify typical image processing problems and questions of generative computer graphics and to understand the main features of current related literature.
Examination achievement
Written exam (usually 90 to 180 minutes)

Course achievement
none
Recommendation
Participation in exercises is recommended to be prepared for the exam.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Weiterführende Vorlesung | Advanced Lectures ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Essential Lectures in Computer Science Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	Number of module
Image Processing and Computer Graphics	11LE13MO-2050 ESE PO 2021
course	
Image Processing and Computer Graphics - Lecture	
Event type	Number
lecture course	11LE13V-2050
Organizer	
Department of Computer Science, Computer Graphics Department of Computer Science, Pattern Recognition and Image Processing	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	41 Stunden | hours
Independent study	126 Stunden | hours
Hours of week	3.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The lecture provides an introduction of basic approaches and illustrates the state-of-the-art in image processing and computer graphics. The curriculum covers image generation, point operations on images, linear and non-linear filters, image segmentation, optical flow and techniques such as calculus of variations and energy minimization. In the context of computer graphics, rasterization-based image generation, i.e. the rendering pipeline of modern graphics cards, is covered. Here, homogeneous coordinates, transforms, color spaces, rasterization, visibility, local illumination models and textures are addressed.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Literature
Will be announced in each lesson.
Compulsory requirement
keine | none
Recommended requirement
Fundamental mathematical knowledge and programming skills in C/C++

↑

Name of module	**Number of module**
Image Processing and Computer Graphics	11LE13MO-2050 ESE PO 2021
course	
Image Processing and Computer Graphics - Exercise	
Event type	Number
excercise course	11LE13Ü-2050
Organizer	
Department of Computer Science, Computer Graphics Department of Computer Science, Pattern Recognition and Image Processing	

ECTS-Points	
Attendance	13 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The exercises are intended to give students a better understanding of the most important techniques they learn during lectures. They are expected to implement some selected methods in C/C++ and develop an intuition of their usage.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Introduction to Embedded Systems	11LE13MO-910 ESE PO 2021
Responsible	
Prof. Dr. Oliver Amft Prof. Dr. Christoph Scholl	
Organizer	
Department of Computer Science, Operating Systems Department of Computer Science, Professorship in Embedded Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge in the field of technical informatics, analog and digital circuits, programming knowledge in C / C ++

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Einführung in Embedded Systems / Introduction to Embedded Systems - Lecture	lecture course	Compulsory	6.0	3.0	180 Stunden | hours
Einführung in Embedded Systems / Introduction to Embedded Systems - Exercises	excercise course	Compulsory		1.0	

Qualification
Students understand the specific properties of embedded systems, their architecture and components, their hardware and software interface, the communication between components, basic analog-digital-analog conversion methods, low-power designs and specification techniques. They will be able to specify embedded systems with VHDL, statechart and petri-nets and reason about properties of the modeled system, and write basic programs in C for an embedded platform.
Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes)

Course achievement
Es gibt Übungsaufgaben im regelmäßigen Rhythmus, die bearbeitet und abgegeben werden müssen. Diese werden korrigiert und mit Punkten bewertet. Die Studienleistung ist bestanden, wenn mindestens 50% der Gesamtpunkte im Semester erreicht sind. | Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points. The Studienleistung counts as passed if at least 50% of the overall number of achievable points for the semester has been reached.
Recommendation
The lecture will be held in English (there are some recordings available in German from previous semesters). The exercises will be offered in German as well as in English.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) in Essential Lectures in Computer Science Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Pflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021) ■ Bachelor of Science in Mikrosystemtechnik (PO 2018), im Wahlpflichtbereich, Bereich Mikrosystemtechnik

↑

Name of module	**Number of module**
Introduction to Embedded Systems	11LE13MO-910 ESE PO 2021
course	
Einführung in Embedded Systems / Introduction to Embedded Systems - Lecture	
Event type	Number
lecture course	11LE13V-910
Organizer	
Department of Computer Science, Operating Systems Department of Computer Science, Professorship in Embedded Systems	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	45 Stunden | hours
Independent study	120 Stunden | hours
Hours of week	3.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Languages	german, english

Contents
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. | Embedded Systems are considered the key application in information technology for the years to come. As the name suggests, they are systems embedding information processing into an environment, where complex control or data processing tasks are executed. The lecture deals with the basic concepts for modelling and designing embedded systems. Among others it covers specification languages and methods for embedded systems (such as statecharts, petri nets, VHDL), the mapping of specifications on processes, hardware of Embedded Systems as well as hardware/software codesign. It addresses the construction elements of an embedded system (e.g. processors, AD/DA converters, sensors, sensor interfaces, memory devices) and presents methods for the design and optimization of the associated circuits with respect to speed, energy consumption and testability.
Examination achievement
Siehe Modulebene | See module level

Course achievement
Siehe Modulebene | See module level
Literature
1. Marwedel, P.: Embedded System Design. Springer-Verlag New York, Inc., 2006. 2. Marwedel, P. ; Wehmayer, L.: Eingebettete Systeme. Springer-Verlag Berlin, 2007. 3. Ritter, J. ; Molitor, P.: VHDL - Eine Einführung. Pearson Studium, 2004. 4. Chang, K. C.: Digital Design and Modeling with VHDL and Synthesis. IEEE Computer Society Press, 1996. 5. Teich, J. ; Haubelt, C.: Digitale Hardware/Software-Systeme. Berlin : Springer-Verlag Berlin, 2007. 6. Baker, R. J.; Li, H. W.; Boyce, D. E.: CMOS Circuit Design, Layout, and Simulation. IEEE Press Series on Microelectronic Systems, 1998. 7. Rabaey, J. M.; Chandrakasan, A. P.; Nikolic, B.: Digital Integrated Circuits. Prentice-Hall, 2003. 8. Tietze, U.; Schenk, C.: Halbleiter Schaltungstechnik. Springer-Verlag, 2002. 9. Weste, N.; Eshraghian, K.: Principles of CMOS VLSI Design; A Systems Perspective. Addison-Wesley, 1993.
Compulsory requirement
keine | none
Recommended requirement
Grundkennnisse im Bereich Technische Informatik, analoge und digitale Schaltkreise, Programmierkenntnisse in C / C++ | Basic knowledge in the field of technical informatics, analog and digital circuits, programming knowledge in C / C ++

↑

Name of module	**Number of module**
Introduction to Embedded Systems	11LE13MO-910 ESE PO 2021
course	
Einführung in Embedded Systems / Introduction to Embedded Systems - Exercises	
Event type	Number
excercise course	11LE13Ü-910
Organizer	
Department of Computer Science, Operating Systems Department of Computer Science, Professorship in Embedded Systems	

ECTS-Points	
Attendance	15 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Languages	german, english

Contents
Die Übungen bestehen aus theoretischen Aufgaben und Programmieraufgaben, um die Methoden und Konzepte der Vorlesung in praktischen Anwendungen einzusetzen. | The exercises consist of theoretical assignments and programming assignments, to apply the methods and concepts from the lecture.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Machine Learning	11LE13MO-1153 ESE PO 2021
Responsible	
Prof. Dr. Joschka Bödecker Prof. Dr. Frank Roman Hutter	
Organizer	
Department of Computer Science, Professorship in Neurorobotics Department of Computer Science, Professorship in Machine Learning	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
We have to rely on a solid background in basic math, specifically linear algebra (an eigenvalue decomposition, matrix operations, covariance matrices etc. should be very familiar concepts), calculus and probability theory. We use the Python programming language for most of our assigments. If you do not yet have Python experience, you must ramp up at least basic knowledge thereof. We recommend basic knowledge of optimization and of the scikit-learn Python library.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Maschinelles Lernen / Machine Learning - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Maschinelles Lernen / Machine Learning - Exercises	excercise course	Core elective		1.0	

Qualification
This course provides you with a good theoretical understanding and practical experience about the basic concepts of machine learning. You shall be enabled to implement a number of basic algorithms, understand advantages and drawbacks of single methods and know typical application domains thereof. Furthermore, you should be able to use (Python) software libraries in order to work on novel data analysis problems.

The course will prepare you to dive deeper into advanced methods of ML, e.g. deep learning, recurrent networks, reinforcement learning, hyperparameter optimization, and into specific application domains such as image analysis, brain signal analysis, robot learning, bioinformatics etc., for which specialized courses are available.

Examination achievement
Ususally a written exam (duration of 90 to 180 minutes) If the number of participants is small, an oral examination (with a duration of 35 minutes) may be held instead. The students will be informed in good time.
Course achievement
To prepare for the exam, there can be a mock exam (written or oral).
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Weiterführende Vorlesung | Advanced Lectures ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Essential Lectures in Computer Science ■ Students of the M.Sc. programs Microsystems Engg. and Mikrosystemtechnik (PO 2021) can select this module in the concentration area Biomedical Engineering (Biomedizinische Technik). Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	Number of module
Machine Learning	11LE13MO-1153 ESE PO 2021
course	
Maschinelles Lernen / Machine Learning - Lecture	
Event type	Number
lecture course	11LE13V-1153
Organizer	
Department of Computer Science, Professorship in Machine Learning	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	45 Stunden | hours
Independent study	120 Stunden | hours
Hours of week	3.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

- Applications / typical problems dealt with by machine learning
- basic data analysis pipeline (from data recording to output shaping)
- software libraries
- linear methods (e.g. LDA, logistic regression, ICA, PCA, OLSR) for dimensionality reduction, classification, regression and blind source separation
- non-linear methods (e.g. support vector machines, kernel PCA, decision trees / random forests, neural networks) for classification and regression
- unsupervised clustering (e.g. k-means, DBSCAN)
- algorithm independent principles in machine learning (z.b. bias-variance trade-off, model complexity, regularization, validation strategies, interpretation of trained machine learning models, basic optimization approaches, feature selection, data visualization)

Examination achievement

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

Literature

Duda, Hart and Stork: Pattern Classification
Christopher Bishop: Pattern Recognition and Machine Learning
Hastie, Tibshirani and Friedman: The Elements of Statistical Learning
Mitchell: Machine Learning

Murphy: Machine Learning – a Probabilistic Perspective Criminisi et. al: Decision Forests for Computer Vision and Medical Image Analysis Schölkopf & Smola: Learning with Kernels Goodfellow, Bengio and Courville: Deep Learning Michael Nielsen: Neural Networks and Deep Learning In addition, literature for every section of the course is announced during these sections.
Compulsory requirement
keine | none
Recommended requirement
We have to rely on a solid background in basic math, specifically linear algebra (an eigenvalue decomposition, matrix operations, covariance matrices etc. should be very familiar concepts), calculus and probability theory. We use the Python programming language for most of our assigments. If you do not yet have Python experience, you must ramp up at least basic knowledge thereof. We recommend basic knowledge of optimization and of the scikit-learn Python library.
Teaching method
For in-class lectures: Despite the large lecture rooms, a teacher-centered style shall be enriched as much as possible by measures like: ■ interactive question and answer rounds ■ discussions in sub-groups, reporting to the large group ■ cross-teaching ■ problem-oriented teaching e.g. via data analysis competition ■ repetition of important concepts in slightly altered contexts. **For virtual lectures:** ■ flipped classroom teaching with videos provided ■ Q&A sessions to discuss the videos' content ■ Cross-teaching via Ilias forum ■ problem-oriented teaching e.g. via data analysis competition ■ repetition of important concepts in slightly altered contexts.

↑

Name of module	**Number of module**
Machine Learning	11LE13MO-1153 ESE PO 2021
course	
Maschinelles Lernen / Machine Learning - Exercises	
Event type	Number
excercise course	11LE13Ü-1153
Organizer	
Department of Computer Science, Professorship in Machine Learning	

ECTS-Points	
Attendance	15 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The exercises are intended to give students a better understanding of the most important techniques they learn during lectures. They are expected to implement some selected methods to gain experience in practical applications.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
Software Engineering	11LE13MO-2030 ESE PO 2021
Responsible	
Prof. Dr. Andreas Podelski	
Organizer	
Department of Computer Science, Programming Languages Department of Computer Science, Software Engineering	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge about practical Computer Science concepts, algorithms and datastructure, Programming Skills

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Softwaretechnik / Software Engineering - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Softwaretechnik / Software Engineering - Exercises	excercise course	Core elective		1.0	

Qualification
Students know the basic modeling techniques and construction principles for software systems, they have an overview over the challenges of software engineering and the techniques and tools to address these challenges. They have knowledge of the main activities during software development (in particular project management, requirements engineering, design, testing, formal verification) with an emphasis on formal methods. Students know the foundations of process models, software metrics, approaches to requirements specification and analysis, (formal) modelling and analysis techniques, design and architecture patterns, testing, and program verification, and can apply these techniques on a small scale and can acquire advanced techniques on their own. Students have applied formal methods in example scenarios and are able to assess in which situations such methods are useful.

Examination achievement
Written exam (usually 90 to 180 minutes)
Course achievement
Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points. To successfully complete the course work (Studienleistung), you need to have reached at least 50% of points.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Weiterführende Vorlesung | Advanced Lectures ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Essential Lectures in Computer Science Part of the specialization Cyber-Physical Systems in Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	Number of module
Software Engineering	11LE13MO-2030 ESE PO 2021
course	
Softwaretechnik / Software Engineering - Lecture	
Event type	Number
lecture course	11LE13V-2030
Organizer	
Department of Computer Science, Programming Languages Department of Computer Science, Software Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	40 Stunden | hours
Independent study	127 Stunden | hours
Hours of week	3.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Software engineering is "the application of engineering to software". This lecture provides knowledge of the fundamental techniques in software engineering:
Revision Control, Process Models, Requirements Analysis, Formal and Semiformal Modeling Techniques, Object Oriented Analysis, Object Oriented Design, Design Patterns, Testing.

Examination achievement

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

Literature

- Ludewig, J. and Lichter, H. Software Engineering
- Jacobson, I. et al. Object Oriented Software-Engineering - A Use Case Driven Approach
- Davis, A. Software Requirements - Analysis and Specification

Compulsory requirement

keine | none

Recommended requirement

Basic knowledge about practical Computer Science concepts, algorithms and datastructure,
Programming Skills

(for Bachelor of Science: Participation in Softwarepraktikum)

↑

Name of module	**Number of module**
Software Engineering	11LE13MO-2030 ESE PO 2021
course	
Softwaretechnik / Software Engineering - Exercises	
Event type	Number
excercise course	11LE13Ü-2030
Organizer	
Department of Computer Science, Programming Languages Department of Computer Science, Software Engineering	

ECTS-Points	
Attendance	13 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
The exercises consist of theoretical assignments and programming assignments, to apply the methods and concepts from the lecture.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of node	Number of node
Elective Courses in Computer Science	11LE50KT-MSc-787-2021-ElectiveCS
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Compulsory

Comment
Students have to take at least 3 Specialization Courses in Computer Science. Together with the chosen Essential Courses in Computer Science, the amount of ECTS credits must not surpass 54. Overall, the limit of ECTS credits is 90 for the areas of ■ Essential Lectures in Computer Science ■ Elective Courses in Computer Science ■ Advanced Microsystems Engineering ■ Microsystems Engineering Concentration Areas ■ (as well as the optional area of Customized Course Selection) Instead of Specialization Courses, students can opt to take up to two seminars (3 ECTS credits each) or a Study Project (18 ECTS credits).

↑

Name of module	**Number of module**
Advanced Algorithms	11LE13MO-1326 ESE PO 2021
Responsible	
Prof. Dr. Fabian Kuhn	
Organizer	
Department of Computer Science, Algorithms and Complexity	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
some background in algorithm design/analysis and probability theory is expected (as gained in the course "Algorithms Theory")

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Advanced Algorithms	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Advanced Algorithms	excercise course	Core elective		2.0	

Qualification
Students have advanced knowlegde about modern algorithmic techniques. They know the advantages and disadvantages of various methods for different applications.
Examination achievement
Oral exam (usually 30 or 45 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

↑

Name of module	**Number of module**
Advanced Algorithms	11LE13MO-1326 ESE PO 2021
course	
Advanced Algorithms	
Event type	Number
lecture course	11LE13V-1326
Organizer	
Department of Computer Science, Algorithms and Complexity	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	28
Independent study	124
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

In the course, we discuss modern algorithmic techniques. The course covers a variety of topics, such as for example:

- approximation algorithms
- randomized algorithms
- graph embeddings
- graph sparsification
- theory of learningk
- sketching and streaming algorithms
- continuous methods in combinatorial optimization

Examination achievement

See module level

Course achievement

See module level

Literature

Literature will be provided in the lecture.

Compulsory requirement

none

Recommended requirement
There is no formal requirement, however some background in algorithm design/analysis and probability theory is expected. Having passed the algorithm theory course (or a similar course) prior to taking the advanced algorithms lecture is highly recommended.

↑

Name of module	**Number of module**
Advanced Algorithms	11LE13MO-1326 ESE PO 2021
course	
Advanced Algorithms	
Event type	Number
excercise course	11LE13Ü-1326
Organizer	
Department of Computer Science, Algorithms and Complexity	

ECTS-Points	
Attendance	28
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The lecture will be complemented by theoretical exercises that allow to apply and further develop ideas and techniques discussed in the lecture. The exercises are an integral part of the lecture, the topics covered by the exercises will also be part of the oral exam. There are two graded homework assignments that count 30% towards the final grade of the course.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Advanced Computer Graphics	11LE13MO-1106 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Matthias Teschner	
Organizer	
Department of Computer Science, Computer Graphics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Programming skills Knowledge in Algorithms and Data Structures, Linear Algebra and Analysis Knowledge in Image Processing and Computer Graphics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Fortgeschrittene Computergraphik / Advanced Computer Graphics - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Fortgeschrittene Computergraphik / Advanced Computer Graphics - Exercises	excercise course	Core elective		2.0	

Qualification
Students know the main concepts for image synthesis as well as global illumination approaches. They are able to use formal governing equation and solution techniques and know how to describe light. They know bidirectional reflectance distribution functions for material modeling and can apply Monte-Carlo techniques for approximately solving the rendering equation that describes the interaction of light with surfaces.
Examination achievement
Written exam (usually 90 to 180 minutes)

Course achievement
none
Recommendation
Working on the exercise sheets is voluntary, but strongly recommended.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	Number of module
Advanced Computer Graphics	11LE13MO-1106 ESE PO 2021
course	
Fortgeschrittene Computergraphik / Advanced Computer Graphics - Lecture	
Event type	Number
lecture course	11LE13V-1106
Organizer	
Department of Computer Science, Computer Graphics	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	30 Stunden
Independent study	90 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

The course addresses all aspects of the raytracing technique. The curriculum covers photometric quantities to describe light, bidirectional reflectance distribution functions for material modeling and Monte-Carlo techniques for approximately solving the rendering equation that describes the interaction of light with surfaces. The curriculum also addresses the homogeneous notation, spatial data structures for ray-object intersections and sampling strategies.

Examination achievement

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

Literature

- Dutre, Bala, Bekaert: Advanced Global Illumination, A K Peters, 2006
- Pharr, Humphreys: Physically Based Rendering, Elsevier, 2010
- Shirley, Keith Morley: Realistic Ray Tracing, A K Peters, 2003
- Suffern: Ray Tracing From The Ground Up, A K Peters, 2007
- Foley, vanDam, Feiner, Hughes: Computer Graphics - Principles and Practice -, Addison Wesley, ISBN 0-201-84840-6
- Tomas Moller and Eric Haines: Real-Time Rendering, A. K. Peters Limited, 1999, ISBN 1-56881-182-9
- David F. Rogers: Procedural Elements for Computer Graphics, McGraw-Hill, 1998, ISBN 0-07-053548-5

■ OpenGL Programming Guide, Second Edition, Addison-Wesley, 1997, ISBN 0-201-461138-2
Compulsory requirement
Recommended requirement
Programming skills Knowledge in Algorithms and Data Structures, Linear Algebra and Analysis Knowledge in Image Processing and Computer Graphics

↑

Name of module	**Number of module**
Advanced Computer Graphics	11LE13MO-1106 ESE PO 2021
course	
Fortgeschrittene Computergraphik / Advanced Computer Graphics - Exercises	
Event type	Number
excercise course	11LE13Ü-1106
Organizer	
Department of Computer Science, Computer Graphics	

ECTS-Points	
Attendance	30 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Practical development of ray tracing components based on concepts from lectures
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Advanced Deep Learning	11LE13MO-1146 ESE PO 2021
Responsible	
Prof. Dr. Abhinav Valada	
Organizer	
Department of Computer Science, Autonomous Intelligent Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
none
Recommended requirement
Fundamentals of Deep Learning Machine Learning

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Advanced Deep Learning	lecture course	Core elective	6.0	2.0	180 hours
Advanced Deep Learning	excercise course	Core elective		2.0	

Qualification
Students have a clear understanding of advanced deep learning techniques and know how to apply them in various domains. They know modern architectures including topics in Graph Neural Networks, Multi-dimensional Deep Learning, Transformers, Metric Learning, Cross-modal Learning, Transfer Learning, Domain Adaptation, Self-supervised Learning, Multi-task Learning, Meta-Learning, and Continual Learning.
Examination achievement
Oral examination (usually 30 or 45 minutes)
Course achievement
Presentation

Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Artificial Intelligence in Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering

↑

Name of module	**Number of module**
Advanced Deep Learning	11LE13MO-1146 ESE PO 2021
course	
Advanced Deep Learning	
Event type	Number
lecture course	11LE13V-1146_PO 2020
Organizer	
Department of Computer Science, Autonomous Intelligent Systems	

ECTS-Points	6.0
Workload	180 hours
Attendance	32 Stunden
Independent study	116 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Deep learning techniques are constantly evolving and are nowadays recognized as the state-of-the-art solution in many problems in various domains. This course will provide a clear understanding of advanced deep learning techniques and modern architectures include topics in Graph Neural Networks, Multi-dimensional Deep Learning, Transformers, Metric Learning, Cross-modal Learning, Transfer Learning, Domain Adaptation, Self-supervised Learning, Multi-task Learning, Meta-Learning, and Continual Learning.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement
Recommended requirement
Fundamentals of Deep Learning Machine Learning

↑

Name of module	**Number of module**
Advanced Deep Learning	11LE13MO-1146 ESE PO 2021
course	
Advanced Deep Learning	
Event type	Number
excercise course	11LE13Ü-1146_PO 2020
Organizer	
Department of Computer Science, Autonomous Intelligent Systems	

ECTS-Points	
Attendance	32 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Students learn to apply some of the techniques from the lecture.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Algorithms for Wireless Communication	11LE13MO-1157_PO 2020
Responsible	
Prof. Dr. Christian Schindelhauer	
Organizer	
Department of Computer Science, Computer Networks and Telematics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge about Distributed Systems, Computer Networks, Algorithms and Data Structures

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Algorithms for Wireless Communication	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Algorithms for Wireless Communication	excercise course	Core elective		2.0	

Qualification
After this course students can apply existent theoretical communication models of computer science and information theory to a given problem and analyse the quality of a given algorithmic solutions.
Examination achievement
If there are 20 or fewer registered participants, an oral exam (usually 30 or 45 minutes); if there are more than 20 registered participants, a written exam (usually 90 to 180 minutes). Details will be announced in due time.
Course achievement
Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points. To successfully complete the course work (Studienleistung), you need to have reached at least 50% of the achievable points.

Usability
Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Cyber-Physical Systems in Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering

↑

Name of module	**Number of module**
Algorithms for Wireless Communication	11LE13MO-1157_PO 2020
course	
Algorithms for Wireless Communication	
Event type	Number
lecture course	11LE13V-1157_PO 2020
Organizer	
Department of Computer Science, Computer Networks and Telematics	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	32 Stunden
Independent study	116 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The course offers a selected view from the wide area of topics regarding wireless communication under the algorithmic and partly also the information theoretic view. E.g. wireless communication models in computer science and information theory. Physical foundations of wireless communication: electromagnetic and accoustic communication. Medium access from Radio Networking to MACAW. Multi- and single-commodity flow problems, shortest path for route detection and optimization for congestions, delay and energy. Network coding, graph embedding, MIMO power gain and diversity gain. Models for nearfield and quantum communication.
Examination achievement
See module level
Course achievement
See module level
Literature
Current research papers to be announced in the course.
Compulsory requirement
none
Recommended requirement
Distributed Systems, Computer Networks, Algorithms and Data Structures
Recommendation
The lecture will be recorded (unlike the exercise class). All course material will be made available online to participants.

↑

Name of module	**Number of module**
Algorithms for Wireless Communication	11LE13MO-1157_PO 2020
course	
Algorithms for Wireless Communication	
Event type	Number
excercise course	11LE13Ü-1157_PO 2020
Organizer	
Department of Computer Science, Computer Networks and Telematics	

ECTS-Points	
Attendance	32 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
Exercise class with tasks in discrete optimization for network routing, path loss estimations for SNR models, mathematical simulations of networks in computer algebra systems, the mathematics of basic signal processing, algorithm design and analysis of routing algorithms and shortest path algorithms, lower bound analysis.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Automated Machine Learning	11LE13MO-1415 ESE PO 2021
Responsible	
Prof. Dr. Frank Roman Hutter	
Organizer	
Department of Computer Science, Professorship in Machine Learning	
Faculty	
Faculty of Engineering	

ECTS-Points	
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement

- either lecture: "Machine Learning"
- or lecture: "Foundations of Deep Learning"

Recommended requirement

- Solid understanding of machine learning
- Hands-on experience with deep learning
- Programming skills in Python

Assigned Courses

Name	Type	C/E	ECTS	HoW	Workload
Automated Machine Learning	lecture course	Core elective	6.0	2.0	180 hours
Automated Machine Learning	excercise course	Core elective		2.0	

Qualification

Based on machine learning (ML), AI achieved major breakthroughs in the last years. However, applying machine learning and in particular deep learning (DL) in practice is a challenging task and requires a lot of expertise. Among other things, the success of ML/DL applications depends on many design decisions, including an appropriate preprocessing of the data, choosing a well-performing machine learning algorithm and tuning its hyperparameters, giving rise to a complex pipeline. Unfortunately, even experts need days, weeks or even months to find well-performing pipelines and can still make mistakes when optimizing their pipelines.

After completion of this course students will be able to discuss meta-algorithmic approaches to automatically search for, and obtain well-performing machine learning systems by means of automated machine learning (AutoML). Such AutoML systems allow for faster development of new ML/DL applications, require far less expert knowledge than doing everything from scratch and often even outperform human developers. Students know how to use such AutoML systems, to develop their own systems and to understand ideas behind state-of-the-art AutoML approaches.
Examination achievement
oral examination (usually 30 or 45 minutes)
Course achievement
Doing a project (workload about 80h)
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science   Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering **and** Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

↑

Name of module	**Number of module**
Automated Machine Learning	11LE13MO-1415 ESE PO 2021
course	
Automated Machine Learning	
Event type	Number
lecture course	11LE13V-1415
Organizer	
Department of Computer Science, Professorship in Machine Learning	

ECTS-Points	6.0
Workload	180 hours
Attendance	30
Independent study	90
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
* Design of configuration spaces for automated machine learning * Hyperparameter Optimization with Bayesian Optimization * Neural architecture search with Reinforcement learning, Bayesian Optimization and Evoluationary strategies * Transfer-learning, meta-learning, pre-training and fine-tuning * Learning-to-learn * Hyperparameter importance analysis
Examination achievement
See module level
Course achievement
See module level
Literature
Selected material from the book "AutoML: Methods, Systems, Challenges" by Hutter, Kotthoff and Van-Schoren (freely available online at www.automl.org/book), as well as other surveys and research articles.
Compulsory requirement
* Lecture: "Machine Learning" * Lecture: "Foundations of Deep Learning"
Recommended requirement
* Solid understanding of machine learning * Hands-on experience with deep learning

↑

Name of module	**Number of module**
Automated Machine Learning	11LE13MO-1415 ESE PO 2021
course	
Automated Machine Learning	
Event type	Number
excercise course	11LE13Ü-1415
Organizer	
Department of Computer Science, Professorship in Machine Learning	

ECTS-Points	
Attendance	30
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Die Übungen orientieren sich an den Vorlesungen. In den praktisch angelegten Übungen werden die Inhalte der Vorlesung praktisch selbstständig umgesetzt.
Am Ende gibt es ein großes Projekt (80h), in dem die Studierenden die Inhalte eigenständig auf ein neues Problem anwenden.
Dieses Projekt wird im ersten Teil der mündlichen Prüfung vorgestellt.

The exercises follow the lectures. In the practically-oriented exercises students will independently implement the lecture material.
In the end there is a large project (80h), in which the students apply the contents of the course to a new problem domain.
This project will be presented in the first part of the oral exam.

Examination achievement

See module level

Course achievement

See module level

Compulsory requirement

↑

Name of module	**Number of module**
Bioinformatics I	11LE13MO-1309 ESE PO 2021
Responsible	
Prof. Dr. Rolf Backofen	
Organizer	
Department of Computer Science, Bioinformatics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Advantageous or strongly recommended prerequisites: ■ Basic, simple knowledge of molecular biology ■ Basic knowledge of algorithms, such as from computer science undergraduate / bachelor's degree

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Bioinformatik I / Bioinformatics I - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Bioinformatik I / Bioinformatics I - Exercises	excercise course	Core elective		2.0	

Qualification
The course shall give an overview of basic bioinformatics topics and understanding of some fundamental algorithms. The special focus of the course is on sequence analysis. In the module we fundamental principles in biology are revised and illustrate target problems and associated applications. Students will be able to explain and apply fundamental algorithms regarding sequence alignment and phylogenetic trees and will be capable to design and analyze algorithms that elaborate discrete sequences. Students will understand how to solve an optimization problem using Dynamic Programming techniques and be able to design and analyze new algorithms. By the end of the module, students will become familiar with applications of Markov models in Bioinformatics and be able to compute phylogenetic trees.

Examination achievement
Written exam (usually 90 to 180 minutes) If the number of participants is small (< 20), an oral examination may be held instead. The students will be informed in good time.
Course achievement
none
Recommendation
Solving exercise sheets is optional but highly recommended.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. M.Sc. Embedded Systems Engineering **and** Part of the specialization Biomedical Engineering (BE) in M.Sc. Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Bioinformatics I	11LE13MO-1309 ESE PO 2021
course	
Bioinformatik I / Bioinformatics I - Lecture	
Event type	Number
lecture course	11LE13V-1309
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	30
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Sequenzalignment:
- global und lokal, Distanz und Ähnlichkeit
- affine and beliebige Gap-Kostenfunktionen

Substitutionsmatrizen und Markov-Ketten:
- Markov-Modelle und deren Eigenschaften
- Markov-Ketten und Substitutionsmatrizen, z.B. PAM

Phylogenetische Bäume:
- hierarchische Methoden und clustering
- Markov-Prozesse und maximum likelihood
- quartet puzzling

Examination achievement

See module level

Course achievement

See module level

Compulsory requirement

Recommended requirement

Von Vorteil bzw. vorausgesetzt sind
Grundlegende, einfache molekularbiologische Kenntnisse

Grundlegende Kenntnisse in Algorithmen, wie aus Informatik Grundstudium/Bachelor

↑

Name of module	**Number of module**
Bioinformatics I	11LE13MO-1309 ESE PO 2021
course	
Bioinformatik I / Bioinformatics I - Exercises	
Event type	Number
excercise course	11LE13Ü-1309
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	
Attendance	28 Stunden
Independent study	124 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Participating in the the exercise sessions and solving the sheets deepens your understanding. You can use the exercise session for (supervised) solving the sheets or to ask questions. You can solve them independently or as group.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Bioinformatics II	11LE13MO-1310 ESE PO 2021
Responsible	
Prof. Dr. Rolf Backofen	
Organizer	
Department of Computer Science, Bioinformatics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
Bioinformatics I
Recommended requirement
The foundations laid in Bioinformatics I will be assumed to be known. Additional prerequisites: ■ Basic, simple knowledge of molecular biology ■ Basic knowledge of algorithms, such as from computer science undergraduate / bachelor's degree

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Bioinformatik II / Bioinformatics II - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Bioinformatik II / Bioinformatics II - Exercises	excercise course	Core elective		2.0	

Qualification
This module is designed as a follow up for the course “Bioinformatics 1” or a similar one. Students will be given an advanced overview of bioinformatics topics with a deeper understanding of many fundamental algorithms. They will learn well known multiple sequence alignment and analysis algorithms like BLAST and t-coffee and be able to explain them in detail. They will understand Hidden Markov modelling and will apply them to specific problems in Bioinformatics. Students will be able to distinguish various protein models and to com-

pile folding kinetics information based on energy landscape models. Finally, they can calculate optimal RNA structures based on central prediction algorithms and explain the according methods.
Examination achievement
Oral exam (usually 30 or 45 minutes) If the number of participants is very high (< 30), a written examination may be held instead. The students will be informed in good time.
Course achievement
none
Recommendation
Solving exercise sheets is optional but highly recommended.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. M.Sc. Embedded Systems Engineering **and** Part of the specialization Biomedical Engineering (BE) in M.Sc. Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Bioinformatics II	11LE13MO-1310 ESE PO 2021
course	
Bioinformatik II / Bioinformatics II - Lecture	
Event type	Number
lecture course	11LE13V-1310
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	32 Stunden
Independent study	116 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Multiple sequence alignment
- Scoring schemes
- Exact and heuristic methods (progressive approaches, t-coffee etc.)

Hidden markov models
- Profile HMMs for multiple alignment
- Learning profile HMMs

Protein structure
- Simple protein models

Fast sequence search
- BLAST
- BLAT
- Suffix trees

Energy Landscapes
- Monte-Carlo sampling
- Abstractions
- Folding dynamics

Examination achievement

See module level

Course achievement

See module level

Literature
■ Clote, Backofen: Computational Molecular Biologie, An Introduction. Wiley & Sons. ISBN-10: 0471872520 ISBN-13: 978-0471872528 ■ Durbin et al.: Biological Sequence Analysis. Cambridge University Press. ISBN-10: 0521629713 ISBN-13: 978-0521629713 ■ D.W. Mount: Bioinformatics - Sequence and Genome Analysis Cold Spring Harbor
Compulsory requirement
Bioinformatics I
Recommended requirement
The foundations laid in Bioinformatics I will be assumed to be known. Additional prerequisites: ■ Basic, simple knowledge of molecular biology ■ Basic knowledge of algorithms, such as from computer science undergraduate / bachelor's degree

↑

Name of module	**Number of module**
Bioinformatics II	11LE13MO-1310 ESE PO 2021
course	
Bioinformatik II / Bioinformatics II - Exercises	
Event type	Number
excercise course	11LE13Ü-1310
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	
Attendance	32 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Participating in the exercise sessions and solving the sheets deepens your understanding by applying the concepts from the lecture to real-life situations. It is recommended as a preparation for the examination at the end of the semester.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Blockchain and Cryptocurrencies	11LE13MO-1235 ESE PO 2021
Responsible	
Prof. Dr. Peter Thiemann	
Organizer	
Department of Computer Science, Programming Languages	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Blockchain and Cryptocurrencies	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Blockchain and Cryptocurrencies	excercise course	Core elective		2.0	

Qualification
Students know the concepts of how blockchains work. They have insight in application scenarios, especially regarding the monetary background,Bitcoin and other crypto currencies. Cryptographic foundations, Transaction ability, Transaction legitimation, Consensus from Proof of Work to Proof of Stake are understood. Nonmonetary applications like Smart contracts from Ethereum to Tezos are known. Students are aware of security impliciations and risks.
Examination achievement
Written exam (usually 90 to 180 minutes)

Course achievement
keine | none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018)

↑

Name of module	**Number of module**
Blockchain and Cryptocurrencies	11LE13MO-1235 ESE PO 2021
course	
Blockchain and Cryptocurrencies	
Event type	Number
lecture course	11LE13V-1235
Organizer	
Department of Computer Science, Programming Languages	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	28
Independent study	124
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Monetary background,Bitcoin and other crypto currencies, Cryptographic foundations, Transaction ability, Transaction legitimation, Consensus from Proof of Work to Proof of Stake, Nonmonetary applications, Smart contracts from Ethereum to Tezos, Security impliciations and risks
Examination achievement
See module level
Course achievement
See module level
Literature
■ Fabian Schär, Aleksander Berentsen. Bitcoin, Blockchain und Kryptoassets: Eine umfassende Einführung. Books on Demand. 2017 ■ Narayanan et al. Bitcoin and Cryptocurrency Technologies. Princeton University Press. 2016.
Compulsory requirement
keine | none
Recommended requirement
keine | none

↑

Name of module	**Number of module**
Blockchain and Cryptocurrencies	11LE13MO-1235 ESE PO 2021
course	
Blockchain and Cryptocurrencies	
Event type	Number
excercise course	11LE13Ü-1235

ECTS-Points	
Attendance	28
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Repetition, application, and consolidation of the lecture material with theoretical and practical tasks
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Compilerbau / Compiler Construction	11LE13MO-1208_PO 2020
Responsible	
Prof. Dr. Peter Thiemann	
Organizer	
Department of Computer Science, Programming Languages	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Compilerbau / Compiler Construction	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Compilerbau / Compiler Construction	excercise course	Core elective		2.0	

Qualification
The students know basic techniques and tools of compiler construction and are able to apply them. They will be able to read and create specifications for syntactic and semantic analysis. They will know all stages of a simple compiler and be able to develop and assemble them into a working compiler. They know abstract intermediate representations and the concept of staging of different processing stages and are able to apply them.
Examination achievement
If there are 20 or fewer registered participants, an oral exam (usually 30 or 45 minutes); if there are more than 20 registered participants, a written exam (usually 90 to 180 minutes). Details will be announced in due time.

Course achievement
keine | none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science ■ M.Sc. in Sustainable Systems Engineering (PO 2021) Part of the specialization Cyber-Physical Systems in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Compilerbau / Compiler Construction	11LE13MO-1208_PO 2020
course	
Compilerbau / Compiler Construction	
Event type	Number
lecture course	11LE13V-1208
Organizer	
Department of Computer Science, Programming Languages	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	28 Stunden | hours
Independent study	152 Stunden | hours
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents

- Architektur eines Compilers
- Syntaktische und semantische Analyse
- Zwischensprachen und Transformation
- Instruktionsauswahl
- Registerallokation
- Analyse und Optimierung
- Garbage Collection
- Typen und Typinferenz

|

- Architecture of a compiler
- Syntactic and semantic analysis
- Intermediate representation and transformation
- Instruction selection
- Register allocation
- Code analysis and optimization
- Garbage collection
- Types and type inference

Examination achievement

See module level

Course achievement

See module level

Literature
■ Andrew Appel with Jens Palsberg, Modern Compiler Implementation in Java, 2nd edition. Cambridge University Press (2002) ■ Alfred V. Aho, Monica S. Lam, Ravi Sethi, and Jeffrey D. Ullman. Compilers, Principles, Techniques, and Tools (2nd Edition). Prentice Hall, 2006. ■ Reinhard Wilhelm and Dieter Maurer. Übersetzerbau -- Theorie, Konstruktion, Generierung -- 2. Auflage. Lehrbuch. Springer-Verlag, Berlin, Heidelberg, 1996
Compulsory requirement
keine | none
Recommended requirement
keine | none

↑

Name of module	Number of module
Compilerbau / Compiler Construction	11LE13MO-1208_PO 2020
course	
Compilerbau / Compiler Construction	
Event type	Number
excercise course	11LE13Ü-1208
Organizer	
Department of Computer Science, Programming Languages	

ECTS-Points	
Attendance	28 Stunden | hours
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
Im Rahmen der Übung wird exemplarisch ein Compiler für eine kleine Programmiersprache entwickelt. Dabei kommen die Techniken und Inhalte der Vorlesung zum Einsatz. | The subject of the exercise is the development of a compiler for a small programming language. The development builds on the techniques and tools introduced in the lecture.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Computer Vision	11LE13MO-1123 ESE PO 2021
Responsible	
Prof. Dr. Thomas Brox	
Organizer	
Department of Computer Science, Pattern Recognition and Image Processing	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Fundamental mathematical knowledge and programming skills (in C++ or Python) Basic knowledge in image processing and/or computer graphics concepts

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Computer Vision - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Computer Vision - Exercises	excercise course	Core elective		2.0	

Qualification
This course introduces the most important concepts in today's Computer Vision research. Students learn about some of the typical problems and methodologies in computer vision. After the module, they are capable to read current related literature and understand standard concepts used in computer vision research. Moreover, they can implement the techniques discussed in the lectures and to adapt them to their needs, if necessary.

Examination achievement
If there are 30 or fewer registered participants, an oral exam (usually 30 or 45 minutes); if there are more than 30 registered participants, a written exam (usually 90 to 180 minutes). Details will be announced in due time.
Course achievement
keine | none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Computer Vision	11LE13MO-1123 ESE PO 2021
course	
Computer Vision - Lecture	
Event type	Number
lecture course	11LE13V-1123
Organizer	
Department of Computer Science, Pattern Recognition and Image Processing	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	32 Stunden
Independent study	148 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The course presents the most relevant computer vision tasks and current solutions. It covers nonlinear diffusion, variational optimization, spectral clustering, image segmentation, optical flow, video segmentation, stereo reconstruction, camera calibration, structure from motion, recognition, and deep learning.
Examination achievement
See module level
Course achievement
See module level
Literature
current literature, as announced directly in lecture
Compulsory requirement
keine | none
Recommended requirement
Fundamental mathematical knowledge and programming skills (in C++ or Python) Basic knowledge in image processing and/or computer graphics concepts

Recommendation
Usually the course is offered every winter semester; as there might be rare exceptions in some years, it's marked as "irregularly"

↑

Name of module	**Number of module**
Computer Vision	11LE13MO-1123 ESE PO 2021
course	
Computer Vision - Exercises	
Event type	Number
excercise course	11LE13Ü-1123
Organizer	
Department of Computer Science, Pattern Recognition and Image Processing	

ECTS-Points	
Attendance	30 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The exercises consist of programming assignments (usually in C/C++), where students learn to implement the most important techniques presented in the lectures.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Concurrency, Theory and Practice	11LE13MO-1225 ESE PO 2021
Responsible	
Prof. Dr. Peter Thiemann	
Organizer	
Department of Computer Science, Programming Languages	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine
Recommended requirement
keie

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Concurrency, Theory and Practice	lecture course	Core elective	6.0	2.0	180 Stunden/hours
Concurrency, Theory and Practice	excercise course	Core elective		2.0	

Qualification
Knowledge of issues arising in writing correct concurrent programs; typical problems like race conditions, deadlocks, and techniques to address them; techniques for modeling and analyzing concurrency programs: calculi for concurrency, dynamic and static analysis; concurrency patterns and primitives
Examination achievement
Klausur/written exam
Literature
The Art of Multiprocessor Programming (Herlihy, Shavit) Concurrency in Go (O'Reilly) Fundamentals of Session Types (Vasconcelos)

↑

Name of module	**Number of module**
Concurrency, Theory and Practice	11LE13MO-1225 ESE PO 2021
course	
Concurrency, Theory and Practice	
Event type	Number
lecture course	11LE13V-1225
Organizer	
Department of Computer Science, Programming Languages	

ECTS-Points	6.0
Workload	180 Stunden/hours
Attendance	32 Stunden/hours
Independent study	116 Stunden/hours
Hours of week	2.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
A concurrent language; dataraces, deadlocks and their detection; concurrent programming patterns; specification of concurrent programs; concurrent datastructures; a concurrency calculus with types
Examination achievement
See module level
Course achievement
See module level
Literature
The Art of Multiprocessor Programming (Herlihy, Shavit) Concurrency in Go (O'Reilly) Fundamentals of Session Types (Vasconcelos) further materials to be announced on the lecture webpage
Compulsory requirement
keine
Recommended requirement
keine

↑

Name of module	**Number of module**
Concurrency, Theory and Practice	11LE13MO-1225 ESE PO 2021
course	
Concurrency, Theory and Practice	
Event type	Number
excercise course	11LE13Ü-1225
Organizer	
Department of Computer Science, Programming Languages	

ECTS-Points	
Attendance	32 Stunden/hours
Hours of week	2.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Extension, consolidation, and practical exploration of lecture contents
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Cyber-Physical Systems – Program Verification	11LE13MO-1207_v2 ESE PO 2021
Responsible	
Prof. Dr. Andreas Podelski	
Organizer	
Department of Computer Science, Software Engineering	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Basic concepts in logic (propositional logic, first-order logic), mathematics (sets, relations, functions, linear algebra), formal languages (regular expressions, automata).

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Cyber-Physische Systeme - Programmverifikation / Cyber-Physical Systems – Program Verification	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Cyber-Physische Systeme - Programmverifikation / Cyber-Physical Systems – Program Verification	excercise course	Core elective		2.0	

Qualification
Often computers are used in embedded, networked, safety-critical applications. The cost of failure is high. The student learns the basic concepts, methods, and tools for ensuring that a system does not have bad behaviors. The student learns how to use propositional logic and first-order logic reasoning for specification, analysis, and verification. The student learns how to formally specify the correctness of a given program. In particular, correctness can be specified by an annotation of the program with a special kind of comments. The student learns how the correctness of the program can be reduced to the validity of a first-order logical formula and how the validity can be proven automatically by a new generation of powerful reasoning engines. The student also learns how verification can be done with static analysis methods, i.e.,

methods which have been developed originally in compiler optimization and which have been formalized by Patrick and Radhia Cousot's framework of abstract interpretation.
Examination achievement
Written exam (usually 90 to 180 minutes) If the number of participants is small (< 15), an oral examination may be held instead. The students will be informed in good time.
Course achievement
Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points. To pass the course work (Studienleistung), you must obtain at least 50% of the exercise points. Also, every student must present his/her solution to an exercise in an exercise group at least once in the semester.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Cyber-Physical Systems – Program Verification	11LE13MO-1207_v2 ESE PO 2021
course	
Cyber-Physische Systeme - Programmverifikation / Cyber-Physical Systems – Program Verification	
Event type	Number
lecture course	11LE13V-1207_v2
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Programming Languages Department of Computer Science, Software Engineering Department of Computer Science, Operating Systems	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	26 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
In this lecture we introduce basic concepts, methods, and tools for ensuring that a system does not have bad behaviors. We start with an introduction to propositional logic and first-order logic reasoning. We establish a formal setting for the specification, analysis, and verification of behaviors of programs. We show how correctness can be specified by an annotation of the program with a special kind of comments. We show how the correctness of a program can be reduced to the validity of a logical formula. The validity can be proven automatically by a new generation of powerful reasoning engines. Finally, we connect verification with static analysis methods which have been developed originally in compiler optimization and which are formalized by Patrick and Radhia Cousot's framework of abstract interpretation. To give an example of a verification problem, we take device driver programs for Windows and Linux operating systems; such programs come with rules that specify the order of certain operations and file accesses. A violation of such a rule leads to system crash or deadlock, unexpected exceptions, and the failure of runtime checks. An example of a rule is that calls to lock and unlock must alternate (an attempt to re-acquire an acquired lock or release a released lock will cause a deadlock). We can formalize the correctness properties expressed by such a rulesin the form of a temporal property (safety or liveness) or a finite automaton.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level

Literature
Baier, C., Katoen, J. - Principles of Model Checking Almeida, J.B., Frade, M.J., Pinto, J.S., Melo de Sousa, S. - Rigorous Software Development - An Introduction to Program Verification
Compulsory requirement
keine | none
Recommended requirement
Basic concepts in logic (propositional logic, first-order logic), mathematics (sets, relations, functions, linear algebra), formal languages (regular expressions, automata).

↑

Name of module	**Number of module**
Cyber-Physical Systems – Program Verification	11LE13MO-1207_v2 ESE PO 2021
course	
Cyber-Physische Systeme - Programmverifikation / Cyber-Physical Systems – Program Verification	
Event type	Number
excercise course	11LE13Ü-1207_v2
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Programming Languages Department of Computer Science, Software Engineering Department of Computer Science, Operating Systems	

ECTS-Points	
Attendance	26 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Debugging and Fuzzing	11LE13MO-1158_PO 2020
Responsible	
Prof. Dr. Armin Biere	
Organizer	
Department of Computer Science, Computer Architecture	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Good programming experience necessary Highly recommended: Advanced Programming Skills (in C, C++, Java, or Python) Basic knowledge in Software Engineering, Algorithms and Data-Structures

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Debugging and Fuzzing	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Debugging and Fuzzing	excercise course	Core elective		2.0	

Qualification
The main goal is to understand debugging from a scientific perspective and learn how to apply advanced debugging techniques to real world system design mostly in the context of software engineering and in combination with modern fuzzing and testing techniques.
Examination achievement
Written exam (usually 90 to 180 minutes)

Course achievement
You have to complete and hand in your solutions for exercise sheets and perform experiments on a regular basis. These will be scored and awarded with points. To successfully complete the course work (Studienleistung), you need to have reached at least 50% of the overall number of achievable points for the semester.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

↑

Name of module	**Number of module**
Debugging and Fuzzing	11LE13MO-1158_PO 2020
course	
Debugging and Fuzzing	
Event type	Number
lecture course	11LE13V-1158_PO 2020
Organizer	
Department of Computer Science, Computer Architecture	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	30
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
We will discuss failures, tracking, contracts/assertions,delta-debugging, quick-check, symbolic debugging, coverage, automatic/unit/regression/combinatorial/model-based testing, data-races, deadlocks, sanitizers and also spend some time on fuzzing, including white/gray/black-box fuzzing, coverage, grammar-aware fuzzing, and symbolic execution.
Examination achievement
See module level
Course achievement
See module level
Literature
"Why Programs Fail", A. Zeller. "The Fuzzing Book", A. Zeller et.al.
Compulsory requirement
Recommended requirement
Good programming experience necessary Highly recommende: Advanced Programming Skills (in C, C++, Java, or Python) Software Engineering, Algorithms and Data-Structures

↑

Name of module	**Number of module**
Debugging and Fuzzing	11LE13MO-1158_PO 2020
course	
Debugging and Fuzzing	
Event type	Number
excercise course	11LE13Ü-1158_PO 2020
Organizer	
Department of Computer Science, Computer Architecture	

ECTS-Points	
Attendance	30
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Using the acquired debugging techniques in exercises on paper and applying debugging and fuzzing tools to real complex code from automated reasoning, electronic design automation or compilers.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Digital Health (DH)	11LE50MO-1160 ESE PO 2021
Responsible	
Prof. Dr. Oliver Amft	
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
none
Recommended requirement
Basic timeseries analysis methods, basic programming skills, coding in Python

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Digital Health (DH)	lecture course	Core elective	6.0	2.0	180 hours
Digital Health (DH)	excercise course	Compulsory		2.0	

Qualification
* Understand the data sources and modalities in digital medicine and the processes of data integration in clinical information systems and DGAs * Understand the German DGA regulation and issues relating to data privacy * Apply ubiquitous technology (ambient, mobile, wearable, implantable) for digital health * Apply context recognition and personalisation methods to qualify ubiquitous system data * Apply data-based privacy preserving techniques (obfuscation) * Design and implement digital biomarkers based on multimodal data * Design and apply digital health twins and clinical data modelling * Design medical decision support systems based on multimodal data

Examination achievement
mündliche Prüfung (i.d.R. 30 oder 45 Minuten) | Oral exam (usually 30 or 45 minutes) If there are too many students for a reasonably organized oral exam, it will be held as a written exam instead, announced well in advance.
Course achievement
written composition Reports on exercises to be submitted
Literature
Up-to-date literature recommendations are provided during the lectures.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science **OR** in Microsystems Engineering Concentrations Area Biomedical Engineering ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering **and** Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

↑

Name of module	Number of module
Digital Health (DH)	11LE50MO-1160 ESE PO 2021
course	
Digital Health (DH)	
Event type	Number
lecture course	11LE13V-1160_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	6.0
Workload	180 hours
Attendance	32 hours
Independent study	116 hours
Hours of week	2.0
Recommended semester	1
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Digital health is a branch of digital medicine that integrates and leverages multisource and multimodal data for medical knowledge extraction and decision support across a wide range of preventive, diagnostic, and therapeutic applications. The course starts by introducing the basic properties of medically relevant data sources and their different modalities. The course introduces the medical benefits of using ubiquitous technologies for data collection, in particular, between hospital visits. The process of medical data integration in clinical information systems and in digital health applications ("Digitale Gesundheitsanwendungen", DGA) is discussed. The German DGA regulations and their consequences are introduced, in particular relating to digital health application qualification and data privacy. Privacy preserving techniques are discussed and applied. Subsequently, data interpretation in telemedicine and digital biomarker design are analysed regarding context recognition and personalisation methods and algorithms. Decision support systems are dissected regarding their components and data analysis algorithms. Finally, the concept, realisation, and application of digital health twins in medicine is developed. The exercises will include practical experiments and implementation tasks, e.g. smartphone apps, 3D digital twin modelling, and data analysis for decision support.
Examination achievement
see module level
Course achievement
see module level
Literature
Up-to-date literature recommendations are provided during the lectures.
Compulsory requirement
None

Recommended requirement
Basic timeseries analysis methods, basic programming skills, coding in Python

↑

Name of module	**Number of module**
Digital Health (DH)	11LE50MO-1160 ESE PO 2021
course	
Digital Health (DH)	
Event type	Number
excercise course	11LE13Ü-1160_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	
Attendance	32 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents
Students will investigate concrete data science methods related to medical data, including context recognition, data interpretation and abstraction.
Examination achievement
see module level
Course achievement
see module level
Compulsory requirement

↑

Name of module	**Number of module**
Distributed Systems	11LE13MO-1312 ESE PO 2021
Responsible	
Prof. Dr. Fabian Kuhn	
Organizer	
Department of Computer Science, Algorithms and Complexity	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge in algorithm design & analysis, some mathematical maturity (in particular, we use some graph theory and probability theory) Knowledge about databases and information systems

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Verteilte Systeme / Distributed Systems - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Verteilte Systeme / Distributed Systems - Exercises	excercise course	Core elective		2.0	

Qualification
The students know the specific problems in distributed systems that arise from the interaction of concurrent processes. They know and apply solutions to such problems.

Examination achievement
mündliche Prüfung (i.d.R. 30 oder 45 Minuten) | Oral exam (usually 30 or 45 minutes) (Wenn die Teilnehmerzahl sehr groß ist, kann stattdessen eine schriftliche Prüfung (i.d.R. 90 bis 180 Minuten) durchgeführt werden. Die Studierenden werden rechtzeitig informiert. | If number of participants is very high, might be exceptionally changed to written examination (usually 90 to 180 minutes) instead. Students will be notified in good time.)
Course achievement
keine | none
Recommendation
Please note: The exercises are an integral part of the lecture, the topics covered by the exercises will also be part of the exam.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Distributed Systems	11LE13MO-1312 ESE PO 2021
course	
Verteilte Systeme / Distributed Systems - Lecture	
Event type	Number
lecture course	11LE13V-1312
Organizer	
Department of Computer Science, Algorithms and Complexity	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	26 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The course provides an introduction to the fundamentals of distributed systems and algorithms. The course will in particular cover the following topics: - distributed systems models - time and global states in distributed systems - sychronous and asynchronous systems - fault tolerance - basic distributed algorithms for coordination and agreement tasks - basic distributed network algorithms - distributed and parallel graph algorithms - impossibility results and lower bounds
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Literature
Some of the content is for example covered by the following books: Distributed Computing: Fundamentals, Simulations and Advanced Topics Hagit Attiya, Jennifer Welch. McGraw-Hill Publishing, 1998, ISBN 0-07-709352 6

Distributed Computing: A Locality-Sensitive Approach David Peleg. Society for Industrial and Applied Mathematics (SIAM), 2000, ISBN 0-89871-464-8 Additional literature will be provided in the lecture.
Compulsory requirement
keine | none
Recommended requirement
Basic knowledge in algorithm design & analysis, some mathematical maturity (in particular, we use some graph theory and probability theory)

↑

Name of module	**Number of module**
Distributed Systems	11LE13MO-1312 ESE PO 2021
course	
Verteilte Systeme / Distributed Systems - Exercises	
Event type	Number
excercise course	11LE13Ü-1312
Organizer	
Department of Computer Science, Algorithms and Complexity	

ECTS-Points	
Attendance	26 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The lecture will be complemented by theoretical exercises that allow to apply and further develop ideas and techniques discussed in the lecture. The exercises are an integral part of the lecture, the topics covered by the exercises will also be part of the oral exam.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 ESE PO 2021
Responsible	
Prof. Dr. Oliver Amft	
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Embedded Computing Entrepreneurship (2ES)	lecture course	Core elective	6.0	1.0	180 Stunden / Hours
Embedded Computing Entrepreneurship (2ES)	seminar	Core elective		1.0	
Embedded Computing Entrepreneurship (2ES)	excercise course	Core elective		2.0	

Qualification
* Conceptualise and design embedded sensor systems along a specific application. * Develop and demonstrate key components of embedded sensor systems, including signal and pattern analysis and recognition algorithms. * Develop a basic market analysis and business plan. * Implement an agile development process.

Examination achievement
Presentation followed by an oral examination (10 minutes per person, total duration depends on group size)
Course achievement
Regular attendance of the course (seminar and exercise) according to §13 (2) of the General Examination Regulations for the Bachelor of Science/Master of Science, as otherwise the required group work and scientific discussion is not possible. Further elements of the course work are the creation of demonstrators or software as well as a written elaboration/protocol.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems **or** Concentration Biomedical Engineering **OR** Elective Courses in Computer Science ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering **and** Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 ESE PO 2021
course	
Embedded Computing Entrepreneurship (2ES)	
Event type	Number
lecture course	11LE13V-1404_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Attendance	16 Stunden / Hours
Independent study	116 Stunden / Hours
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The course combines technical and business-related lectures on embedded sensor systems with a practical system development project using agile development methods. Students will organise in groups and define together with their advisor(s) goals for the technical development, market analysis, etc. Student groups can enter their projects for an award of the VDE.
Examination achievement
see module details
Course achievement
see module details
Literature
Relevant literature will be provided during the lectures and consultations.
Compulsory requirement
None
Recommended requirement
Basic pattern recognition methods; basic programming skills

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 ESE PO 2021
course	
Embedded Computing Entrepreneurship (2ES)	
Event type	Number
seminar	11LE13S-1404_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	
Attendance	16 Stunden / Hours
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 ESE PO 2021
course	
Embedded Computing Entrepreneurship (2ES)	
Event type	Number
excercise course	11LE13Ü-1404_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	
Attendance	32 Stunden / Hours
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Foundations of Deep Learning	11LE13MO-1145 ESE PO 2021
Responsible	
Prof. Dr. Frank Roman Hutter	
Organizer	
Department of Computer Science, Professorship in Machine Learning	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
none
Recommended requirement
Knowledge of linear algebra and machine learning

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Foundations of Deep Learning	lecture course	Core elective	6.0	3.0	180 Stunden
Foundations of Deep Learning	excercise course	Core elective			

Qualification
Foundations of Deep Learning, as covered in the book "Deep Learning" by Goodfellow, Bengio, and Courville.
Examination achievement
Written exam (usually 90 to 180 minutes) If the number of participants is small, an oral examination (usually 30 or 45 minutes) may be held instead. The students will be informed in good time.

Course achievement
Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points. To successfully complete the course work (Studienleistung), you need to have reached at least 50% of the overall number of achievable points for the semester.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Foundations of Deep Learning	11LE13MO-1145 ESE PO 2021
course	
Foundations of Deep Learning	
Event type	Number
lecture course	11LE13V-1145
Organizer	
Department of Computer Science, Professorship in Machine Learning	

ECTS-Points	6.0
Workload	180 Stunden
Hours of week	3.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
In this course, we will cover the Foundations of Deep Learning, primarily using the book "Deep Learning" by Goodfellow, Bengio, and Courville.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement
Recommended requirement
Knowledge of linear algebra and machine learning

↑

Name of module	**Number of module**
Foundations of Deep Learning	11LE13MO-1145 ESE PO 2021
course	
Foundations of Deep Learning	
Event type	Number
excercise course	11LE13Ü-1145
Organizer	
Department of Computer Science, Professorship in Machine Learning	

ECTS-Points	
Hours of week	
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Functional Programming	11LE13MO-1510 ESE PO 2021
Responsible	
Prof. Dr. Peter Thiemann	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Interest in learning and applying new programming concepts and languages. Also beneficial: Introduction to programming successfully completed Own laptop

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Funktionale Programmierung / Functional Programming - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden
Funktionale Programmierung / Functional Programming - Exercises	excercise course	Core elective		1.0	

Contents
This course conveys fundamental concepts of functional programming using the programming language Haskell
Qualification
Development of a non-procedural view on algorithms and data structures, confident handling of higher-order functions and data, knowledge and ability to apply fundamental functional programming techniques, knowledge of advanced programming concepts, ability to develop medium-size functional programs independently.

Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes) (Wenn die Teilnehmerzahl < 20 ist, kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert. | If number of participants is < 20, might be changed to oral exam instead. Students will be notified in good time.)
Course achievement
keine | none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	Number of module
Functional Programming	11LE13MO-1510 ESE PO 2021
course	
Funktionale Programmierung / Functional Programming - Lecture	
Event type	Number
lecture course	11LE13V-1510
Organizer	
Department of Computer Science, Programming Languages Department of Computer Science, Software Engineering	

ECTS-Points	6.0
Workload	180 Stunden
Attendance	39 Stunden
Independent study	128 Stunden
Hours of week	3.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

In diesem Kurs werden grundlegende bis fortgeschrittene Konzepte der funktionalen Programmierung anhand der Programmiersprache Haskell vermittelt.
Behandelte Themen:
- Definition von Funktionen, Patternmatching und Funktionen höherer Ordnung
- Typen und Typklassen
- Algebraische Datentypen
- Funktionale Datenstrukturen
- Applicative Parser
- Monaden und Monadentransformer
- Arrows
- Verifikation von funktionalen Programmen
- Monadische Ein/Ausgabe und Stream Ein/Ausgabe

|
This course covers foundational and some advanced concepts of functional programming using the programming language Haskell. The list of topics includes
- Definition of functions, pattern matching, and higher-order functions
- Types and type classes
- Algebraic datatypes
- Functional datastructures
- I/O, monads, and monad transformers
- Parsers and applicatives
- Arrows
- Verification of functional programs
- Generic programming with algebras

Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Literature
Grundlage für das erste Drittel der Vorlesung ist das Lehrbuch Programming in Haskell von Graham Hutton, welches auch in der TF-Bibliothek steht. Stephen Diehl's WHAT I WISH I KNEW WHEN LEARNING HASKELL | The book Programming in Haskell by Graham Hutton is the basis for the first 30% of the lecture. This book is available in the TF-library. Stephen Diehl's WHAT I WISH I KNEW WHEN LEARNING HASKELL
Compulsory requirement
keine | none
Recommended requirement
Spaß am Programmieren und am Lernen und Anwenden neuer Programmierkonzepte und -sprachen. Weiterhin empfehlenswert: Einführung in die Programmierung erfolgreich absolviert Eigener Laptop | Interest in learning and applying new programming concepts and languages. Also beneficial: Introduction to programming successfully completed Own laptop

↑

Name of module	**Number of module**
Functional Programming	11LE13MO-1510 ESE PO 2021
course	
Funktionale Programmierung / Functional Programming - Exercises	
Event type	Number
excercise course	11LE13Ü-1510
Organizer	
Department of Computer Science, Programming Languages	

ECTS-Points	
Attendance	13 Stunden
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
In den Übungen lernen die Studierenden anhand von Beispielszenarien, die Prinzipien und Methoden aus den Vorlesungen anzuwenden. | In the exercises, students will learn through example scenarios to apply the principles and methods from the lectures.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Grundlagen von Programmiersprachen / Essentials of Programming Languages	11LE13MO-1222 ESE PO 2021
Responsible	
Prof. Dr. Peter Thiemann	
Organizer	
Department of Computer Science, Programming Languages	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Interest in learning and applying new programming concepts and languages. Also beneficial: Basic programming knowledge We recommend having and using your own laptop

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Grundlagen von Programmiersprachen / Essentials of Programming Languages - Lecture	lecture course	Core elective		3.0	180 Stunden | hours
Grundlagen von Programmiersprachen / Essentials of Programming Languages - Exercises	excercise course	Core elective		1.0	

Qualification
Students have a basic understanding of the descriptive means that a programming language can provide. They have mastered methods for modeling the syntax and semantics of programming languages. Students know tools to support modeling and can use them for selected problems.

Usability
As compulsory elective in ■ M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) in Elective Courses in Computer Science Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

↑

Name of module	Number of module
Grundlagen von Programmiersprachen / Essentials of Programming Languages	11LE13MO-1222 ESE PO 2021
course	
Grundlagen von Programmiersprachen / Essentials of Programming Languages - Lecture	
Event type	Number
lecture course	11LE13V-1222
Organizer	
Department of Computer Science, Programming Languages	

ECTS-Points	
Workload	180 Stunden | hours
Attendance	42 Stunden | hours
Independent study	124 Stunden | hours
Hours of week	3.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
This course conveys the mathematical and logical concepts underlying programming languages using the language Agda. Agda is a functional language with an advanced type system that enables the encoding of many program properties in its types. Agda's type checker verifies proofs of these properties, so that one could also say this course is about verified programming. The first part of the course covers the logical background needed to study the theory of programming languages to the extent that we can give formal guarantees about the execution of a program. The second part of the course puts this toolbox to work. We use Agda's features to model the syntax and the semantics of (simple) programming languages. We model type systems and connect them to the semantics through type soundness theorems.
Examination achievement
schriftliche Hausarbeit | written homework
Course achievement
siehe Übung | see exercises
Literature
online book Programming Language Foundations in Agda (PLFA) by Philipp Wadler, Wen Kokke, and Jeremy Siek
Compulsory requirement
keine | none
Recommended requirement
Interest in learning and applying new programming concepts and languages. Basic programming knowledge as well as basic foundations in mathematical logic.

We recommend having and using your own laptop.

↑

Name of module	**Number of module**
Grundlagen von Programmiersprachen / Essentials of Programming Languages	11LE13MO-1222 ESE PO 2021
course	
Grundlagen von Programmiersprachen / Essentials of Programming Languages - Exercises	
Event type	Number
excercise course	11LE13Ü-1222
Organizer	
Department of Computer Science, Programming Languages	

ECTS-Points	
Attendance	14 Stunden | hours
Hours of week	1.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Repetition of lecture's material and deepening of selected topics. We discuss the exercises of the corresponding chapters (contained in the online book "Programming Language Foundations in Agda" (PLFA) by Philipp Wadler, Wen Kokke, and Jeremy Siek), and answer general questions related to Agda, Theorem Proving and Programming Language Theory.
Examination achievement
siehe Vorlesung | see lecture
Course achievement
keine | none Both the exercises and the exercise sessions are voluntary, but we highly recommend doing the exercises and participating in the discussions.
Compulsory requirement

↑

Name of module	**Number of module**
Hardware Security and Trust	11LE13MO-1227 ESE PO 2021
Responsible	
Prof. Dr. Christoph Scholl	
Organizer	
Department of Computer Science, Operating Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge of cryptography and authentication, VLSI design, testing and verification Basic knowledge of technical computer science

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Hardware Security and Trust - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Hardware Security and Trust - Exercise	excercise course	Core elective		1.0	

Qualification
Students know the basics of cryptography, authentication, secret sharing, VLSI design, testing, reliability and verification. Based on this, they will have an overview of the current state of research in the field of "Hardware Security and Trust". They know about various potential attack techniques and know how to avert or minimize these dangers. Especially: Physical and invasive attacks, side-channel attacks, physically unclonable functions, hardware-based true random number generators, watermarking of Intellectual Property (IP) blocks, FPGA security, passive and active metering for prevention of piracy, access control, hardware Trojan detection and isolation in IP cores and integrated circuits (ICs).

Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes) (Wenn die Teilnehmerzahl sehr klein ist, kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert. | If number of participants is small, might be changed to oral exam instead. Students will be notified in good time.)
Course achievement
keine | none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	Number of module
Hardware Security and Trust	11LE13MO-1227 ESE PO 2021
course	
Hardware Security and Trust - Lecture	
Event type	Number
lecture course	11LE13V-1227
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Operating Systems	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	48 Stunden
Independent study	116 Stunden
Hours of week	3.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
Die Konvergenz von IT-Systemen, Datennetzwerken und allgegenwärtigen eingebetteten Geräten in sogenannten Cyber Physical Systems hat zum Entstehen neuer Sicherheitsbedrohungen und -anforderungen im Zusammenhang mit der System-Hardware geführt. Die Manipulation von Hardware-Komponenten, die Sicherheitsfunktionen implementieren, kann die Systemintegrität beeinträchtigen, unautorisierten Zugang zu geschützten Daten ermöglichen und geistiges Eigentum (Intellectual Property) gefährden. Diese Gefährdungen zu adressieren, ist wesentlich, wenn verhindert werden soll, dass Hardware zur Schwachstelle des gesamten Systems wird. Zumindest ein Grundlagenwissen in "Hardware Security and Trust" ist wichtig für jeden Systemingenieur. Zu Beginn werden die (notwendigen) Grundlagen über Kryptographie, Authentifizierung, Secret Sharing, VLSI Entwurf, Test, Zuverlässigkeit und Verifikation gelegt. Dann erfolgt eine Einführung in "Hardware Security and Trust", bei der folgende Themen angesprochen werden: Physical and invasive attacks, side-channel attacks, physically unclonable functions, hardware-based true random number generators, watermarking of Intellectual Property (IP) blocks, FPGA security, passive and active metering for prevention of piracy, access control, hardware Trojan detection and isolation in IP cores and integrated circuits (ICs). | The convergence of IT systems, data networks (including but not limited to the Internet) and ubiquitous embedded devices within the cyber-physical system paradigm has led to the emergence of new security threats associated with the system hardware. Manipulating the hardware components that implement security functions can compromise system integrity, provide unauthorized access to protected data, and endanger intellectual property. Addressing these vulnerabilities is essential in order to prevent the hardware from becoming the weak spot of today's systems. At least a basic knowledge of hardware security and trust issues is of importance to all system designers.

Starting with (necessary) basics on cryptography, authentication, secret sharing, VLSI design, test, reliability and verification the course will provide an introduction to hardware security and trust covering the following topics: physical and invasive attacks, side-channel attacks, physically unclonable functions, hardware-based true random number generators, watermarking of Intellectual Property (IP) blocks, FPGA security, passive and active metering for prevention of piracy, access control, hardware Trojan detection and isolation in IP cores and integrated circuits (ICs).

Examination achievement

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

Literature

Introduction to Hardware Security and Trust
Editors: Tehranipoor, Mohammad, Wang, Cliff (Eds.), Springer

Compulsory requirement

keine | none

Recommended requirement

Grundlagenwissen zu Kryptographie und Authentifizierung, VLSI Entwurf, Test und Verifikation |
Basic knowledge of cryptography and authentication, VLSI design, testing and verification

Grundlagenwissen zu Technischer Informatik
Basic knowledge of technical computer science

↑

Name of module	**Number of module**
Hardware Security and Trust	11LE13MO-1227 ESE PO 2021
course	
Hardware Security and Trust - Exercise	
Event type	Number
excercise course	11LE13Ü-1227
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Operating Systems	

ECTS-Points	
Attendance	16 Stunden
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
Übungen vertiefen Methoden und Algorithmen, die in der Vorlesung eingeführt wurden, anhand von praktischen Beispielen. | Exercises expand on the methods and algorithms that were introduced in the lecture using practical examples.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
High-throughput data analysis with Galaxy	11LE13MO-1350_PO 2020
Responsible	
Prof. Dr. Rolf Backofen	
Organizer	
Department of Computer Science, Bioinformatics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden/hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	each term

Compulsory requirement
None
Recommended requirement
Basic knowledge in bioinformatics. It is highly recommended to attend the lecture and exercise "Introduction to data driven life sciences" (11LE13V-1335) before attending this course. This course builds on the content of this lecture.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
High-throughput data analysis with Galaxy	lecture course	Core elective	6.0	1.0	180 Stunden | hours
High-throughput data analysis with Galaxy	excercise course	Core elective		3.0	

Qualification

In biological and medical research big data analysis is urgently needed for understandig the information which is encoded in the molecules of life. Many diseases, such as cancer, are caused by aberrations in those molecules. This lecture and exercise gives an practical introduction to the analysis of big data in life sciences. The open source web-based framework Galaxy (usegalaxy.eu) is used for data intensive biomedical research. Galaxy provides access to a powerful analysis infrastructure and allows for reproducible and transparent data analysis. Creating pipelines and workflows in Galaxy ensure a transparent and reproducible analysis of data.

After attending the course, students:

- can name different data formats

- know tools for bioinformatics data analysis
- know about different data analysis concepts
- know basic workflows of bioinformatics data analysis
- are able to visualize the results
- know major resources of biologcal reference data
- can use Galaxy for data analyis

Examination achievement
Klausur / written exam
Course achievement
schriftliche Ausarbeitung, Protokoll / written composition
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Pass/fail only compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (MSE) (2021) in Cuostomized Course Selection: Courses offered by other departmens of the University of Freiburg ■ M.Sc. Mikrosystemtechnik (MST) (2021) in Individuelle Ergänzung Lehrangebot Uni Freiburg

↑

Name of module	**Number of module**
High-throughput data analysis with Galaxy	11LE13MO-1350_PO 2020
course	
High-throughput data analysis with Galaxy	
Event type	Number
lecture course	11LE13V-1350_PO 2020

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	10 Stunden / hours
Independent study	140 Stunden / hours
Hours of week	1.0
Recommended semester	2
Frequency	each term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The course is offered as block course of one week. In the morning, a theoretical introduction gives an overview of the topic of the day and the underlying theoretical background of data types, tools, workflows and Galaxy functions.
Examination achievement
See module level
Course achievement
See module level
Literature
Resources used in the course - about the Galaxy project: https://galaxyproject.org - the European Galaxy server: https://usegalaxy.eu
Compulsory requirement
none
Recommended requirement
Basic knowledge in bioinformatics It is highly recommended to attend the lecture and exercise "Introduction to data driven life sciences" (11LE13V-1335) before attending this course. This course builds on the content of this lecture.

↑

Name of module	**Number of module**
High-throughput data analysis with Galaxy	11LE13MO-1350_PO 2020
course	
High-throughput data analysis with Galaxy	
Event type	Number
excercise course	11LE13Ü-1350_PO 2020
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	
Attendance	30 Stunden / hours
Hours of week	3.0
Recommended semester	2
Frequency	each term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Afterwards the gained knowledge is applied by hands-on experience of real data analysis. The course is led by different experts and supervisors to assist the participants in the practical part.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Information Retrieval	11LE13MO-1304 ESE PO 2021
Responsible	
Prof. Dr. Hannah Bast	
Organizer	
Department of Computer Science, Algorithms and Data Structures	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Grundlagen zu Algorithmen und Datenstrukturen, Programmierkenntnisse (C++ / C) | Fundamental knowledge about algorithms and data structures, programming skills (C++ / C)

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Suchmaschinen / Information Retrieval - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Suchmaschinen / Information Retrieval - Exercises	excercise course	Core elective		2.0	

Qualification
Students should be able to understand and apply the basics of information systems, especially search engines. This applies to both the algorithmic aspects (e.g. index data structures) and quality aspects (e.g. ranking of search results), as well as network communication and user interfaces (e.g. AJAX programming).

Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes) (Wenn die Teilnehmerzahl sehr klein ist, kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert. | If number of participants is small, might be changed to oral exam instead. Students will be notified in good time.)
Course achievement
Es gibt Übungsaufgaben im regelmäßigen Rhythmus, die bearbeitet und abgegeben werden müssen. Diese werden korrigiert und mit Punkten bewertet. Die Studienleistung ist bestanden, wenn mindestens 50% der Gesamtpunkte im Semester erreicht sind. | Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points. To successfully complete the course work (Studienleistung), you need to have reached at least 50% of the overall number of achievable points for the semester.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	Number of module
Information Retrieval	11LE13MO-1304 ESE PO 2021
course	
Suchmaschinen / Information Retrieval - Lecture	
Event type	Number
lecture course	11LE13V-1304
Organizer	
Department of Computer Science, Algorithms and Data Structures	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	30 Stunden
Independent study	120 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

In dieser Vorlesung werden alle Themen behandelt, die man zur Realisierung der typischen Funktionalität eines Informationssystems / einer Suchmaschine nach dem Stand der Kunst braucht, und die nicht oder nicht in der erforderlichen Tiefe in Bachelor- oder Mastervorlesungen zum Thema Algorithmen oder Netzwerke vermittelt werden. Dazu gehören:
Algorithmen und Datenstrukturen, z.B.: invertierter Index, Präfixsuche, fehlertolerante Suche, I/O-Effizienz.
Qualitätsaspekte: Ranking von Suchergebnissen, Clustering, maschinelle Lernverfahren.
Netzwerkkommunikation und Benutzerschnittstellen: Webserver, Socket-Kommunikation, AJAX-Programmierung.
|
This course teaches all topics required to understand and implement a search engine with standard functionality according to the state of the art. Topics include: inverted index, ranking, list intersection, compression, fuzzy search, web applications, synonym search, clustering, text classification, and ontology search.

Examination achievement

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

Literature

Wird in der Veranstaltung bekanntgegeben.

Ein Standartbuch das einen Großteil des Veranstaltungsinhalts abdeckt, ist “Manning, Raghavan, Schütze: Introduction to Information Retrieval” (auch online verfügbar: http://nlp.stanford.edu/IR-book).

| All materials needed for the course are provided during the course. A standard text book covering much of the course material is “Manning, Raghavan, Schütze: Introduction to Information Retrieval”, which is also available online: http://nlp.stanford.edu/IR-book .
Compulsory requirement
keine | none
Recommended requirement
Grundlagen zu Algorithmen und Datenstrukturen, Programmierkenntnisse (C++ / C) | Fundamental knowledge about algorithms and data structures, programming skills (C++ / C)

↑

Name of module	**Number of module**
Information Retrieval	11LE13MO-1304 ESE PO 2021
course	
Suchmaschinen / Information Retrieval - Exercises	
Event type	Number
excercise course	11LE13Ü-1304
Organizer	
Department of Computer Science, Algorithms and Data Structures	

ECTS-Points	
Attendance	30 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Praktische Anwendung der Methoden aus der Vorlesung | Practical application of the methods from the lecture
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Interactive Proof Systems and Cryptographic Protocols	11LE13MO-1351 ESE PO 2021
Responsible	
Prof. Dr. Christian Schindelhauer	
Organizer	
Department of Computer Science, Computer Networks and Telematics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden
Hours of week	4.0
Attendance	32 Studen
Independent study	116 Stunden
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine / none
Recommended requirement
Introduction to Cryptography

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Interactive Proof Systems and Cryptographic Protocols	lecture course	Core elective		2.0	
Interactive Proof Systems and Cryptographic Protocols	excercise course	Compulsory		2.0	

Qualification
Upon successful completion of this module, students will be able to understand, evaluate, and apply cryptographic protocols. They will be able to explain the theoretical foundations of interactive proof systems (e.g., AM, IP, MIP, PCP) and analyze their significance for complexity theory and modern cryptography. Additionally, they will be capable of implementing Zero-Knowledge Proofs and related concepts (e.g., Bulletproofs and mental card games) and assessing their applicability to real-world problems.

Examination achievement
Bei mehr als 16 Teilnehmern findet eine schriftliche Prüfung statt (Dauer zwischen 90 und 180 Minuten). Ansonsten findet eine mündliche Prüfung statt (Dauer 20 bis 30 Minuten). | In case there are more than 16 students there will be an written exam (duration between 90 and 180 minutes). Otherwise an oral exam will take place (duration 20 to 30 minutes).
Course achievement
Es gibt Übungsaufgaben im regelmäßigen Rhythmus, die bearbeitet und abgegeben werden müssen. Diese werden korrigiert und mit Punkten bewertet. Die Studienleistung ist bestanden, wenn mindestens 50% der Gesamtpunkte im Semester erreicht sind. | Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points. To pass the course work (Studienleistung), you must obtain at least 50% of the exercise points overall.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021) ■

↑

Name of module	**Number of module**
Interactive Proof Systems and Cryptographic Protocols	11LE13MO-1351 ESE PO 2021
course	
Interactive Proof Systems and Cryptographic Protocols	
Event type	Number
lecture course	11LE13V-1351_PO 2020
Organizer	
Department of Computer Science, Computer Networks and Telematics	

ECTS-Points	
Attendance	32 Stunden
Independent study	116 Stunden
Hours of week	2.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
. Cryptographic Protocols: Fiat-Shamir Protocol, Digital Signatures, Blockchain, Authentication 2. Interactive Proof Systems: Arthur-Merlin Systems (AM), IP (Interactive Proofs), Relationships between Complexity Classes: AM, IP, PSPACE, NP, Multi-Prover Interactive Proofs (MIP), Probabilistically Checkable Proofs (PCP): The PCP Theorem, Zero-Knowledge Proofs, particularly Bulletproofs 3. Mental Card Games: Coin Switching over the Telephone, Mental Poker, Card Game Toolboxes, Bayer-Grothe Shuffle
Examination achievement
Course achievement
Literature
Thaler, J., 2022. Proofs, Arguments, and Zero-knowledge Delfs, H., Knebl, H. and Knebl, H., 2002. Introduction to cryptography
Compulsory requirement
keine / None
Recommended requirement
Introduction to Cryptography

↑

Name of module	**Number of module**
Interactive Proof Systems and Cryptographic Protocols	11LE13MO-1351 ESE PO 2021
course	
Interactive Proof Systems and Cryptographic Protocols	
Event type	Number
excercise course	11LE13Ü-1351_PO 2020
Organizer	
Department of Computer Science, Computer Networks and Telematics	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents
Design, analysis and implementation of cryptographic protocols. Proof of correctness, soundness and completeness of Interactive Proof Systems. Mathematical questions about the underlying theory.
Examination achievement
Course achievement
Compulsory requirement

↑

Name of module	**Number of module**
Introduction to Cryptography	11LE13MO-1401 ESE PO 2021
Responsible	
Prof. Dr. Christian Schindelhauer	
Organizer	
Department of Computer Science, Computer Networks and Telematics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Einführung in die Kryptographie/Introduction to Cryptography- Lecture	lecture course	Core elective		2.0	180 Stunden | hours
Einführung in die Kryptographie/Introduction to Cryptography-Exercise	excercise course	Core elective		2.0	

Qualification
Students know the meaning of symmetric and asymmetric cryptographic methods and understand their fundamentals. They gain the ability to understand current scientific literature.
Examination achievement
Bei mehr als 10 Teilnehmern findet eine schriftliche Prüfung statt (Dauer zwischen 90 und 180 Minuten). Ansonsten findet eine mündliche Prüfung statt (Dauer 20 bis 30 Minuten). | In case there are more than 10 students there will be an written exam (duration between 90 and 180 minutes). Otherwise an oral exam will take place (duration 20 to 30 minutes).

Course achievement
keine | none
Usability
As compulsory elective in ■ M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) in Elective Courses in Computer Science Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	Number of module
Introduction to Cryptography	11LE13MO-1401 ESE PO 2021
course	
Einführung in die Kryptographie/Introduction to Cryptography- Lecture	
Event type	Number
lecture course	11LE13V-1401
Organizer	
Department of Computer Science, Computer Networks and Telematics-VB	

ECTS-Points	
Workload	180 Stunden | hours
Attendance	32 Stunden
Independent study	116 Stunden
Hours of week	2.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Vorlesungsthemen:
- Symmetrische Verschlüsselung
- Asymmetrische Verschlüsselung
- kryptographische Protokolle
- One-Way-Funktionen
- One-Time-Pads
- Quantum Cryptography

|
Lecture topics
- Symmetric-Key Cryptography
- Public-Key-Cryptography
- Cryptographic Protocols
- One-Way-Functions
- One-Time Pads
- Quantum Cryptography

Examination achievement

Siehe Modulebene | See module level

Course achievement

Siehe Modulebene | See module level

Literature

- Introduction to Cryptography, Principles and Applications, Hans Delfs, Helmut Knebel, Springer 2015
- Einführung in die Kryptographie, Johannes Buchmann, Springer, 2009

Compulsory requirement
keine | none
Recommended requirement
keine | none

↑

Name of module	**Number of module**
Introduction to Cryptography	11LE13MO-1401 ESE PO 2021
course	
Einführung in die Kryptographie/Introduction to Cryptography-Exercise	
Event type	Number
excercise course	11LE13Ü-1401
Organizer	
Department of Computer Science, Computer Networks and Telematics-VB	

ECTS-Points	
Attendance	32 Stunden
Hours of week	2.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Übung: ■ Analyse der Sicherheit kryptographischer Verfahren ■ Algorithmen zur Berechnung ■ Analyse kryptographischer Protokolle ■ Anwendung von Verschlüsselungsverfahren | Exercise: ■ Analysis of the security of cryptographic methods ■ Algorithms for the computation ■ Analysis of cryptographic protocols ■ Using encryption methods
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Introduction to data driven life sciences	11LE13MO-1335 ESE PO 2021
Responsible	
Prof. Dr. Rolf Backofen	
Organizer	
Department of Computer Science, Bioinformatics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Introduction to data driven life sciences	lecture course	Core elective	6.0	2.0	180 hours
Introduction to data driven life sciences	excercise course	Core elective		2.0	

Qualification
In biological and medical research big data analysis is urgently needed for understandig the information that is encoded in the molecules of life. Many diseases, such as cancer, are caused by aberrations in those molecules. Students understand the theoretical biological and bioinformatics background and know about techniques for generation and analysis of high-throughput data in life sciences.
Examination achievement
Oral exam (usually 30 or 45 minutes) If the number of participants is very high (> 30), a written examination may be held instead. The students will be informed in good time.

Course achievement
none Solving exercise sheets is optional but highly recommended.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	Number of module
Introduction to data driven life sciences	11LE13MO-1335 ESE PO 2021
course	
Introduction to data driven life sciences	
Event type	Number
lecture course	11LE13V-1335
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	6.0
Workload	180 hours
Attendance	30 hours
Independent study	120 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
In biological and medical research big data analysis is urgently needed for understandig the information that is encoded in the molecules of life. Many diseases, such as cancer, are caused by aberrations in those molecules. In this lecture you will learn the theoretical biological and bioinformatics background and techniques for generation and analysis of high-throughput data in life sciences.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
None

Recommendation
Important note for M.Sc. Computer Science: This module is available as both ▪ a specialization lecture in Computer Science (with a graded assessment / Prüfungsleistung) ▪ as a course in the application area Applied Bioinformatics (as pass/fail course / Studienleistung) Take care during the booking process, as that will define the category in which the course is considered. **You can't change the category afterwards!** So, you can't change it from PL to SL or vice versa.

↑

Name of module	**Number of module**
Introduction to data driven life sciences	11LE13MO-1335 ESE PO 2021
course	
Introduction to data driven life sciences	
Event type	Number
excercise course	11LE13Ü-1335
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	
Attendance	30 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
To apply the gained knowledge from the lecture, exercises to various topics of high-throughput data analysis are offered. Moreover, we will get to know the workflow management framework Galaxy which is an open source tool for life science data analysis.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Isabelle/HOL: programming, verified!	11LE13MO-1336_PO 2020
Responsible	
Prof. Dr. Armin Biere	
Organizer	
Department of Computer Science, Computer Architecture	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
None
Recommended requirement
There is no formal requirement, but this course will deal with proofs of correctness (of programs, data structures). Therefore, you should not be scared by reading quantifiers and understanding properties.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Isabelle/HOL: programming, verified!	lecture course	Core elective		2.0	180 Stunden | hours
Isabelle/HOL: programming, verified!	excercise course	Core elective		2.0	

Qualification
The student knows how write proofs in the proof assistant Isabelle/HOL and verify programs and data structures. In particular, they are familiar with the concept of induction, inductive predicates, program refinement, and program generation.
Examination achievement
Written graded assessment (Please see "Bemerkung / Empfehlung" resp. "Remark / Recommendation" for more information)

Course achievement
Weekly exercise with proofs to do in Isabelle will be given every week. You need to (at least try to) solve those.
Recommendation
There will be no exam, but instead there will be a project: You will work on your own formalization.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Informatik (PO 2018) ■ B.Sc. in Embedded Systems Engineering (PO 2018)

↑

Name of module	Number of module
Isabelle/HOL: programming, verified!	11LE13MO-1336_PO 2020
course	
Isabelle/HOL: programming, verified!	
Event type	Number
lecture course	11LE13V-1336_PO 2020
Organizer	
Department of Computer Science, Computer Architecture	

ECTS-Points	
Workload	180 Stunden | hours
Attendance	28 Stunden | hours
Independent study	124 Stunden | hours
Hours of week	2.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
This course is divided in two parts. In the first one, you will learn to use the proof assistant Isabelle/HOL and how to convince the system that your proof is correct. In the second part, you will work on verifying programs in Isabelle/HOL and exporting them such that you can also execute them outside of the proof assistant.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Literature
The part of the lecture that focuses on Isabelle can be nicely completed by reading the first part of "Concrete Semantics in Isabelle/HOL" book by Nipkow and Klein (http://concrete-semantics.org/, PDF available). The second part of lecture focuses on program verification. It will draw some inspiration from the "Functional Algorithms Verified" book (https://functional-algorithms-verified.org/, PDF available) that focuses on data structures and their performance.
Compulsory requirement
None
Recommended requirement
There is no formal requirement, but this course will deal with proofs of correctness (of programs, data structures). Therefore, you should not be scared by reading quantifiers and understanding properties.

↑

Name of module	**Number of module**
Isabelle/HOL: programming, verified!	11LE13MO-1336_PO 2020
course	
Isabelle/HOL: programming, verified!	
Event type	Number
excercise course	11LE13Ü-1336_PO 2020
Organizer	
Department of Computer Science, Computer Architecture	

ECTS-Points	
Attendance	28 Stunden | hours
Hours of week	2.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
You are required to bring a laptop for the exercise session. During the exercises, you will practice theorems proving and refinement in Isabelle. At the end of the course, you will have a larger project to do (most likely over three weeks) that will replace the exercise sessions in order for you to practise on a larger scale proofs.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Machine Learning in Life Science	11LE13MO-1112 ESE PO 2021
Responsible	
Prof. Dr. Rolf Backofen	
Organizer	
Department of Computer Science, Bioinformatics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Knowledge in Machine Learning and Bioinformatics, basic knowledge in Molecular biology, and practical experience in Python.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science - Exercises	excercise course	Core elective		2.0	

Qualification
Students learn to consider machine learning applications in life sciences from different perspectives. They understand the biological point of view in regards to problems in the domains of genomics, proteomics, systems biology and biological literature information mining. They also have an understanding of different questions from the machine learning point of view, such as underlying assumptions in predictive models, the quality assessment problem, the design choices for supervised and unsupervised models.

Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes)
Course achievement
keine | none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Students of the M.Sc. programmes Microsystems Engg. and Mikrosystemtechnik (PO 2021) can select this module in the concentration area Biomedical Engineering (Biomedizinische Technik).

↑

Name of module	**Number of module**
Machine Learning in Life Science	11LE13MO-1112 ESE PO 2021
course	
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science - Lecture	
Event type	Number
lecture course	11LE13V-1112
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	30 Stunden
Independent study	120 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The course will maintain a double perspective: from the biological point of view we consider problems in the domains of genomics, proteomics, systems biology and biological literature information mining; from the machine learning point of view, we consider questions such as the underlying assumptions in predictive models, the quality assessment problem, the design choices for supervised and unsupervised models.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Literature
The course material is based on influential publications both in the Machine Learning and/or Bioinformatics literature: ▪ P Baldi, S Brunak, Y Chauvin, C.A.F Andersen, H Nielsen, Assessing the accuracy of prediction algorithms for classication: an overview, Bioinformatics 2000 ▪ T Fawcett, An introduction to ROC analysis, Pattern Recognition Letters 2006 ▪ T Dietterich, Approximate statistical tests for comparing supervised classication learning algorithms, Neural Computation 1998 ▪ D Jiang, C Tang, A Zhang, Cluster analysis for gene expression data: A survey, IEEE transactions on knowledge and data engineering 2004

- S.C Madeira, A.L Oliveira, Biclustering algorithms for biological data analysis: a survey, IEEE Transactions on computational Biology and Bioinformatics 2004
- A Krause, J Stoye, Large scale hierarchical clustering of protein sequences, BMC bioinformatics 2005
- P Baldi, G Pollastri, The principled design of large-scale recursive neural network architectures-dag-rnns and the protein structure prediction problem, The Journal of Machine Learning Research 2003
- C Leslie, E Eskin, W Noble, The spectrum kernel: A string kernel for SVM protein classication,Pacic Symposium on Biocomputing 2002
- X.W. Chen, Prediction of protein-protein interactions using random decision forest framework, Bioinformatics 2005

Compulsory requirement
none

Recommended requirement
Knowledge in Machine Learning and Bioinformatics, basic knowledge in Molecular biology, and practical experience in Python.

↑

Name of module	Number of module
Machine Learning in Life Science	11LE13MO-1112 ESE PO 2021
course	
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science - Exercises	
Event type	Number
excercise course	11LE13Ü-1112
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	
Attendance	30 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
In the exercises, students will learn through example scenarios to apply the principles and methods from the lectures.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Network Algorithms	11LE13MO-1313 ESE PO 2021
Responsible	
Prof. Dr. Fabian Kuhn	
Organizer	
Department of Computer Science, Algorithms and Complexity	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge in algorithm design/analysis, mathematical maturity (in particular, we use some graph theory and probability theory)

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Netzwerkalgorithmen / Network Algorithms - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Netzwerkalgorithmen / Network Algorithms - Exercises	excercise course	Core elective		1.0	

Qualification
Networks and distributed computing are essential in modern computing and information systems. The objective of the course is to learn fundamental principles and mathematical/algorithmic techniques underlying the design of distributed algorithms for solving tasks in networks and distributed systems.

Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes) (Wenn die Teilnehmerzahl sehr klein ist, kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert. | If number of participants is small, might be changed to oral exam instead. Students will be notified in good time.)
Course achievement
keine | none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Network Algorithms	11LE13MO-1313 ESE PO 2021
course	
Netzwerkalgorithmen / Network Algorithms - Lecture	
Event type	Number
lecture course	11LE13V-1313
Organizer	
Department of Computer Science, Algorithms and Complexity	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	39 Stunden
Independent study	128 Stunden
Hours of week	3.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The topics are taught by going through many key example problems. Particular topics that are covered include: communication, coordination, fault-tolerance, locality, parallelism, self-organization, symmetry breaking, synchronization, uncertainty
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement
Recommended requirement
Basic knowledge in algorithm design/analysis, mathematical maturity (in particular, we use some graph theory and probability theory)

↑

Name of module	**Number of module**
Network Algorithms	11LE13MO-1313 ESE PO 2021
course	
Netzwerkalgorithmen / Network Algorithms - Exercises	
Event type	Number
excercise course	11LE13Ü-1313
Organizer	
Department of Computer Science, Algorithms and Complexity	

ECTS-Points	
Attendance	13 Stunden
Hours of week	1.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Numerical Optimal Control in Science and Engineering	11LE50MO-5249 ESE PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	6.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses. Numerical Optimization (NUMOPT), Modelling and System Identification (MSI), Systems and Control Bachelor or Master lectures.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Numerical Optimal Control in Science and Engineering	lecture course	Core elective	6.0	6.0	180 hours
Numerical Optimal Control in Science and Engineering	excercise course	Core elective		2.0	

Qualification
The students can formulate optimal control problems and implement and analyze several numerical methods for solving them.
Examination achievement
Written exam (180 minutes)
Course achievement
The course work is completed if students pass the mid-term online quiz.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems **OR** in Elective Courses in Computer Science ■ M.Sc. Informatik / Computer Science (PO 2020), in Spezialvorlesung | Specialization Courses Part of the specialization Cyber-Physical Systems in Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	Number of module
Numerical Optimal Control in Science and Engineering	11LE50MO-5249 ESE PO 2021
course	
Numerical Optimal Control in Science and Engineering	
Event type	Number
lecture course	11LE50V-5249
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	6.0
Workload	180 hours
Attendance	78 hours
Independent study	102 hours
Hours of week	6.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

- 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

Examination achievement

see module details

Course achievement

see module details

Literature

1. Manuscript "Numerical Optimal Control" by M. Diehl and S. Gros
2. Biegler, L.T., Nonlinear Programming, SIAM, 2010

Compulsory requirement

None

Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses. Numerical Optimization (NUMOPT), Modelling and System Identification (MSI), Systems and Control Bachelor or Master lectures.

↑

Name of module	**Number of module**
Numerical Optimal Control in Science and Engineering	11LE50MO-5249 ESE PO 2021
course	
Numerical Optimal Control in Science and Engineering	
Event type	Number
excercise course	11LE50Ü-5249
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
In the tutorial, the contents of the lecture will be deepened by means of theoretical examples and computer exercises.
Examination achievement
see moodule details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses. Numerical Optimization (NUMOPT), Modelling and System Identification (MSI), Systems and Control Bachelor or Master lectures.

↑

Name of module	**Number of module**
Numerical Optimization	11LE50MO-5243 ESE PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	6.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Numerische Optimierung / Numerical Optimization - Lecture	lecture course	Core elective	6.0	4.0	180 hours
Numerische Optimierung / Numerical Optimization - Exercises	excercise course	Core elective		2.0	

Qualification
The students know different types of optimization problems and can discuss their theoretical background and implement and analyze numerical methods for solving them.
Examination achievement
Written exam (180 minutes)
Course achievement
The course work is completed if students pass the mid-term online quiz.

Usability
As compulsory elective in ■ M.Sc. Embedded Systems Engineering (ESE) in Microsystems Engineering Concentrations Area: Circuits and Systems **OR** in Elective Courses in Computer Science ■ M.Sc. Microsystems Engineering in Microsystems Engineering Concentrations Area: Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses Part of the specialization Cyber-Physical Systems in Master of Science Informatik/Computer Science resp. M.Sc. Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Numerical Optimization	11LE50MO-5243 ESE PO 2021
course	
Numerische Optimierung / Numerical Optimization - Lecture	
Event type	Number
lecture course	11LE50V-5243
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	6.0
Workload	180 hours
Attendance	90 hours
Independent study	90 hours
Hours of week	4.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The course is divided into four major parts: 1. Fundamental Concepts of Optimization: Definitions, Types, Convexity, Duality 2. Unconstrained Optimization and Newton Type Algorithms: Stability of Solutions, Gradient and Conjugate Gradient, Exact Newton, Quasi-Newton, BFGS and Limi- ted Memory BFGS, and Gauss-Newton, Line Search and Trust Region Methods, Algorithmic Differentiation 3. Equality Constrained Optimization Algorithms: Newton Lagrange and Generalized Gauss-Newton, Range and Null Space Methods, Quasi-Newton and Adjoint Based Inexact Newton Methods 4. Inequality Constrained Optimization Algorithms: Karush-Kuhn-Tucker Conditions, Linear and Quadratic Programming, Active Set Methods, Interior Point Methods, Se- quential Quadratic and Convex Programming, Quadratic and Nonlinear Parametric Optimization
Examination achievement
see module details
Course achievement
see module details
Literature
1. Jorge Nocedal and Stephen J. Wright, Numerical Optimization, Springer, 2006 2. Amir Beck, Introduction to Nonlinear Optimization, MOS-SIAM Optimization, 2014 3. Stephen Boyd and Lieven Vandenberghe, Convex Optimization, Cambridge Univ. Press, 2004
Compulsory requirement
None

Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses

↑

Name of module	**Number of module**
Numerical Optimization	11LE50MO-5243 ESE PO 2021
course	
Numerische Optimierung / Numerical Optimization - Exercises	
Event type	Number
excercise course	11LE50Ü-5243
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
In der Übung werden die Inhalte der Vorlesung anhand theoretischer Beispielaufgaben sowie mit Rechnerübungen vertieft.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses

↑

Name of module	**Number of module**
Probabilistic Graphical Models	11E13MO-1228 ESE PO 2021
Responsible	
Prof. Dr. Joschka Bödecker	
Organizer	
Department of Computer Science, Professorship in Neurorobotics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden / houers
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine / none
Recommended requirement
Prior knowledge of probability theory, machine learning, deep learning, reinforcement learning is an advantage.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Probabilistic Graphical Models	lecture course	Core elective	6.0	3.0	180 Stunden / hours
Probabilistic Graphical Models	excercise course	Core elective		1.0	

Qualification
Students understand the concepts of probabilistic graphical models, including the mathematical foundations, representation, structure, inference, learning, identifying causal relations, as well as connections to deep learning and control. They are able to apply these methods to practical modeling and control problems from various domains of science and engineering.
Examination achievement
Klausur / written exam
Course achievement
Bearbeitung von Übungsblättern / Completing excercise assignments

↑

Name of module	**Number of module**
Probabilistic Graphical Models	11E13MO-1228 ESE PO 2021
course	
Probabilistic Graphical Models	
Event type	Number
lecture course	11E13V-1228_PO 2020
Organizer	
Department of Computer Science, Professorship in Neurorobotics	

ECTS-Points	6.0
Workload	180 Stunden / hours
Attendance	48 Stunden / hours
Independent study	116 Stunden / Hours
Hours of week	3.0
Recommended semester	1
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Lectures will cover: Introduction, Review of fundamental concepts from probability and graph theory, Bayesian classifiers, Hidden Markov Models, Bayesian Networks, Extension to dynamic and temporal variants, Decision Graphs, Markov Decision Processes, Control as Inference, Graphical Causal Models, Causal Discovery, Deep Learning and Graphical Models
Examination achievement
See module level
Course achievement
See module level
Literature
"Probabilistic Graphical Models: Principles and Applications", second edition, by Luis Enrique Sucar, Springer Nature Switzerland, https://doi.org/10.1007/978-3-030-61943-5
Compulsory requirement
keine / none
Recommended requirement
Prior knowledge of probability theory, machine learning, deep learning, reinforcement learning is an advantage.

↑

Name of module	**Number of module**
Probabilistic Graphical Models	11E13MO-1228 ESE PO 2021
course	
Probabilistic Graphical Models	
Event type	Number
excercise course	11E13Ü-1228_PO 2020
Organizer	
Department of Computer Science, Professorship in Neurorobotics	

ECTS-Points	
Hours of week	1.0
Recommended semester	1
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Theoretical and coding-based exercises in Python will accompany the lectures to help deepen the understanding of concepts from lectures, as well as provide the opportunity to gain some hands-on experience in applying the methods to solve selected problems.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Peer-to-Peer Networks	11LE13MO-13146 ESE PO 2021
Responsible	
Prof. Dr. Christian Schindelhauer	
Organizer	
Department of Computer Science, Computer Networks and Telematics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge in algorithms and data structures, computer networks, telecommunication systems and distributed systems

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Peer-to-Peer Netzwerke / Peer-to-Peer Networks - Lecture	lecture course	Core elective		2.0	180 Stunden | hours
Peer-to-Peer Netzwerke / Peer-to-Peer Networks - Exercises	excercise course	Core elective		2.0	180 Stunden | hours

Qualification
Students know the underlying methods and algorithms for peer-to-peer network architectures. They know and can apply different methods for storing, resulting in various networks for different purposes. They understand the application of cryptographic methods to peer-to-peer networks, especially Block-chain technology. Students have knowledge about self-organizing networks, allowing for the use of repair mechanisms of peer-to-peer networks under churn and attacks.
Examination achievement
mündliche Prüfung (i.d.R. 30 oder 45 Minuten) | Oral exam (usually 30 or 45 minutes)

Course achievement
keine | none
Usability
Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021) Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

↑

Name of module	**Number of module**
Peer-to-Peer Networks	11LE13MO-13146 ESE PO 2021
course	
Peer-to-Peer Netzwerke / Peer-to-Peer Networks - Lecture	
Event type	Number
lecture course	11LE13V-1314
Organizer	
Department of Computer Science, Computer Networks and Telematics	

ECTS-Points	
Workload	180 Stunden | hours
Attendance	32 Stunden
Independent study	116 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

After a brief introduction to the history of peer-to-peer networks relevant topics related to the Internet and distributed systems are deepened. First, the example of unstructured networks Gnutella are discussed, followed by structured networks. These, e.g. such as CAN, Chord, Pastry and Tapestry, are presented in very detail. We concentrate on data and network structures, as well the theoretical analysis of peer-to-peer networks. Other issues are minimal networks, networks with tree structures and self-organizing networks.
As special issues we discuss security, anonymity and game theory in peer-to-peer networks

Examination achievement

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

Literature

- Mahlmann, Schindelhauer: Peer-to-Peer-Netzwerke - Methoden und Algorithmen, Springer 2007
- Shen, X.; Yu, H.; Buford, J.; Akon, M. (Eds.): Handbook of Peer-to-Peer Networking, Springer 2010

Compulsory requirement

keine | none

Recommended requirement

Basic knowledge in algorithms and data structures, computer networks, telecommunication systems and distributed systems

↑

Name of module	**Number of module**
Peer-to-Peer Networks	11LE13MO-13146 ESE PO 2021
course	
Peer-to-Peer Netzwerke / Peer-to-Peer Networks - Exercises	
Event type	Number
excercise course	11LE13Ü-1314
Organizer	
Department of Computer Science, Computer Networks and Telematics	

ECTS-Points	
Workload	180 Stunden | hours
Attendance	32 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Real-Time Operating Systems and Worst-Case Execution Times	11LE13MO-1240 ESE PO 2021
Responsible	
Prof. Dr. Christoph Scholl	
Organizer	
Department of Computer Science, Operating Systems-VB	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	
Compulsory/Elective (C/E)	Core elective
Frequency	each term

Compulsory requirement
keine | none
Recommended requirement
Knowledge in computer architecture / Computer Architecture and software technology / Software Engineering

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Echtzeitbetriebssysteme und Worst-Case-Execution-Times / Real-Time Operating Systems and Worst-Case Execution Times	lecture course	Core elective	6.0	3.0	180 hours
Echtzeitbetriebssysteme and Worst-Case-Execution-Times/ Real-Time Operating Systems and Worst-Case Execution Times	excercise course	Core elective		1.0	

Qualification
The students are proficient in the basic methods for real-time operating systems. In particular, they know the essential differences between standard operating systems and real-time operating systems for embedded systems with respect to both requirements and implementation concepts (especially in the area of scheduling). The students have knowledge of the most important functions of real-time operating systems as well as programming experience with real-time systems.

Examination achievement
Written exam (usually 90 to 180 minutes) (If number of participants is small, might be changed to oral exam instead. Students will be notified in good time.)
Course achievement
none
Usability
As compulsory elective in ■ M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) in Elective Courses in Computer Science Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

↑

Name of module	**Number of module**
Real-Time Operating Systems and Worst-Case Execution Times	11LE13MO-1240 ESE PO 2021
course	
Echtzeitbetriebssysteme und Worst-Case-Execution-Times / Real-Time Operating Systems and Worst-Case Execution Times	
Event type	Number
lecture course	11LE13V-1240
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Operating Systems	

ECTS-Points	6.0
Workload	180 hours
Attendance	64 Stunden | hours
Independent study	116 Stunden | hours
Hours of week	3.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
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.
Examination achievement
see module level
Course achievement
see module level
Literature
Will be announced at the beginning of the course.
Compulsory requirement
keine | none

Recommended requirement
Knowledge in computer architecture / Computer Architecture and software technology / Software Engineering

↑

Name of module	Number of module
Real-Time Operating Systems and Worst-Case Execution Times	11LE13MO-1240 ESE PO 2021
course	
Echtzeitbetriebssysteme and Worst-Case-Execution-Times/ Real-Time Operating Systems and Worst-Case Execution Times	
Event type	Number
excercise course	11LE13Ü-1240
Organizer	
Department of Computer Science, Computer Architecture	

ECTS-Points	
Attendance	16 Stunden | hours
Hours of week	1.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Exercises are used to deepen the understanding of methods and algorithms introduced in the lectures by application to practical examples.
Examination achievement
see module level
Course achievement
see module level
Compulsory requirement

↑

Name of module	**Number of module**
Reinforcement Learning	11LE13MO-1141 ESE PO 2021
Responsible	
Prof. Dr. Joschka Bödecker	
Organizer	
Department of Computer Science, Professorship in Neurorobotics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge of practical and applied computer science, algorithms and data structures, programming skills Basic knowledge of artificial intelligence and machine learning

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Reinforcement Learning	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Reinforcement Learning	excercise course	Core elective		1.0	

Qualification
▪ Understanding the basic concepts of optimizing learning ▪ Ability to think on different levels of abstraction ▪ Knowledge of exemplary implementations of learning algorithms ▪ Ability to independently recognize connections between the presented concepts ▪ Knowledge of practical application

Examination achievement
mündliche Prüfung (i.d.R. 30 oder 45 Minuten) | Oral exam (usually 30 or 45 minutes) (Wenn die Teilnehmerzahl sehr groß ist, kann stattdessen eine schriftliche Prüfung (i.d.R. 90 bis 180 Minuten) durchgeführt werden. Die Studierenden werden rechtzeitig informiert. | If number of participants is very high, might be exceptionally changed to written examination (usually 90 to 180 minutes) instead. Students will be notified in good time.)
Course achievement
keine | none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Reinforcement Learning	11LE13MO-1141 ESE PO 2021
course	
Reinforcement Learning	
Event type	Number
lecture course	11LE13V-1141
Organizer	
Department of Computer Science, Professorship in Neurorobotics	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	45 Stunden
Independent study	120 Stunden
Hours of week	3.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The lecture deals with methods of Reinforcement Learning that constitute an important class of machine learning algorithms. Starting with the formalization of problems as Markov decision processes, a variety of Reinforcement Learning methods are introduced and discussed in-depth. The connection to practice-oriented problems is established by basing the lecture on many examples.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Literature
Sutton, Barton: Reinforcement Learning – An Introduction. Bertsimas: Neuron Dynamic Programming.
Compulsory requirement
keine | none
Recommended requirement
Grundlagenkenntnisse in praktischer und angewandter Informatik, Algorithmen und Datenstrukturen, Programmierkenntnisse Grundlagenwissen zu Künstlicher Intelligenz und Machine Learning |

Basic knowledge of practical and applied computer science, algorithms and data structures, programming skills Basic knowledge of artificial intelligence and machine learning

↑

Name of module	**Number of module**
Reinforcement Learning	11LE13MO-1141 ESE PO 2021
course	
Reinforcement Learning	
Event type	Number
excercise course	11LE13Ü-1141
Organizer	
Department of Computer Science, Professorship in Neurorobotics	

ECTS-Points	
Attendance	15 Stunden
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
In the exercises, students will learn through example scenarios to apply the principles and methods from the lectures.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
RNA Bioinformatics	11LE13MO-1318 ESE PO 2021
Responsible	
Prof. Dr. Rolf Backofen	
Organizer	
Department of Computer Science, Bioinformatics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Fundamental understanding of RNA sequence/structure analysis Knowledge about principle methods used in Bioinformatics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
RNA Bioinformatik / RNA Bioinformatics - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
RNA Bioinformatik / RNA Bioinformatics-Exercises	excercise course	Core elective		2.0	

Qualification
The goal of this module is to get a deeper understanding of the essential algorithms and methods for RNA sequence/structure analysis going beyond the topics covered in Bioinformatics 1 and 2. Students will learn about fundamental algorithms and methods for sequence and structure analysis of the biological macromolecule RNA. Students will be able to predict optimal RNA secondary structure and to explain the methods. At the end of the course, they can use probabilistic analysis of structure by partition function approaches, and thus compute base pair probabilities. Furthermore, participants will be able to compare and align RNAs according to their sequence and structural information. This will be possible using techniques for the alignment of folded RNA as well as for the simultaneous operations of alignment and folding. As special topics, students will be

able to explain fundamental concepts of and methods for RNA-RNA-interaction prediction, as well as the algorithmic treatment of pseudoknots.
Examination achievement
Written exam (usually 90 to 180 minutes) (If number of participants is small, might be changed to oral exam instead. Students will be notified in good time.)
Course achievement
keine | none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Biomedical Engineering (BE) in M.Sc. Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	Number of module
RNA Bioinformatics	11LE13MO-1318 ESE PO 2021
course	
RNA Bioinformatik / RNA Bioinformatics - Lecture	
Event type	Number
lecture course	11LE13V-1318
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	26 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Introduction
Structure prediction

- Nussinov algorithm
- Zuker algorithm
- McCaskill algorithm

Comparative RNA analysis:

- Plan A: first align, then fold
- Plan C: first fold, then align
- Plan B: simultaneous alignment and folding

Overview of RNA related tasks and algorithms

- RNA-RNA interactions
- Pseudoknot prediction - Eddy algorithm
- Binding sites of RNA-binding proteins

Examination achievement

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

Literature
■ Clote, Backofen: Computational Molecular Biologie, An Introduction. Wiley & Sons. ISBN-10: 0471872520 ISBN-13: 978-0471872528 ■ Durbin et al. Biological Sequence Analysis. Cambridge University Press. ISBN-10: 0521629713 ISBN-13: 978-0521629713
Compulsory requirement
keine | none
Recommended requirement
Fundamental understanding of RNA sequence/structure analysis Knowledge about principle methods used in Bioinformatics

↑

Name of module	Number of module
RNA Bioinformatics	11LE13MO-1318 ESE PO 2021
course	
RNA Bioinformatik / RNA Bioinformatics- Exercises	
Event type	Number
excercise course	11LE13Ü-1318
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	
Attendance	26 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
In the exercises, students will learn through example scenarios to apply the principles and methods from the lectures.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	Number of module
SAT Solving	11LE13MO-1165_PO 2020
Responsible	
Prof. Dr. Armin Biere	
Organizer	
Department of Computer Science, Computer Architecture	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
none
Recommended requirement
none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
SAT Solving	lecture course	Core elective	6.0	3.0	180 Stunden | hours
SAT Solving	excercise course	Core elective		1.0	

Qualification
Proficiency in applying and developping state-of-the-art algorithms for solving propositional satisfiability problems (SAT).
Examination achievement
mündliche Prüfung (i.d.R. 30 oder 45 Minuten) | Oral exam (usually 30 or 45 minutes)
Course achievement
You have to complete and hand in your solutions for exercise sheets/projects and perform experiments on a regular basis. These will be scored and awarded with points. To successfully complete the course work (Studienleistung), you need to have reachedat least 50% of the overall number of achievable points for the semester.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018)

↑

Name of module	**Number of module**
SAT Solving	11LE13MO-1165_PO 2020
course	
SAT Solving	
Event type	Number
lecture course	11LE13V-1165
Organizer	
Department of Computer Science, Computer Architecture	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	41 Stunden | hours
Independent study	126 Stunden | hours
Hours of week	3.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
- Encoding: NNF, Tseitin, AIGs, cardinality constrains encoding, bit-blasting. - Preprocessing: DP, BVE, BVA, blocked clauses, autarkies, Stalmarck, Recursive Learning, clause redundancy, probing. - Solving: DPLL, CDCL, learning, implication graph, failed literals, UIP, clause minimization, restarts, clause reduction.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
SAT Solving	11LE13MO-1165_PO 2020
course	
SAT Solving	
Event type	Number
excercise course	11LE13Ü-1165

ECTS-Points	
Attendance	13 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Simulation in Computer Graphics	11LE13MO-1113 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Matthias Teschner	
Organizer	
Department of Computer Science, Computer Graphics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
■ Programming Skills ■ Knowledge in Algorithms and Data Structures, Linear Algebra and Analysis

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Simulation in Computergraphik / Simulation in Computer Graphics - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Simulation in Computergraphik / Simulation in Computer Graphics - Exercises	excercise course	Core elective		2.0	

Qualification
The module offers insights into physically-based animation techniques. Various models, numerical techniques, data structures and algorithms for rigid or deformable solids and for fluids are covered. The students learn a variety of relevant techniques. They also learn how to combine, e.g., fluids and solids in animation frameworks.

Examination achievement
mündliche Prüfung (i.d.R. 30 oder 45 Minuten) | Oral exam (usually 30 or 45 minutes) (Wenn die Teilnehmerzahl groß ist, kann stattdessen eine schriftliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert. | If number of participants is high, might be exceptionally changed to written examination instead. Students will be notified in good time.)
Course achievement
keine | none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Simulation in Computer Graphics	11LE13MO-1113 ESE PO 2021
course	
Simulation in Computergraphik / Simulation in Computer Graphics - Lecture	
Event type	Number
lecture course	11LE13V-1113
Organizer	
Department of Computer Science, Computer Graphics	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	30 Stunden
Independent study	120 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The course addresses high-performance approaches for the particle-based simulation of fluids, elastic solids, rigid bodies and their interactions. The course introduces relevant concepts with a strong focus on high-performance implementations. The introduced concepts are used in interactive games and in the entertainment industry in general, but also for large-scale simulations in engineering. Topics: 1. Equations for the motion of particle-based fluids, elastic solids and rigid bodies. 2. Time derivatives to compute particle motion. 3. Spatial derivatives with SPH to compute particle forces. 4. Efficient matrix-free implementations of linear solvers for robust implicit formulations. 5. Spatial data structures for accelerated fluid-rigid and rigid-rigid interactions. 6. Efficient implementations of spatial data structures with hashing and sorting.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level

Literature
■ Koschier et al: Smoothed Particle Hydrodynamics Techniques for the Physics Based Simulation of Fluids and Solids. ■ Ihmsen et al: SPH Fluids in Computer Graphics. ■ Bridson: Fluid Simulation for Computer Graphics. ■ Ericson: Real-time Collision Detection.
Compulsory requirement
keine | none
Recommended requirement
■ Programming Skills (C, C++, Java) ■ Knowledge in Algorithms and Data Structures, Linear Algebra and Analysis
Teaching method
Lectures, discussions, theoretical and practical exercises.

↑

Name of module	**Number of module**
Simulation in Computer Graphics	11LE13MO-1113 ESE PO 2021
course	
Simulation in Computergraphik / Simulation in Computer Graphics - Exercises	
Event type	Number
excercise course	11LE13Ü-1113
Organizer	
Department of Computer Science, Computer Graphics	

ECTS-Points	
Attendance	30 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
In the exercises, students will learn to apply the methods from the lectures in a practical setting.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Statistical Pattern Recognition	11LE13MO-1114 ESE PO 2021
Responsible	
Prof. Dr. Thomas Brox	
Organizer	
Department of Computer Science, Pattern Recognition and Image Processing	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Fundamental mathematical knowledge, particularly statistic

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Statistische Mustererkennung / Statistical Pattern Recognition - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Statistische Mustererkennung / Statistical Pattern Recognition - Exercises	excercise course	Core elective		2.0	

Qualification
Students know the most relevant techniques of pattern recognition. They are able to understand current related literature and can apply appropriate techniques to solve pattern recognition problems in different areas of application.
Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes)
Course achievement
keine | none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Statistical Pattern Recognition	11LE13MO-1114 ESE PO 2021
course	
Statistische Mustererkennung / Statistical Pattern Recognition - Lecture	
Event type	Number
lecture course	11LE13V-1114
Organizer	
Department of Computer Science, Pattern Recognition and Image Processing	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	28 Stunden
Independent study	126 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The course introduces the basic ideas of recognition and learning, and reviews the most important terminology of probabilistic methods. Afterwards the most common techniques for classification, regression, and clustering are presented, among them linear regression, Gaussian processes, logistic regression, support vector machines, non-parametric density estimation, and expectation-maximization. Additionally, the course includes dimensionality reduction methods and inference in graphical models. Programming assignments in Matlab or Python help deepen the understanding of the material.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Literature
"Pattern Recognition and Machine Learning" by Christopher Bishop
Compulsory requirement
keine | none
Recommended requirement
Fundamental mathematical knowledge, particularly statistic

Recommendation
Usually the course is offered every summer semester; as there might be rare exceptions in some years, it's marked as "irregularly"

↑

Name of module	**Number of module**
Statistical Pattern Recognition	11LE13MO-1114 ESE PO 2021
course	
Statistische Mustererkennung / Statistical Pattern Recognition - Exercises	
Event type	Number
excercise course	11LE13Ü-1114
Organizer	
Department of Computer Science, Pattern Recognition and Image Processing	

ECTS-Points	
Attendance	26 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The exercises consist of theoretical assignments and programming assignments, to apply the methods and concepts from the lecture.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Test and Reliability	11LE13MO-1202 ESE PO 2021
Responsible	
Prof. Dr. Armin Biere	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Knowledge of technical informatics and computer architecture

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Test und Zuverlässigkeit / Test and Reliability - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Test und Zuverlässigkeit / Test and Reliability - Exercises	excercise course	Core elective		1.0	

Qualification
The students know the basic questions of testing digital circuits and, based on this, know, apply and, if necessary, adapt important algorithmic techniques to new needs. Students are able to carry out "Design for Testability" and assess the advantages and disadvantages of these measures. They are familiar with the challenges of the new technologies and they can assess state-of-the-art approaches.
Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes) (Wenn die Teilnehmerzahl sehr klein ist, kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert. | If number of participants is small, might be changed to oral exam instead. Students will be notified in good time.)

Course achievement
keine | none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Test and Reliability	11LE13MO-1202 ESE PO 2021
course	
Test und Zuverlässigkeit / Test and Reliability - Lecture	
Event type	Number
lecture course	11LE13V-1202
Organizer	
Department of Computer Science, Computer Architecture	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	45 Stunden
Independent study	120 Stunden
Hours of week	3.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The manufacturing process of integrated circuits (ICs, chips) is a yield process, i.e. some of the ICs will be inherently prone to failures. Since shipping of defective chips implies high follow-up costs, a test phase is necessary to detect defective chips as early as possible. Today, the so-called structural test flow is widely accepted. Here, defects are abstracted with the help of fault models and test patterns are generated that guarantee a high fault coverage with respect to the fault model considered. Taken together, test costs are responsible for up to 40% of the IC's production costs. Furthermore, it is widely accepted that already during the design phase testability has to be taken into account (design for testability, DFT). Because of this, at least a basic knowledge of IC test issues is of importance also for IC designers. Consequently, the course starts with standard test topics like fault models, (stuck-at)-fault simulation and automatic test pattern generation (ATPG). We will also provide an introduction to DFT methods, in particular scan design and built-in self-test. Finally, current research topics such as defect based testing, non-standard fault models, test for systems-on-a-chip (SOCs), variation aware testing, robustness analysis are addressed.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level

Literature
■ Abramovici, Breuer, Friedman, "Digital Systems Testing & Testable Design", IEEE Press, 1994, ISBN: 0780310624 (available in our library). ■ Jha, Gupta, "Testing of Digital Systems", Cambridge University Press, 2003, ISBN 05217 73563 (available in our library).
Compulsory requirement
keine | none
Recommended requirement
Kenntnisse in Technische Informatik und Rechnerarchitektur / Computer Architecture | Knowledge of technical informatics and computer architecture

↑

Name of module	Number of module
Test and Reliability	11LE13MO-1202 ESE PO 2021
course	
Test und Zuverlässigkeit / Test and Reliability - Exercises	
Event type	Number
excercise course	11LE13Ü-1202
Organizer	
Department of Computer Science, Computer Architecture	

ECTS-Points	
Attendance	15 Stunden
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Verification of Digital Circuits	11LE13MO-1223 ESE PO 2021
Responsible	
Prof. Dr. Christoph Scholl	
Organizer	
Department of Computer Science, Operating Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Requires basic knowledge in Technical Computer Science

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Verifikation Digitaler Schaltungen / Verification of Digital Circuits - Lecture	lecture course	Core elective		3.0	180 Stunden
Verifikation Digitaler Schaltungen / Verification of Digital Circuits - Exercises	excercise course	Core elective		1.0	

Qualification
Students know about formal methods used in semi conductor industries to systematically search for faults and, optimally, prove their absence. Students know data structures and can apply methods that form the basis for formal verification of digital circuits, like binary decision diagrams, SAT solvers, And-Inverter-Graphs. Based on these methods, students will be able to analyze and use symbolic methods for equivalence checks and automatic model checking for digital circuits.

Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes) (Wenn die Teilnehmerzahl sehr klein ist, kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert. | If number of participants is small, might be changed to oral exam instead. Students will be notified in good time.)
Course achievement
keine | none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Verification of Digital Circuits	11LE13MO-1223 ESE PO 2021
course	
Verifikation Digitaler Schaltungen / Verification of Digital Circuits - Lecture	
Event type	Number
lecture course	11LE13V-1223
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Operating Systems	

ECTS-Points	
Workload	180 Stunden
Hours of week	3.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Viele moderne Produkte basieren auf mikroelektronischen Komponenten. Oftmals ist das korrekte Funktionieren dieser Produkte lebenswichtig, etwa in Medizintechnik oder Autoelektronik. Daher werden hohe Anforderungen an die Qualität der darin eingesetzten mikroelektronischen Systeme gestellt. Die Anforderungen lassen sich in drei Gruppen unterteilen: (1) Das System muss korrekt entsprechend der Spezifikation entworfen sein. (2) Das gemäß Entwurf physikalisch gefertigte System soll zum Zeitpunkt seiner Herstellung fehlerfrei funktionieren. (3) Darüber hinaus soll das System für einen gegebenen Zeitraum zuverlässig (d.h. ohne Ausfall) eingesetzt werden können.
Während Anforderung (2) durch Testmethoden und Anforderung (3) durch Methoden zur Erhöhung der Ausfallsicherheit behandelt werden, spielen für die Einhaltung von Anforderung (1) Verifikations- und Validierungsmethoden eine Rolle. Der Schwerpunkt der Vorlesung liegt auf Verifikations- und Validierungsmethoden für digitale Komponenten. Dabei interessiert sowohl der formale Nachweis von Systemeigenschaften als auch die Übereinstimmung des Entwurfs im Vergleich zu einer gegebenen Spezifikation. Es werden zunächst verschiedene existierende Basistechniken zur formalen Verifikation vorgestellt, wie z.B. Decision Diagrams, SAT-Solver und And-Inverter-Graphen. Darauf aufsetzend werden auf symbolischen Methoden beruhende Ansätze zum Äquivalenzvergleich kombinatorischer und sequentieller Schaltungen sowie zur Eigenschaftsprüfung beschrieben

Examination achievement

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

Literature

- Kropf: "Introduction to Formal Hardware Verification" , Springer, 1999, ISBN 3-540-65445-3
- Clarke, Grumberg, Peled, "Model Checking”, MIT Press 1999

- Kropf (Ed.): "Formal Hardware Verification", Springer, 1997, ISBN 3-540-63475-4
- Diverse Originalarbeiten
- Presentation of powerpoint slides. Slides and exercise sheets can be downloaded from the course website.

Compulsory requirement

Recommended requirement
Basiswissen in Technische Informatik

↑

Name of module	**Number of module**
Verification of Digital Circuits	11LE13MO-1223 ESE PO 2021
course	
Verifikation Digitaler Schaltungen / Verification of Digital Circuits - Exercises	
Event type	Number
excercise course	11LE13Ü-1223
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Operating Systems	

ECTS-Points	
Attendance	16 Stunden
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Wearable and Implantable Computing (WIC)	11E13MO-1402_PO 2020
Responsible	
Prof. Dr. Oliver Amft	
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Attendance	32 Stunden / Hours
Independent study	116 Stunden / Hours
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Basic timeseries analysis methods, basic programming skills, coding in Python

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Wearable and Implantable Computing (WIC)	lecture course	Core elective	6.0	2.0	180 Stunden / Hours
Wearable and Implantable Computing (WIC)	excercise course	Core elective		2.0	

Qualification
Students are able to ■ Understand design concepts and apply/analyse wearable and implantable system design methods. ■ Analyse physical principles, select and optimise on-body energy harvesting and power management techniques. ■ Create context recognition and energy-efficient pattern analysis pipelines using sparse sampling and pattern processing methods. ■ Build wearable system prototypes and apply system evaluation methods, including design for biocompatibility.

Examination achievement
mündliche Prüfung (i.d.R. 30 oder 45 Minuten) | Oral exam (usually 30 or 45 minutes) If there are too many students for a reasonably organized oral exam, it will be held as a written exam instead, announced well in advance.
Course achievement
Durchführung von Versuchen und Ergebnisprotokoll | Execution of experiments and written report of results
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung **|** Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science **OR** in Microsystems Engineering Concentrations Area Circuits and Systems/Biomedical Engineering ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems/Biomedical Engineering ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme/Biomedizinische Technik Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. M.Sc. Embedded Systems Engineering **and** Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. M.Sc. Embedded Systems Engineering

↑

Name of module	**Number of module**
Wearable and Implantable Computing (WIC)	11E13MO-1402_PO 2020
course	
Wearable and Implantable Computing (WIC)	
Event type	Number
lecture course	11E13V-1402_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Attendance	32 Stunden / Hours
Independent study	116 Stunden / Hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The course provides students with a comprehensive overview and in-depth skills on system design of sensor-based wearable and implantable computing systems. Course covers frequent sensors and actuators and their system integration, context recognition methods and selected algorithms, powering and energy management concepts (task scheduling, sparse sampling, and on-demand signal processing), energy harvesting methods, and system design topics (flexible electronics, electronics textile integration, multiprocess additive manufacturing), as well as principles of system validation.
Examination achievement
see module details
Course achievement
see module details
Literature
Up-to-date literature recommendations are provided during the lectures.
Compulsory requirement
None
Recommended requirement
Basic timeseries analysis methods, basic programming skills, coding in Python

↑

Name of module	**Number of module**
Wearable and Implantable Computing (WIC)	11E13MO-1402_PO 2020
course	
Wearable and Implantable Computing (WIC)	
Event type	Number
excercise course	11E13Ü-1402_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	
Attendance	32 Stunden / Hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Student groups will investigate concrete cases including context recognition, energy-efficient signal processing, and digital design of wearable systems. A wearable device prototype will be realised per student group.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Seminar 1	11LE50MO-Seminar 1
Responsible	
Prof. Dr. Hannah Bast	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 hours
Hours of week	2.0
Recommended semester	2
Duration	
Compulsory/Elective (C/E)	Core elective
Frequency	each term

Compulsory requirement
none
Recommended requirement
general mathematical knowledge, practical and theoretical foundations in Computer Science, possibly subject-specific knowledge for the chosen topics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload

Qualification
The students get an in-depth insight into scientific work in a special field of computer science. On the basis of selected topics from the various research and work areas of the professors and work groups, the students deepen their knowledge of how to read scientific texts, carry out background research, present scientific results and take part in scientific and technical discussions. They expand their knowledge of the rules and techniques of scientific work (e.g. correct quoting), especially regarding intellectual honesty; this knowledge is required for writing the Master thesis. Preparing and holding your own presentation as part of the seminar prepares you directly for the presentation of the Master thesis.
Examination achievement
The examination consists of the preparation and implementation of a scientific presentation.
Course achievement
As a rule, the course work consists of the following components: - regular attendance in the seminar meetings - preparation of 3-4 questions on seminar topics of other participants - written summary with citation of the references

Recommendation
Information about booking procedure for seminars: https://www.tf.uni-freiburg.de/en/studies-and-teaching/a-to-z-study-faq
Usability
Compulsory module for students of the study pogram ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Sc. in Informatik / Computer Science (PO 2020) Compulsory elective module for students of the study pogram ■ Master of Education Erweiterungsfach Informatik (PO 2021) ■ M.Sc. Embedded Systems Engineering (PO 2021)

↑

Name of module	**Number of module**
Seminar 2	11LE13MO-Seminar 2
Responsible	
Prof. Dr. Hannah Bast	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 hours
Hours of week	2.0
Recommended semester	3
Duration	
Compulsory/Elective (C/E)	Core elective
Frequency	each term

Compulsory requirement
none
Recommended requirement
general mathematical knowledge, practical and theoretical foundations in Computer Science, possibly subject-specific knowledge for the chosen topics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload

Qualification
The students get an in-depth insight into scientific work in a special field of computer science. On the basis of selected topics from the various research and work areas of the professors and work groups, the students deepen their knowledge of how to read scientific texts, carry out background research, present scientific results and take part in scientific and technical discussions. They expand their knowledge of the rules and techniques of scientific work (e.g. correct quoting), especially regarding intellectual honesty; this knowledge is required for writing the Master thesis. Preparing and holding your own presentation as part of the seminar prepares you directly for the presentation of the Master thesis.
Examination achievement
The examination consists of the preparation and implementation of a scientific presentation.
Course achievement
As a rule, the course work consists of the following components: - regular attendance in the seminar meetings - preparation of 3-4 questions on seminar topics of other participants - written summary with citation of the references

Recommendation
Information about booking procedure for seminars: https://www.tf.uni-freiburg.de/en/studies-and-teaching/a-to-z-study-faq
Usability
Compulsory module for students of the study pogram ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Sc. in Informatik / Computer Science (PO 2020) Compulsory elective module for students of the study pogram ■ Master of Education Erweiterungsfach Informatik (PO 2021) ■ M.Sc. Embedded Systems Engineering (PO 2021)

↑

Name of module	**Number of module**
Studienprojekt MSc ESE	11LE50MO-8140 ESE PO 2021
Responsible	
Prof. Dr. Hannah Bast	
Faculty	
Faculty of Engineering	

ECTS-Points	18.0
Workload	540 Stunden | hours
Hours of week	
Recommended semester	3
Duration	
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
allgemeine mathematische Grundlagen, praktische und theoretische Grundlagen der Informatik, themenspezifische Vorkenntnisse für den gewählten Themenbereich | general fundamental mathematical knowledge, practical and theoretical foundations in Computer Science, subject-specific knowledge for the chosen topics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload

Qualification
In this module students get involved in the actual research process of the chosen work group/chair. Depending on their personal field of interest and their expertise in various research and teaching areas offe- red at the Department of Computer Science, they decide on a specific topic and deepen their knowledge and skills in this area as well as their overall proficiency in academic work and research. They learn to work on the different tasks required for the specific project under given technical specifications, to develop appro- priate systems and to work constructively in projects. Students acquire the ability to familiarize themselves with new problems and do indepent background research. They will work with modern development environments and adhere to the generally accepted quality standards. During the project, working in a team as well as observing the rules of good scientific work will be expected.
Examination achievement
The graded assessment is (depending on the topic) either a written research paper (if it is rather a theoretical or fundamentally based topic; length usually maximum 40 pages) or the creation of a software or a demonstrator including a sufficient documentation (according to the scientific standards). Details are agreed upon with the supervisor (usually a person authorized to conduct examinations at the Department of Computer Science) when the topic is assigned.

Course achievement
As a rule, the course work consists of the following components: - regular attendance of (team) meetings or discussions with the supervisor - oral presentation (usually 20 - 30 minutes) with subsequent discussion
Recommendation
Language is usually English, but might be negotiable (changed to German). Please learn about the procedure of finding a topic and registering for the project in good time. (For instance, see "A to Z - Study FAQ" under "Studies and Teaching" on our faculty website.) Students are expected to self-organize the given tasks and do background research.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Elective Courses in Computer Science: In the area of Elective Courses in Computer Science, instead of Specialization Courses in Computer Science, students can choose to earn 18 ECTS credits by completing a Studienprojekt / Study project.

↑

Name of node	Number of node
Microsystems Engineering	11LE50KT-MSc-787-2021-MSE
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Compulsory

↑

Name of node	Number of node
Advanced Microsystems Engineering	11LE50KT-MSc-787-2021-AdvancedMSE
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Compulsory

Comment
Students have to choose at least 3 lectures from the following selection of Microsystems Engineering lectures. ■ Assembly and Packaging Technology ■ Micro-electronics ■ Micro-mechanics ■ Micro-optics ■ Modelling and System Identifcation ■ MST Technologies and Processes ■ Sensors ■ Signal Processing If they want to take more (or also the as elective available "Probability and Statistics"), they can take at most 6 of these lectures. Together with the chosen courses in the Microsystems Engineering Concentration Areas, the amount of ECTS credits must not surpass 54. Overall, the limit of ECTS credits is 90 for the areas of ■ Essential Lectures in Computer Science ■ Elective Courses in Computer Science ■ Advanced Microsystems Engineering ■ Microsystems Engineering Concentration Areas ■ (as well as the optional area of Customized Course Selection)

↑

Name of module	**Number of module**
Assembly and packaging technology	11LE50MO-7700/986 ESE PO 2021
Responsible	
Prof. Dr. Jürgen Wilde	
Organizer	
Department of Microsystems Engineering, Assembly and Packaging Technology	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Assembly and packaging technology	lecture course	Core elective	6.0	2.0	180 hours
Assembly and packaging technology - Exercises	excercise course	Core elective		1.0	

Qualification
Using the example of packaging and interconnection technology, the realization step from basically functioning microsystems to industrial products is demonstrated. In addition, an overview is given of the main technologies that are frequently used for the realization of demonstrators within the scope of the master's thesis. AVT is a complex technology that serves to generate the hardware of electronic systems. This technology draws directly from materials science, manufacturing technology, engineering mechanics and also electrical engineering. The aim of this module is to build operationally higher integrated systems by integrating and contacting a functional element and at the same time providing a barrier to protect it from environmental influences. The main learning objective is to understand the manufacturing technologies for electronic hardware and specifically for microsystems using modern industrial manufacturing processes. Another important learning

objective is the knowledge of the concepts for the design and optimization of the assembly and interconnection technology in microsystems technology, taking into account functionality, service life, stress and operating conditions, and the ability to apply them to one's own scientific questions. The learning objective is also to qualify students specifically for the practical questions on assembly and interconnection technology that frequently arise during the master's thesis.
Examination achievement
written examination (150 minutes)
Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Advanced Microsystems Engineering ■ M.Sc. Microsystems Engineering (PO 2021), Advanced Microsystems

↑

Name of module	**Number of module**
Assembly and packaging technology	11LE50MO-7700/986 ESE PO 2021
course	
Assembly and packaging technology	
Event type	Number
lecture course	11LE50V-7700/986_2018

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Assembly and packaging comprises a complex technology which aims at the fabrication of electronic hardware. This technology is mainly based on Materials Science and Engineering, Mechanical and Electrical Engineering. The target is to connect a functional element to an application and at the same time to protect it from the environment.
Fabrication technologies comprise assembly, joining and interconnection, while the main constructional elements are substrates, housings or packages. For all of these present days' state of the art is presented and the fundamental requirements are demonstrated. So the students will get an overview of the basic manufacturing operations and the required materials in order to integrate electronic hardware.
Besides, it is indispensable that knowledge about modern techniques for design optimisation will be taught. Electronic systems must fulfil specifications concerning integration density, high frequency behaviour, thermal management, thermal-mechanical behaviour and lifetime. To that purpose, the basic techniques for performance and reliability optimization will be regarded. In this way, it is desired that the students will become capable of finding own solutions in the field of assembly and packaging of microsystems.
The course comprises the following

1. Housing and packaging technologies - Hermetic and plastic packaging, wafer-level packaging
2. Substrates - Printed circuit boards, multi-chip-modules, moulded interconnect devices
3. Assembly technologies - Surface mount technology, adhesive bonding
4. Interconnection technology - Wire bonding, flip-chip-bonding
5. Electromagnetic compatibility EMC -Integrity and speed of electrical signals and equivalent circuits
6. Thermal management -Temperature problems and cooling techniques
7. Mechanical optimization -Stress-affected problems, solder joint reliability

Examination achievement

see module details

Course achievement

none

Literature
■ An English manuscript will be made available in printed and in electronic form. Sources of information and references for the various fields are given in the manuscript.
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
Assembly and packaging technology	11LE50MO-7700/986 ESE PO 2021
course	
Assembly and packaging technology - Exercises	
Event type	Number
excercise course	11LE50Ü-7700/986_2018

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The exercise helps to reinforce the teaching contents of the lecture. It is the aim that students will be enabled to apply the acquired competences to relevant applications of assembly, packaging and interconnection technology like power electronics or sensor systems. To that purpose specific tasks will be exercised, which help to create suitable application-specific packaging concepts. Also it will be important to select the corresponding materials and fabrication processes properly. A highly relevant aspect is the capability to evaluate assembly and packaging concepts quantitatively with respect to the relevant performance parameters. Such criteria comprise a signal's time-of-flight, the thermal resistance, stress level, and life-time.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
keine

↑

Name of module	Number of module
Micro-electronics	11LE50MO-7050/986 ESE PO 2021
Responsible	
Dr.-Ing. Matthias Keller Prof. Dr.-Ing. Matthias Kuhl	
Organizer	
Department of Microsystems Engineering, Microelectronics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge in electrical engineering and good knowledge in electronics, particularly with regard to the following topics: ■ semiconductor diode ■ bipolar transistor ■ MOS transistor ■ operational amplifier ■ digital circuit design ■ logic gates & logic families ■ sequential circuits

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Micro-electronics - Lecture	lecture course	Compulsory	6.0	2.0	workload: 180 hours
Micro-electronics - Exercises	excercise course	Compulsory		2.0	

Qualification
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 prin-

ciples 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.
Examination achievement
written examination with a duration of 120 minutes
Course achievement
none
Usability
Compulsory module for students of the study pogram ■ M.Sc. Microsystems Engineering (PO 2021) Compulsory elective module for students of the study program ■ M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Advanced Microsystems Engineering

↑

Name of module	**Number of module**
Micro-electronics	11LE50MO-7050/986 ESE PO 2021
course	
Micro-electronics - Lecture	
Event type	Number
lecture course	11LE50V-7050/986
Organizer	
Department of Microsystems Engineering, Microelectronics	

ECTS-Points	6.0
Workload	workload: 180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents
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 behavior 5. Differential amplifiers 6. Noise in electronic circuits 7. Analog layout 8. MEMS Applications
Examination achievement
see module details
Course achievement
none
Literature
1. Allen, Holberg: CMOS Analog Circuit Design, Oxford University Press 2. Sedra, Smith: Microelectronic Circuits, Oxford University Press 3. Razavi: Design of Analog CMOS Integrated Circuits, McGraw-Hill Higher Education

Compulsory requirement
none
Recommended requirement
Basic knowledge in electrical engineering and good knowledge in electronics, particularly with regard to the following topics: ■ semiconductor diode ■ bipolar transistor ■ MOS transistor ■ operational amplifier ■ digital circuit design ■ logic gates & logic families ■ sequential circuits

↑

Name of module	**Number of module**
Micro-electronics	11LE50MO-7050/986 ESE PO 2021
course	
Micro-electronics - Exercises	
Event type	Number
excercise course	11LE50Ü-7050/986
Organizer	
Department of Microsystems Engineering, Microelectronics	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents
The exercise helps to reinforce the teaching contents of the lecture.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
none

↑

Name of module	**Number of module**
Micromechanics	11LE50MO-7100/986 ESE PO 2021
Responsible	
Prof. Dr. Lars Pastewka	
Organizer	
Department of Microsystems Engineering, Simulation	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Participants of this module should have knowledge in mathematical analysis and linear algebra (basic calculus, vector operations, matrices, tensors, …) and basic physics (forces, momenta, …).

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Micro-mechanics	lecture course	Compulsory	6.0	2.0	workload 180 hours
Micro-mechanics	excercise course	Core elective		2.0	

Qualification
The student... ...understands the relationship between displacement, strain and strain energy density. ...can formulate and solve the equations for static force equilibrium of rigid and elastically deformable bodies.
Examination achievement
The final examination will be written and of 150 minutes duration.

Course achievement
none
Usability
Compulsory module for students of the study pogram ■ M.Sc.Microsystems Engineering (PO 2021) Compulsory elective module for students of the study program ■ M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Advanced Microsystems Engineering

↑

Name of module	**Number of module**
Micromechanics	11LE50MO-7100/986 ESE PO 2021
course	
Micro-mechanics	
Event type	Number
lecture course	11LE50V-7100/986
Organizer	
Department of Microsystems Engineering, Simulation	

ECTS-Points	6.0
Workload	workload 180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents

This course is an introduction into the mechanics of structures and materials with a focus on mechanics at small scales. The lecture contains:

- Statics: force systems, force couples, moments, bearings, internal force variables, free body diagrams, distributed loads
- Elastostatics: stress, force equilibrium, stress invariants, displacement, strain, Hooke's law, strain energy, compatibility, plane problems, Airy stress function, Westergaard stress function
- Beams & Plates: Euler-Bernoulli beam theory, buckling of beams, Kirchhoff plate theory
- Failure & Cracks: yield criteria, fracture modes, near-field solution, fracture toughness, strain energy release rate, Griffith criterion

Examination achievement

see module details

Course achievement

see module details

Literature

J.R. Barber, “Elasticity”, Kluwer Academic Publishers, 2012

P.C. Chou, N.J. Pagano, “Elasticity: Tensor, Dyadic, and Engineering Approaches”, Dover, 1992

D. Gross, W. Hauger, J. Schröder, W.A. Wall, J. Bonet, “Engineering Mechanics 2: Mechanics of Materials”, Springer, 2011

D. Gross, T. Seelig, “Fracture Mechanics: With an Introduction to Micromechanics”, Springer, 2017

L.D. Landau, L.P. Pitaevskii, A.M. Kosevich, E.M. Lifshitz, “Theory of Elasticity”, Butterworth-Heinemann, 1986 J.L. Meriam, L.G. Kraige, “Engineering Mechanics: Statics”, John Wiley & Sons, 2014 S.P. Timoshenko, J.N. Goodier, “Theory of Elasticity”, McGraw Hill, 1987
Compulsory requirement
none
Recommended requirement
Participants of this module have knowledge in mathematical analysis and linear algebra (basic calculus, vector operations, matrices, tensors, …) and basic physics (forces, momenta, …).

↑

Name of module	**Number of module**
Micromechanics	11LE50MO-7100/986 ESE PO 2021
course	
Micro-mechanics	
Event type	Number
excercise course	11LE50Ü-7100/986
Organizer	
Department of Microsystems Engineering, Simulation Department of Microsystems Engineering, Design of Microsystems	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The exercises will practice the contents of the lecture with sample problems. The lectures largely introduce the theoretical framework of mechanics analysis, while the exercise provides students the opportunity to engage with applied problems. Due to limitations in both lecture and exercise time, however, it is strongly recommended that students practice problems on their own as well. Exercise problems will not be graded or count toward the final course grade. Exercise problems will give students practice in utilizing and synthesizing multiple concepts in solving practical problems.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
none

↑

Name of module	**Number of module**
Micro-optics	11LE50MO-7600/986 ESE PO 2021
Responsible	
Prof. Dr. Hans Zappe	
Organizer	
Department of Microsystems Engineering, Professorship in Micro-optics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Micro-optics	lecture course	Core elective	6.0	2.0	180 hours
Micro-optics	excercise course	Core elective		2.0	

Qualification
Optics is the science and engineering of light and is one of the most important technical disciplines with wide-ranging applications in both basic science and in industrial application. Micro-optics is optics for microsystems, small-scale components and systems which bring light into MEMS. This course will introduce the physics of light, the concepts of optics and optical components and their use in a broad variety of microsystems. The instructional aim of the course Micro-optics is the establishment of competence in basic optics, including optical components and systems, and generation of the ability to incorporate optical concepts into MEMS. At the completion of the course, the successful student should possess:

• a basic understanding of electromagnetic radiation and its interaction with matter; • the ability to analyze and understand the most important optical components and their functionality; • expertise in the analysis of fundamental lens combinations; • the ability to design and calculate the behavior of simple optical systems; • an awareness of the most important fabrication and assembly processes used in optics; • the ability to understand and apply micro-optical components and concepts in microsystems.
Examination achievement
Written examination with a duration of 120 minutes
Course achievement
There are exercises at regular intervals that have to be worked on and handed in. These are corrected and assessed with points. The course work has been passed if at least 50% of the exercise sheets have been prepared and submitted as well as if 50% of the practice sessions were attended.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Advanced Microsystems ■ M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Advanced Microsystems Engineering

↑

Name of module	Number of module
Micro-optics	11LE50MO-7600/986 ESE PO 2021
course	
Micro-optics	
Event type	Number
lecture course	11LE50V-7600/986
Organizer	
Department of Microsystems Engineering, Professorship in Micro-optics	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

This course covers the fundamentals of micro-optics with a focus on implementation and application in optical microsystems. Following an overview of the relevant basic mathematics and electromagnetics, we will consider optical phenomena including Gaussian optics, optical interfaces and materials. The core of the course consists of an in-depth presentation of reflective, geometric, diffractive and integrated optics. In each section, both the basic optical components as well as their application in microsystems are considered.

Table of contents:

1. Electromagnetic waves
2. Light waves & beams
3. Optical materials
4. Optical interfaces
5. Reflective optics
6. Refractive optics
7. Refractive components
8. Refractive systems
9. Diffractive optics
10. Diffractive components
11. Waveguide optics
12. Fiber optics
13. Fabrication

Examination achievement

see module details

Course achievement
see module details
Literature
English: • H. Zappe: Fundamentals of Micro-optics • E. Hecht: Optics • R. Hunsperger: Integrated Optics • B. Saleh & M. Teich: Fundamentals of Photonics • S. Sinzinger & J. Jahns: Microoptics • W. Smith: Modern Optical Engineering • H. Zappe: Introduction to Semiconductor Integrated Optics In German: • E. Hecht: Optik • G. Litfin: Technische Optik in der Praxis
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
Micro-optics	11LE50MO-7600/986 ESE PO 2021
course	
Micro-optics	
Event type	Number
excercise course	11LE50Ü-7600/986
Organizer	
Department of Microsystems Engineering, Professorship in Micro-optics	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The exercises serve to deepen the learning material in micro-optics.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
Modelling and System Identification	11LE50MO-2080 ESE PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
fundamental knowledge in higher mathematics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Modellbildung und Systemidentifikation / Modelling and System Identification - Lecture	lecture course	Core elective	6.0	2.0	180 hours
Modellbildung und Systemidentifikation / Modelling and System Identification - Exercises	excercise course	Core elective		2.0	

Qualification
Aim of the module is to enable the students to create and identify models that help to describe and predict the behaviour of dynamic systems. In particular, students shall become able to use input-output measurement data in form of time series to identify unknown system parameters and to assess the validity and accuracy of the obtained models.
Examination achievement
Written exam (180 minutes)

Course achievement
The course work is successfully completed if both of the following criteria are met: 1) Passing the exercise: For each exercise sheet, the achieved points are determined in percentage points with respect to the maximum score of the respective exercise sheet. The two exercise sheets with the lowest percentage points achieved will not be included in the assessment. The exercise is considered passed if the average of the achieved percentage points in the remaining exercise sheets is at least 50 percentage points. 2) Passing the micro-examinations: For each micro-examination, the points achieved are determined in percentage points with respect to the maximum number of points. The micro-exam in which the fewest percentage points were obtained will not be included in the evaluation. The microclauses are considered passed if the average of the percentage points achieved in the remaining microclauses is at least 50 percentage points.
Usability
As compulsory elective in ■ M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) in Advanced Microsystems Engineering ■ M.Sc. Microsystems Engineering (PO 2021) in Advanced Microsystems ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Modelling and System Identification	11LE50MO-2080 ESE PO 2021
course	
Modellbildung und Systemidentifikation / Modelling and System Identification - Lecture	
Event type	Number
lecture course	11LE50V-2080
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	6.0
Workload	180 hours
Attendance	60 hours
Independent study	120 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Linear and Nonlinear Least Squares, Maximum Likelihood and Bayesian Estimation, Cramer-Rao-Inequality, Recursive Estimation, Dynamic System Model Classes (Linear and Nonlinear, Continuous and Discrete Time, State Space and Input Output, White Box and Black Box Models), Application of identification methods to several case studies. The lecture course will also review necessary concepts from the three fields Statistics, Optimization, and Systems Theory, where needed.
Examination achievement
see module details
Course achievement
see module details
Literature
1. Lecture manuscript 2. Ljung, L. (1999). System Identification: Theory for the User. Prentice Hall 3. Lecture manuscript "System Identification" by J
Compulsory requirement
None
Recommended requirement
Undergraduate knowledge in analysis, algebra, differential equations as well as in systems theory and feedback control.

↑

Name of module	**Number of module**
Modelling and System Identification	11LE50MO-2080 ESE PO 2021
course	
Modellbildung und Systemidentifikation / Modelling and System Identification - Exercises	
Event type	Number
excercise course	11LE50Ü-2080
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The exercises accompany the lecture content and are mostly computer exercises and case studies.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
MST Technologies and Processes	11LE50MO-7250 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Bastian Rapp	
Organizer	
Department of Microsystems Engineering, Process Technology	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
MST Technologies and Processes	lecture course	Compulsory	6.0	2.0	180 hours
MST technologies and processes - Exercise	excercise course	Compulsory		1.0	

Qualification

It is the learning target that students will have a sound understanding of the fundamentals of MEMS technologies. They will know

- the physical and technological background of microsystems processing
- process flows for the fabrication of MEMS elements
- principals of material sciences (silicon and other semiconductors)
- principals of clean-room and vacuum technologies

Also the students will be able to apply this knowledge practically to own designs, and especially in the MST design laboratories.

Examination achievement

Written examination with a duration of 120 minutes

Course achievement
Within the practical course of this lecture, students will be assembled in teams and given an assignment to perform. The assignment will stem from the context of the lecture and will be solved by the teams independently under supervision of the professor. The assignment will be documented in a 4-page summary report which will be graded and corrected. The result will then be presented in a 10-15 minute presentation.
Usability
Compulsory module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021) Compulsory elective module for students of the study program ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of module	Number of module
MST Technologies and Processes	11LE50MO-7250 ESE PO 2021
course	
MST Technologies and Processes	
Event type	Number
lecture course	11LE50V-7250
Organizer	
Department of Microsystems Engineering, Process Technology	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents

The content of the course:
- overview of MEMS processing (silicon, polymers)
- mechanical, chemical and physical properties of silicon
- cleanrooms – layout, function and operational procedures
- lithographic methods: physical background, optical lithography, ebeam lithography, x-Ray lithography
- vacuum technology, thin film and etching processes: physical and chemical background, Oxidation, Doping, Implantation, Physical Vapor Deposition (PVD), Chemical Vapor Deposition (CVD), Chemical etching processes. Plasma and reactive ion etching (RIE)
- surface and bulk micromachinig (process chains)
- back end processing: wafer bonding, dicing
- assembly and packaging

Examination achievement

see module details

Course achievement

see module details

Literature

Marc Madou: Fundamentals of Microfabrication and Nanotechnology, CRC Press; 3 edition (August 1, 2011), ISBN 978-0849331800
Menz, Mohr, Paul: Microsystem Technology, Wiley-VCH Verlag GmbH & Co. KGaA; Edition: 1 edition (February 15, 2001), ISBN 978-3527296347

Compulsory requirement

none

Recommended requirement
none

↑

Name of module	Number of module
MST Technologies and Processes	11LE50MO-7250 ESE PO 2021
course	
MST technologies and processes - Exercise	
Event type	Number
excercise course	11LE50Ü-7250
Organizer	
Department of Microsystems Engineering, Process Technology	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
keine

↑

Name of module	**Number of module**
Probability and statistics	11LE50MO-6100 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	
Faculty	
Faculty of Engineering Department of Microsystems Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge in mathematics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Probability and statistics	lecture course	Core elective	6.0	2.0	180 hours
Probability and statistics	excercise course	Core elective		2.0	

Qualification
The overall aim of the module is that students will have insights into the field of probability and statistics. Complemented by many examples, the students learn to apply probability theory and statistics in order to analyze data. After the course The students will be able to assess and evaluate the results they obtained.
Examination achievement
■ Written or oral examination ■ Graded exercises/practical exercises The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

Course achievement
There are exercises at regular intervals that have to be worked on and handed in.These are corrected and assessed with points. The exercises are considered passed if 50% of maximum points will be achieved from the tests that are written in the exercises with prior notice.
Grading
The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).
Examination weight
■ 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 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.
Recommendation
Important information for MSc ESE: According to the exam regulations, this module does **NOT**count towards the 18 compulsory ECTS in Advanced MSE! It can only be taken as a surplus course (using 6 credits from the 18 "flexible" ECTS credits as per exam regulations), so overall students gain 24 ECTS credits in the area of Advanced MSE. **Wichtiger Hinweis für MSc ESE:** Diese Modul zählt laut Prüfungsordnung **NICHT**in die 18 Pflicht-ECTS im Berich Advanced MSE! Es kann nur im Rahmen von 6 der "flexibel einsetzbaren" 18 ECTS-Punkte belegt werden, so dass im Bereich Advanced MSE insgesamt mind. 24 ECTS-Punkte absolviert werden.
Usability
Mandatory module for students of the study program ■ Master of Science in Microsystems Engineering Elective module for students of the study program ■ Master of Science in Embedded Systems Engineering - Personal Profile ■ Master of Science in Informatik ■ Master of Science in Mikrosystemtechnik - Personal Profile

↑

Name of module	**Number of module**
Probability and statistics	11LE50MO-6100 ESE PO 2021
course	
Probability and statistics	
Event type	Number
lecture course	11LE50V-6100
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

The topics of this course cover:

- Probability theory:
- Discrete random variables
- Continuous random variables
- Statistics:
- Parameter estimation
- Linear and nonlinear regression
- Statistical tests
- Random numbers and Monte-Carlo simulation
- Experimental design
- Statistical process control

Examination achievement

see module details

Course achievement

see module details

Literature

1. M.R. Spiegel, L.J. Stephens, Theory and Problems of Statistics, Schaum's Outline Series, New York
2. J. Honerkamp, Stochastic Dynamical Systems, VCH, Weinheim
3. J. Pitman, Probability, Springer, Corr. 7th printing, 1993
4. D. Stoyan, Stochastik für Ingenieure und Naturwissenschaftler, Akademie Verlag, 1993
5. U. Krengel, Einführung in die Wahrscheinlichkeitstheorie und Statistik: Für Studium, Berufspraxis und Lehramt, Vieweg und Teubner 2005

Compulsory requirement
none
Recommended requirement
Basic knowledge in mathematics
Recommendation
Important information for MSc ESE: According to the exam regulations, this module does **NOT**count towards the 18 compulsory ECTS in Advanced MSE! **Wichtiger Hinweis für MSc ESE:** Diese Modul zählt laut Prüfungsordnung **NICHT** in die 18 Pflicht-ECTS im Berich Advanced MSE!

↑

Name of module	**Number of module**
Probability and statistics	11LE50MO-6100 ESE PO 2021
course	
Probability and statistics	
Event type	Number
excercise course	11LE50Ü-6100
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
none
Recommendation
Important information for MSc ESE: According to the exam regulations, this module does **NOT**count towards the 18 compulsory ECTS in Advanced MSE! **Wichtiger Hinweis für MSc ESE:** Diese Modul zählt laut Prüfungsordnung **NICHT** in die 18 Pflicht-ECTS im Berich Advanced MSE!

↑

Name of module	**Number of module**
Sensors	11LE50MO-7500/986 ESE PO 2021
Responsible	
Prof. Dr. Gerald Urban	
Organizer	
Department of Microsystems Engineering, Professorship in Sensors	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge in physics, mathematics and materials

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Sensors	lecture course	Core elective	6.0	2.0	180 hours
Sensors Lab Course	practical course	Core elective			

Qualification
Participants should exhibit a comprehensive overview over all technical sensor types, their working principles,measurement ranges, accuracies, their realization technologies.Thermodynamics and material based conversion principles for sensor functions. Students should be enabled to select, apply, optimise, existing sensor types and establish sensor signal handling for a specific task. Furthermore, they should gain abilities to develop novel sensor types and technologies for their realization.
Examination achievement
Written exam (usually 90 to 180 minutes)

Course achievement
To pass the course, you need to do 3 reports for the lab course, which all all three have to be accepted as sufficient. In case a report is insufficient, you have the option to rework it and resubmit within one week. In total, you have three options to rework. The criteria for approvement of the report are based on the description “Writing a Scientific Lab Report” provided in the lab course manual and the tasks defined for each of the three experiments.
Usability
Compulsory elective mdule for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), in Advanced Microsystems ■ M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Advanced Microsystems Engineering

↑

Name of module	**Number of module**
Sensors	11LE50MO-7500/986 ESE PO 2021
course	
Sensors	
Event type	Number
lecture course	11LE50V-7500/986
Organizer	
Department of Microsystems Engineering, Professorship in Sensors	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The lecture Sensors gives an overview about working principles, physical mechanisms, methods and technologies important for sensors with a focus on microtechnology. A general introduction is followed by specific discussion of various sensor types including for example temperature, radiation, magnetic, mechanical and chemical sensors. The lecture bridges fundamentals and applications of sensors. Sensor examples of university and industrial environment will be shown and opportunities and limitations of these sensors will be discussed.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
none
Recommended requirement
Basic knowledge in physics, mathematics and materials

↑

Name of module	Number of module
Sensors	11LE50MO-7500/986 ESE PO 2021
course	
Sensors Lab Course	
Event type	Number
practical course	11LE50P-7500 PO 2021
Organizer	
Department of Microsystems Engineering, Professorship in Electrical Instrumentation and Embedded Systems	

ECTS-Points	
Hours of week	
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Through the three modules of the lab course, we provide you with hands-on experience to deepen the knowledge from the lectures. We like you to spark your interest in sensor applications playfully, but simultaneously expect a university level performance during the experimentation and while writing your reports. All experiments use the Arduino Nicla Sense ME platform, which comprises four state-of-art integrated sensors, an Arm Cortex M4 processor and Bluetooth connectivity. The different sensors are an inertial measurement unit (IMU) measuring acceleration and rotation, a pressure sensor, a magnetometer, and a gas sensor providing deduced parameters like equivalent CO2 and volatile organic compounds (VOC) concentrations together with temperature and humidity. The lab course consists of self-learning modules for which each student borrows one Nicla Sense ME board. Nothing else is needed besides a computer with a USB port, preferably a notebook. Within the given schedule (i.e., deadlines for report submission), you can work on the experiments at your own pace.
Qualification
You have practical experience with different state-of-art sensors (accelerometer, gyroscope, pressure sensor, magnetometer, gas sensor, humidity sensor, temperature sensor) and an embedded sensor platform. 2. You can program an embedded system to interface with different sensors and provide the data to a connected computer. 3. You know how to perform sensor measurements according to scientific standards. 4. You can analyze sensor data (filtering, integration, differentiation). 5. You can document and appropriately discuss your measurements in a report. 6. You understand the working principles of the different sensors and relate your measurements to the limitations of the sensor principle. Lehrinhalt/

Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
Microcontroller programming (Arduino C++), Matlab

↑

Name of module	**Number of module**
Signal Processing	11LE50MO-7400 ESE PO 2021
Responsible	
Prof. Dr. Stefan Rupitsch	
Organizer	
Department of Microsystems Engineering, Professorship in Electrical Instrumentation and Embedded Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Good knowledge in mathematics (complex numbers, trigonometry, calculus, linear algebra, circuit analysis, differential equations)

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Signal processing - lecture	lecture course	Compulsory	6.0	2.0	180 hours
Signal processing - exercises	excercise course	Compulsory		1.0	

Qualification
With this module students will be able to mathematically model the propagation of signals in electronic systems, enabling them to optimize their design. In particular, students will be able to design and test analog and digital filters.
Examination achievement
Written exam (Klausur), 120 minutes
Course achievement
none

Usability
Compulsory Module for students of the study program ■ Master of Science in Microsystems Engineering (PO 2021) Compulsory elective module for students of the study program ■ Bachelor of Science in Mikrosystemtechnik (PO 2018), Wahlpflichtbereich, Bereich Mikrosystemtechnik ■ Master of Science in Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Advanced Microsystems Engineering

↑

Name of module	Number of module
Signal Processing	11LE50MO-7400 ESE PO 2021
course	
Signal processing - lecture	
Event type	Number
lecture course	11LE50V-7400
Organizer	
Department of Microsystems Engineering, Professorship in Electrical Instrumentation and Embedded Systems	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents
The purpose of the course is to teach students how to mathematically model the propagation of signals through electrical systems. The following topics will be covered in the course: Matlab, Analog networks, Network analysis, Convolution, Impulse response, Signal response, Freq response, Bode plot, Phasors, Transfer functions, Pole-zero plot, System response, Stability, Laplace transform, Analog Filter design, Sampling, Quantizing, Analog to digital converter, Digital to analog converter, Digital networks, Z transform, Digital filter design, Digital signal processor, Fourier series, Fourier transform, Discrete Fourier transform, Fast Fourier transform, and Windowing.
Examination achievement
see module details
Course achievement
see module details
Literature
In English: ▪ Denbigh, Philip: System Analysis and Signal Processing ▪ Mertins: Signal Analysis ▪ Mitra: Digital Signal Processing ▪ Kay: Fundamentals of statistical signal processing & Modern spectral estimation ▪ Ingle, Proakis: Digital Signal Processing using MATLAB In German: ▪ Butz, Tilman: Fouriertransformation für Fußgänger ▪ Daniel Ch. von Grüningen: Digitale Signalverarbeitung, Fachbuchverlag Leipzig

- E. Schrüfer: Signalverarbeitung, Hanser Verlag
- R. Scheithauer: Signale und Systeme, Teubner Stuttgart
- Kammeyer, Kroschel: Digitale Signalverarbeitung
- Einführung in MATLAB, Skript zu den Übungen Signalverarbeitung SS2005
- Vorlesungsskript Signalverarbeitung SS2005
- Oppenheim, Schafer: Zeitdiskrete Signalverarbeitung

Compulsory requirement
None
Recommended requirement
Good knowledge in mathematics (complex numbers, trigonometry, calculus, linear algebra, circuit analysis, differential equations).

↑

Name of module	**Number of module**
Signal Processing	11LE50MO-7400 ESE PO 2021
course	
Signal processing - exercises	
Event type	Number
excercise course	11LE50Ü-7400
Organizer	
Department of Microsystems Engineering, Professorship in Electrical Instrumentation and Embedded Systems	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents
Examination achievement
see lecture
Course achievement
none
Compulsory requirement
None
Recommended requirement
Good knowledge in mathematics (complex numbers, trigonometry, calculus, linear algebra, circuit analysis, differential equations).

↑

Name of node	**Number of node**
Microsystems Engineering Concentrations Area	11LE50KT-MSc-787-2021-ConcentrationsMSE
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Compulsory

Comment
Students have to take at least 18 ECTS credits within **one** of the Microsystems Engineering Concentration Areas: ■ Circuits and Systems ■ Materials and Fabrication ■ Biomedical Engineering ■ Photonics If students opt to do more than the minimum number of credits here, those can also come from courses belonging to a different Concentration area. Together with the chosen courses from Advanced Microsystems Engineering, the amount of ECTS credits must not surpass 54. Overall, the limit of ECTS credits is 90 for the areas of ■ Essential Lectures in Computer Science ■ Elective Courses in Computer Science ■ Advanced Microsystems Engineering ■ Microsystems Engineering Concentration Areas ■ (as well as the optional area of Customized Course Selection)

↑

Name of node	Number of node
Circuits and Systems	11LE50KT-MSc-787-2021-MSE-CaS
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Compulsory

↑

Name of module	**Number of module**
Analog CMOS Circuit Design	11LE50MO-5202 ESE PO 2021
Responsible	
Dr.-Ing. Matthias Keller Prof. Dr.-Ing. Matthias Kuhl	
Organizer	
Department of Microsystems Engineering, Microelectronics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
■ Successful completion of the module 5070 - *Micro-electronics*. The limited number of 20 seats will be distributed among applying students based on the ranking of the module grade.
Recommended requirement
see above

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Analog CMOS Circuit Design - Lecture	lecture course	Core elective	6.0	2.0	180 hours
Entwurf Analoger CMOS Schaltungen - Praktikum / Analog CMOS Circuit Design - Laboratory	practical course	Core elective		2.0	

Qualification

- After completing the module, students are familiar with complex analog CMOS circuit design concepts and are thus in the position to analyze and design arbitrary analog circuits.
- The students master the state-of-the-art design approach gm/Id and are thus able to design and implement analog circuits in an arbitrary technology node.
- The students improve their skills in the frequency analysis of feedback systems and are thus able to define the phase margin of feedback systems by relocating poles and zeros.
- The students know how to analyze the noise performance of analog integrated circuits and how to meet noise specifications.

Examination achievement
Written exam at the end of the term with a duration of 2h on the content of the module. The lecture and the practical exercise represent a module; the mark of the written exam will thus be weighted by 6 ECTS.
Course achievement
■ five graded reports, presentation (at the end of the term) ■ The practical exercise *Analog CMOS Circuit Design - Laboratory* is successfully passed if the final presentation is passed and an average grade of 70% is achieved in the five written reports.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Crcuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of module	**Number of module**
Analog CMOS Circuit Design	11LE50MO-5202 ESE PO 2021
course	
Analog CMOS Circuit Design - Lecture	
Event type	Number
lecture course	11LE50V-5202
Organizer	
Department of Microsystems Engineering, Microelectronics	

ECTS-Points	6.0
Workload	180 hours
Attendance	52 hours
Independent study	128 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The fundamentals of microelectronics were presented in the course Microelectronics, in particular the square-law / lambda model depicting the current-voltage characteristic of MOS transistors in different working regions. The square-law model allows gaining a quick and intuitive understanding of the large- and small-signal behavior of the MOS transistor. However, for performing integrated analog circuit design, a more accurate model is required that provides excellent matching between hand calculations and simulations, in particular for modern nanometer CMOS technologies. At first, the gm/Id design methodology will thus be presented. It will be illustrated by and applied to the design and transistor-level implementation of a typical analog circuit, i.e., a two-stage amplifier, in the practical exercise. Another focus of the course is put on the fundamentals of electrical noise, i.e., understanding, predicting, and minimizing noise in CMOS circuits. In addition to the minimization of thermal and 1/f-noise by proper sizing of transistors, the sampled or chopped operation of analog amplifiers will be introduced as a measure to efficiently suppress the CMOS transistor's inherent 1/f-noise. Moreover, it will be shown that chopping also allows for the compensation of further non-idealities such as offset or saturation. The course concludes with the introduction of circuit blocks that are needed for the implementation of near-complete systems, i.e., electrical references for voltage, current, temperature, and time. Moreover, advanced differential architectures will be presented, e.g., folded cascode and inverter-based amplifiers or Gm-C filters. One of these circuit blocks will be analyzed in class by the participants themselves in a simplified flipped-classroom scenario.
Examination achievement
see module details
Course achievement
see module details

Literature
■ Script ■ P. E. Allen and D. R. Holberg, CMOS Analog Circuit Design, Oxford Press, 2002 ■ B. Razavi, Design of Analog CMOS Integrated Circuits, McGraw-Hill, 2001
Compulsory requirement
Successful completion of the module 5070 - Micro-electronics. The limited number of 20 seats will be distributed among applying students based on the ranking of the module grade.
Recommended requirement
■ Successful completion of the module 5070 - Micro-electronics. The limited number of 20 seats will be distributed among applying students based on the ranking of the module grade. ■ system theory (basics)
Recommendation
■ **In case of comments and/or questions, please contact M. Sc. C. Grandauer (christoph.grandauer@imtek.de).** ■ Application for participation is to be performed as soon as possible in HISinOne, even if the result of the exam *Mikroelektronik* / *Microelectronics* is not yet available. Students will get informed on their status, i.e., "accepted / waiting list / rejected", once the results of the exam are available. ■ No participation in the first lecture results in the cancellation of an accepted application. The seat will be given to the first student on the waiting list.

↑

Name of module	**Number of module**
Analog CMOS Circuit Design	11LE50MO-5202 ESE PO 2021
course	
Entwurf Analoger CMOS Schaltungen - Praktikum / Analog CMOS Circuit Design - Laboratory	
Event type	Number
practical course	11LE50Ü-5202
Organizer	
Department of Microsystems Engineering, Microelectronics	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Based on the example of a two-stage amplifier with RC compensation, the practical exercise illustrates the typical design flow of analog integrated circuits. It goes hand in hand with the lecture and trains the students on the implementation of analog integrated circuits based on the gm/Id design approach. After an inital analysis of the circuit by means of hand calculations, the circuit will be implemented and simulated on transistor level using the software Cadence Spectre in order to verify its functionality. In the end, the design will be iteratively improved to withstand real-life conditions and nonidealities, e.g., temperature-, process-, and parameter variations. The student will thus learn that an understanding of the circuit's parameters and their interactions is essential for a successful implementation of an integrated circuit. At the end of the term, a presentation is to be given that covers the design on transistor level.

Examination achievement

see module details

Course achievement

see module details

Compulsory requirement

- Successful completion of the module 5070 - Micro-electronics. The limited number of 20 seats will be distributed among applying students based on the ranking of the module grade.

Recommended requirement

- Successful completion of the module 5070 - Micro-electronics. The limited number of 20 seats will be distributed among applying students based on the ranking of the module grade.
- system theory (basics)

Recommendation
■ Application for participation is to be performed as soon as possible in HISinOne, even if the result of the exam Mikroelektronik / Microelectronics is not yet available. Students will get informed on their status, i.e., "accepted / waiting list / rejected", once the results of the exam are available. ■ No participation in the first lecture results in the cancellation of an accepted application. The seat will be given to the first student on the waiting list.

↑

Name of module	**Number of module**
Angewandte Sensorschaltungstechnik	11LE50MO-5268 ESE PO 2021
Responsible	
Prof. Dr. Peter Woias	
Organizer	
Department of Microsystems Engineering, Design of Microsystems	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.5
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Angewandte Sensorschaltungstechnik - Praktische Übung	practical course	Core elective	3.0	2.5	180 Stunden

Qualification
Die Studierenden haben praktisches "hands-on" Wissen zum Design, zur Simulation, zur Herstellung und zum Test einer elektronischen Sensorschaltung erworben. Sie sind in der Lage elektronische Schaltungen zu entwickeln, diese in PSPICE zu simulieren, ein Schaltungslayout zu entwerfen und die Schaltung als Platine aufzubauen. Sie können eine Schaltung messtechnisch charakterisieren und können ihre Ergebnisse in Form einer Kurzpräsentation vorstellen.
Examination achievement
Practical examination assesment (creation of demonstrators or software)
Course achievement
Carrying out and participating in experiments in regular (weekly or bi-weekly) intervals

Usability
Compulsory elective module for students of the study program ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Microsystems Engineering, (PO 2021) Concentration Circuits and Systems ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of module	Number of module
Angewandte Sensorschaltungstechnik	11LE50MO-5268 ESE PO 2021
course	
Angewandte Sensorschaltungstechnik - Praktische Übung	
Event type	Number
practical course	11LE50prÜ-5268
Organizer	
Department of Microsystems Engineering, Design of Microsystems	

ECTS-Points	3.0
Workload	180 Stunden
Attendance	52 Stunden
Independent study	128 Stunden
Hours of week	2.5
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	german

Contents
Inhalte sind: • Entwurf des Schaltungskonzeptes für ein elektronisches Sensorinterface • PSPICE-Simulation des gefundenen Konzeptes, Optimierung der Schaltung • Platinenlayout • Platinenfertigung und -bestückung • Schaltungstest • Abschlußpräsentation
Examination achievement
siehe Modulebene
Course achievement
siehe Modulebene
Literature
Tietze, Schenk, Gamm, Halbleiter-Schaltungstechnik, 15. Auflage, 2016, Springer, Berlin, ISBN 978-3-662-48354-1. Schrüfer, Reindl, Zagar, Elektrische Messtechnik, 11. Auflage, 2014, Carl-Vieweg-Verlag, München, ISBN 978-3-446-44208-5.
Compulsory requirement

↑

Name of module	Number of module
Clean Room Laboratory for Engineers	11LE50MO-5804 ESE PO 2021
Responsible	
Prof. Dr. Claas Müller Prof. Dr.-Ing. Bastian Rapp	
Organizer	
Department of Microsystems Engineering, Process Technology	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	3.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Reinraumlaborkurs für Ingenieure / Clean Room Laboratory for Engineers	practical course	Core elective	3.0	3.0	

Qualification
The Goal of the Cleanroom Lab Course is to learn Cleanroom behaviour and processing and the creation of a high quality lab report.
Examination achievement
The grade of the lab course is derived from the average of 6 short tests with evaluation of the practical skill of the student by the supervisor (50%) and a lab report (50%).
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication **or** the Customized Course Selection: Courses offered by IMTEK ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Circuits and Systems/Materials and Fabrication

↑

Name of module	Number of module
Clean Room Laboratory for Engineers	11LE50MO-5804 ESE PO 2021
course	
Reinraumlaborkurs für Ingenieure / Clean Room Laboratory for Engineers	
Event type	Number
practical course	11LE50P-5804

ECTS-Points	3.0
Attendance	42 Stunden
Hours of week	3.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Cleanroom behavior and processing: 1. Wafer handling 2. Lithography sequence 3. Cleaning 4. Metal deposition (physical vapour deposition) 5. Profilometry 6. Lift-Off 7. Wafer backside processing 8. Electroplating 9. Characterization 10. Acquisition of relevant processing data and recording
Examination achievement
see module details
Course achievement
see module details
Literature
A script is provided and kept up-to-date. ■ C. Müller, MST Technologies and Processes, lecture ■ W. Menz, J. Mohr, O. Paul, Microsystems Technology, Wiley VCH ■ M. Madou, Fundamentals of Microfabrication, CRC Press ■ S. M. SZE, Physics of Semiconductor Devices, Wiley VCH ■ J. W. Dini, Electrodeposition, Noyes Publications
Compulsory requirement

↑

Name of module	**Number of module**
CMOS MEMS	11LE50MO-5271 ESE PO 2021
Responsible	
Prof. Dr. Oliver Paul	
Organizer	
Department of Microsystems Engineering, Microsystem Materials	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Knowledge of sensors, MEMS technologies, semiconductor physics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
CMOS-Integrierte Mikrosysteme / CMOS MEMS	lecture course	Core elective	6.0	2.0	180 hours
CMOS-Integrierte Mikrosysteme / CMOS MEMS	excercise course	Core elective		2.0	

Qualification
The commercially most successful microsystems to date have been based on silicon. Companies such as Bosch, Analog Devices, Texas Instruments, Sensirion, and other small and medium enterprises have built their success on this wise technological choice which allows to co-integrate microsystems compatible with silicon foundry services and commercial silicon technologies, in particular CMOS technologies. It will offer a healthy mix of technology, physical sensor principles and operating techniques, and will be enriched with examples that made it into the market and others that have remained scientific visions. In tune with the progress of the lecture material, home-work will be assigned, with the presentation and discussion of solutions by students during the course hours. In summary, the attendees will acquire a broad range of skills towards becoming productive engineers in the field of smart MEMS.

Examination achievement
Oral examination if there are 20 or fewer than 20 registered participants; written examination if there are more than 20 registered participants (minimum 60 and maximum 240 minutes). Details will be announced by the examiner in due time.
Course achievement
The "Studienleistung" consists of (1) the documented, successful attempt to solve more than 60% of the homework problems (as checked weekly); "60% of the homework problems" means the fraction of the overall number of homework problems proposed during the course, not of each homework problem separately; "successful" means that the solution could be presented by the student in front of the class; (2) the presentation of a representative number of solutions of homework problems in front of the class.
Usability
Compulsory elective module for students of the study program ■ M.Sc.Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of module	**Number of module**
CMOS MEMS	11LE50MO-5271 ESE PO 2021
course	
CMOS-Integrierte Mikrosysteme / CMOS MEMS	
Event type	Number
lecture course	11LE50V-5271
Organizer	
Department of Microsystems Engineering, Microsystem Materials	

ECTS-Points	6.0
Workload	180 hours
Attendance	60 hours
Independent study	120 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

1. Introduction
2. Basic technologies
3. Magnetic sensors
4. Stress sensors
5. Inertial sensors
6. Thermal sensors
7. Radiation sensors
8. Calibration

Examination achievement

see module details

Course achievement

see module details

Literature

A script will be handed out during the course.

Compulsory requirement

none

Recommended requirement

Knowledge of sensors, MEMS technologies, semiconductor physics

↑

Name of module	**Number of module**
CMOS MEMS	11LE50MO-5271 ESE PO 2021
course	
CMOS-Integrierte Mikrosysteme / CMOS MEMS	
Event type	Number
excercise course	11LE50Ü-5271
Organizer	
Department of Microsystems Engineering, Microsystem Materials	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The exercises will deepen the topics treated during the lecture. They will allow the students to rethink and rework the more theoretical aspects and apply them to realistic examples inspired from commercial products and more academic ideas. Thereby they will see their vision sharpened for the challenges awaiting them in their future professional work in the area of smart MEMS. Solution approaches to the homework problems will be presented weekly by the participants and discussed and elaborated upon with the group of colleagues under the guidance of the professor. This discursive, participative approach allows to learn more than by being presented with up-front oral or written solutions.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Data Converters	11LE50MO-5228 ESE PO 2021
Responsible	
Dr.-Ing. Matthias Keller	
Organizer	
Department of Microsystems Engineering, Microelectronics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 hours
Hours of week	4.0
Attendance	60 Stunden
Independent study	120 Stunden
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
Successful completion of the module 5070 - *Micro-electronics*. The limited number of 20 seats will be distributed among applying students based on the ranking of the module grade.
Recommended requirement
A good understanding of the knowledge imparted in the Micro-electronics module (5070) is crucial for a successful completion of this module.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Data Converters	lecture course	Core elective	3.0	2.0	90 Stunden
Data Converters - praktische Übung	excercise course	Core elective			

Qualification
Upon completion of the course, students will ■ have a thorough understanding of the fundamentals and mathematical depiction of A/D and D/A conversion ■ be in the position to select, for a given application, the right A/D or D/A converter among the state-of-the-art architectures

- know about performance limiting non-idealities of A/D and D/A converters and how to minimize or compensate their effect.

Examination achievement
Written exam at the end of the term with a duration of 2h on the content of the lecture.

Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentration Area Circuits and Systems

↑

Name of module	**Number of module**
Data Converters	11LE50MO-5228 ESE PO 2021
course	
Data Converters	
Event type	Number
lecture course	11LE50V-5228 PO 2021
Organizer	
Department of Microsystems Engineering, Microelectronics	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	28 Stunden
Independent study	62 Stinden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The focus of the course is put on two of the most demanding building blocks for mixed-signal circuit design: the analog-to-digital (A/D) and the digital-to-analog (D/A) converter. With steadily advancing digitization, these components have to satisfy the demands for ever increasing bandwidth, resolution, and optimum power efficiency. The course covers ■ the fundamentals of data conversion, i.e., filtering, sampling, and quantization for A/D conversion and digital-to-analog conversion, analog hold, and reconstruction for D/A conversion ■ the static and spectral metrics and nonidealities of A/D and D/A converters, e.g., gain/offset error, integral/differential nonlinearity, dynamic range, signal-to-noise(-and-distortion) ratio, etc. ■ an overview and discussion of state-of-the-art Nyquist D/A converters ■ an overview and discussion of state-of-the-art Nyquist and oversampled A/D converters.
Examination achievement
see Module details
Course achievement
see Module details
Compulsory requirement
Successful completion of the module 5070 - *Micro-electronics*. The limited number of 20 seats will be distributed among applying students based on the ranking of the module grade.

Recommended requirement
A good understanding of the knowledge imparted in the Micro-electronics module (5070) is crucial for a successful completion of this module.

Recommendation
■ **In case of comments and/or questions, please contact Dr.-Ing. M. Keller (mkeller@imtek.de).** ■ Application for participation is to be performed as soon as possible in HISinOne, even if the result of the exam *Mikroelektronik* / *Microelectronics* is not yet available. Students will get informed on their status, i.e., "accepted / waiting list / rejected", once the results of the exam are available. ■ No participation in the first lecture results in the cancellation of an accepted application. The seat will be given to the first student on the waiting list.

↑

Name of module	**Number of module**
Data Converters	11LE50MO-5228 ESE PO 2021
course	
Data Converters - praktische Übung	
Event type	Number
excercise course	11LE50prÜ-5228 PO 2021
Organizer	
Department of Microsystems Engineering, Microelectronics	

ECTS-Points	
Hours of week	
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
he practical exercise serves to deepen the concepts and circuits presented in the lecture. For this purpose, students are required to work on typical tasks relating to A/D and D/A converters such as * the design of an anti-aliasing filter * the analysis of differential and integral non-linearities of A/D and D/A transfer characteristics * the analysis and design of typical circuit blocks for A/D and D/A converters, e.g., track & hold circuit, latch * the analysis of common architectures for A/D converters and their non-idealities, e.g., Flash ADC, Pipeline ADC, Delta-Sigma ADC The solutions of the practical exercises will be presented and discussed.
Examination achievement
Course achievement
Compulsory requirement

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 ESE PO 2021
Responsible	
Prof. Dr. Oliver Amft	
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Embedded Computing Entrepreneurship (2ES)	lecture course	Core elective	6.0	1.0	180 Stunden / Hours
Embedded Computing Entrepreneurship (2ES)	seminar	Core elective		1.0	
Embedded Computing Entrepreneurship (2ES)	excercise course	Core elective		2.0	

Qualification
* Conceptualise and design embedded sensor systems along a specific application. * Develop and demonstrate key components of embedded sensor systems, including signal and pattern analysis and recognition algorithms. * Develop a basic market analysis and business plan. * Implement an agile development process.

Examination achievement
Presentation followed by an oral examination (10 minutes per person, total duration depends on group size)
Course achievement
Regular attendance of the course (seminar and exercise) according to §13 (2) of the General Examination Regulations for the Bachelor of Science/Master of Science, as otherwise the required group work and scientific discussion is not possible. Further elements of the course work are the creation of demonstrators or software as well as a written elaboration/protocol.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems **or** Concentration Biomedical Engineering **OR** Elective Courses in Computer Science ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering **and** Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 ESE PO 2021
course	
Embedded Computing Entrepreneurship (2ES)	
Event type	Number
lecture course	11LE13V-1404_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Attendance	16 Stunden / Hours
Independent study	116 Stunden / Hours
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The course combines technical and business-related lectures on embedded sensor systems with a practical system development project using agile development methods. Students will organise in groups and define together with their advisor(s) goals for the technical development, market analysis, etc. Student groups can enter their projects for an award of the VDE.
Examination achievement
see module details
Course achievement
see module details
Literature
Relevant literature will be provided during the lectures and consultations.
Compulsory requirement
None
Recommended requirement
Basic pattern recognition methods; basic programming skills

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 ESE PO 2021
course	
Embedded Computing Entrepreneurship (2ES)	
Event type	Number
seminar	11LE13S-1404_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	
Attendance	16 Stunden / Hours
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 ESE PO 2021
course	
Embedded Computing Entrepreneurship (2ES)	
Event type	Number
excercise course	11LE13Ü-1404_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	
Attendance	32 Stunden / Hours
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Energy Efficient Power Electronics	11LE50MO-9010 ESE PO 2021

Responsible
Prof. Dr. Oliver Ambacher Prof. Dr. Bruno Burger Prof. Dr. Rüdiger Quay
Organizer
Department of Sustainable Systems Engineering-VB Department of Sustainable Systems Engineering, Professorship in Energy-Efficient High-Frequency Electronics
Faculty
Faculty of Engineering

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge of electric and electronic circuits.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Energy Efficient Power Electronics	lecture course	Core elective	6.0	2.0	
Energy Efficient Power Electronics	excercise course	Core elective		2.0	

Qualification
Students will be enabled to understand materials, functioning and design of up to date power devices and circuits suitable for energy efficient power electronic systems. The lecture comprises three aspects: fundamental material and device concepts, power conversion-circuitry and power conversion systems. This includes high voltage AC-DC converter, solar energy photovoltaic converters and converters for engines or windcraft systems. The basic concepts of power conversion, of passive and active semiconductor devices, high-voltage operation, converter- and control concepts, device protection and aspects of system and power network theory are provided. The students will be competent to analyze, understand the fabrication, design of passive and active power devices such as MOSFETs, Insulated Gate Bipolar IGBTs, Junction FETs (JFET),

diodes, and thyristors. Students will be able to design and analyze feedback control systems based on state space control technologies and apply them to power devices.
Examination achievement
Written supervised exam, duration: 120 min. The final written exam covers the content of the lecture (70%) and exercise (30%). Important info for exchange students: the exam must be taken at the official examination date.
Course achievement
None
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc. in Sustainable Systems Engineering (PO 2021) in the technical concentration area *Energy Systems Engineering*

↑

Name of module	Number of module
Energy Efficient Power Electronics	11LE50MO-9010 ESE PO 2021
course	
Energy Efficient Power Electronics	
Event type	Number
lecture course	11LE68V-9010 PO 2021

ECTS-Points	6.0
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

The lecture deals with the materials, topologies and concepts of power devices and circuits. It comprises three parts: fundamental material and device concepts, power conversion-concepts and actual power conversion systems. 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. Typical applications include DC-DC conversion for server systems, photovoltaic power conversion, application to microscopic power converters, and high-voltage windcraft systems.

Examination achievement

See module

Course achievement

See module

Literature

- 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

Compulsory requirement

None

Recommended requirement

Basic knowledge of electric and electronic circuits.

Teaching method

Lecture + exercise

↑

Name of module	**Number of module**
Energy Efficient Power Electronics	11LE50MO-9010 ESE PO 2021
course	
Energy Efficient Power Electronics	
Event type	Number
excercise course	11LE68Ü-9010 PO 2021

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
In the exercises, the contents of the lecture will be illustrated and deepened by means of examples. The students learn in their home studies on the basis of exercise sheets, e.g. to calculate the electrical properties of power electronic devices and circuits, as well as to estimate the lifetime, ruggedness, and energy efficiency of power electronic systems. During the exercises the solutions of the tasks and problems are presented by tutors and explained in detail.
Examination achievement
See module
Course achievement
See module
Compulsory requirement

↑

Name of module	**Number of module**
Energy harvesting	11LE50MO-5703 ESE PO 2021
Responsible	
Prof. Dr. Peter Woias	
Organizer	
Department of Microsystems Engineering, Design of Microsystems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Energiegewinnung / Energy harvesting - Lecture	lecture course	Core elective	6.0	2.0	180 hours
Energiegewinnung / Energy harvesting - Exercises	excercise course	Core elective		2.0	

Qualification
The students know the basic principles of (micro) energy harvesting. They know several energy conversion techniques, energy storage concepts and power management strategies in detail. The students are able to estimate the energy generation of different harvesting techniques and to work on the design of energy autonomous embedded systems. The importance of the system-level design in these systems is, in general, a central objective in this class.

Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes) Wenn die Teilnehmerzahl gering ist (< 20), kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert. | If the number of participants is small (< 20), an oral examination may be held instead. The students will be informed in good time.
Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of module	**Number of module**
Energy harvesting	11LE50MO-5703 ESE PO 2021
course	
Energiegewinnung / Energy harvesting - Lecture	
Event type	Number
lecture course	11LE50V-5703
Organizer	
Department of Microsystems Engineering, Design of Microsystems	

ECTS-Points	6.0
Workload	180 hours
Attendance	52 hours
Independent study	128 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

- Harmonical Oscillator (with bending beams)
- Piezoelectric Energy Harvesters
- Electrodynamic Energy Harvesters
- Electrostatic Energy Harvesters
- Non-Resonant Generators
- Thermoelectric Generators & Processes
- Thermomechanic Generators
- Capacitive Storages and Accumulators
- Step-up Converters and Advanced Step-up Converter Design
- Energy Harvesting Applications

Examination achievement

See module details

Course achievement

See module details

Literature

- S. Roundy et al, "Energy Scavenging for Wireless Sensor Networks: with Special Focus on Vibrations", 2004, Kluver Academic Publishers Group, The Netherlands
- D. Priya, S. Shank, "Energy Harvesting Technologies", 2009, Springer Science+Business Media LLC, New York

Compulsory requirement

None

Recommended requirement
None

↑

Name of module	**Number of module**
Energy harvesting	11LE50MO-5703 ESE PO 2021
course	
Energiegewinnung / Energy harvesting - Exercises	
Event type	Number
excercise course	11LE50Ü-5703
Organizer	
Department of Microsystems Engineering, Design of Microsystems	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
See module details
Course achievement
See module details
Compulsory requirement

↑

Name of module	**Number of module**
Flugregelung Praktikum / Flight Control Laboratory	11LE50MO-5222 PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
None
Recommended requirement
The lab course includes topics as part of the HIGHWIND project (Simulation, Optimimization and Control of High-Altitude Wind Power Generators). As the HIGHWIND project offers a large variety of project topics, students may be assigned topics meeting best their interests and academic background. Prior studies of “Modelling and System Identification” and/or “Optimal Control and Estimation” are recommended.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Flugregelung Praktikum / Flight Control Laboratory	practical course	Core elective	6.0	4.0	180 hours

Qualification
The students will be able to use a theoretical background for real applications in a scientific project. They will be able to find creative solutions to problems and to perform hands-on testing/verification of soft- and hardware. Furthermore, they will have gained experience of working in an international team.
Examination achievement
Project work: 1. A working project result 2. project documentation and oral presentation
Course achievement
none

Grading
The final module grade is determined from an average of the grades of the project documentation and the presentation.

Examination weight
■ 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 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 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.

Usability
Elective Module for students of the study program ■ Bachelor of Science in Embedded Systems Engineering ■ Master of Science in Informatik - Application Field Microsystems Engineering ■ Master of Science in Embedded Systems Engineering - Design and simulation - Circuits and systems - Sensors and actuators - Personal Profile ■ Master of Science in Mikrosystemtechnik - - Design and simulation - Circuits and systems - Sensors and actuators - Personal Profile ■ Master of Science in Microsystems Engineering - Design and simulation - Circuits and systems - Sensors and actuators - Personal Profile ■ Master of Science in Sustainable Systems Engineering - Informationstechnik / Information Processing Technologies

↑

Name of module	**Number of module**
Flugregelung Praktikum / Flight Control Laboratory	11LE50MO-5222 PO 2021
course	
Flugregelung Praktikum / Flight Control Laboratory	
Event type	Number
practical course	11LE50P-5222
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	6.0
Workload	180 hours
Attendance	84 hours
Independent study	96 hours
Hours of week	4.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

In order to register to this course please write a mail to us (moritz.diehl@imtek.uni-freiburg.de, tommaso.sartor@imtek.uni-freiburg.de) including:

- Short motivation statements,
- A brief summary of your relevant achievements in the field of engineering, exams, university projects, personal projects.
- If you already have an idea for a project on which you are interested to work on feel free to add that.

Focus of the lab course is making a real flight control system work for small aerial vehicles equipped with a variety of sensing and actuation equipment. These vehicles, airplanes, quadrotors or helicopters, might be remote controlled or autonomous. They might flight freely or be connected to the ground via a tether. The course will be accompanied by weekly meetings with one or more team members working on complementary projects addressing the same real world control problem. In the last two to three weeks of the lab course, when the main project aims are achieved, the participants will start to work on a short report for documentation and give a final oral presentation to share their findings with all team members.

Examination achievement

see module details

Course achievement

None

Compulsory requirement

None

Recommended requirement
The lab course includes topics as part of the HIGHWIND project (Simulation, Optimimization and Control of High-Altitude Wind Power Generators). As the HIGHWIND project offers a large variety of project topics, students may be assigned topics meeting best their interests and academic background. Prior studies of “Modelling and System Identification” and/or “Optimal Control and Estimation” are recommended.

↑

Name of module	**Number of module**
Power Electronics for Photovoltaics and Wind Energy	11LE50MO-4207 PO 2021
Responsible	
Prof. Dr. Anke Weidlich	
Organizer	
Department of Sustainable Systems Engineering-VB	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 hours
Hours of week	2.0
Attendance	28 Stunden
Independent study	62 Stunden
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
Power Electronics Circuits and Devices (elective module)
Recommended requirement
Knowledge in Electrical Components (Semiconductors, Inductors, Capacitors)

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Power Electronics for the Energy Transition - Vorlesung	lecture course	Core elective	3.0	2.0	90 h

Qualification
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.
Examination achievement
Written or oral examination
Course achievement
None

Grading
The module grade is calculated from the result of the final examination.
Examination weight
■ 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.
Usability
Elective Module for students of the study program ■ Master of Science in Sustainable Systems Engineering - Energiesysteme / Energy Systems

↑

Name of module	Number of module
Power Electronics for Photovoltaics and Wind Energy	11LE50MO-4207 PO 2021
course	
Power Electronics for the Energy Transition - Vorlesung	
Event type	Number
lecture course	11LE68V-4207 PO 2021
Organizer	
Department of Sustainable Systems Engineering-VB	

ECTS-Points	3.0
Workload	90 h
Attendance	30 h
Independent study	60 h
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english
Group size	40

Contents

- Renewable Energy Generation, Transformation Scenarios, Need for Power Electronics
- New Semiconductors Devices
- Single-phase and three-phase PV inverters
- Battery storage integration
- PV systems aspects, MPP-Tracking
- Maximizers, micro-inverters, PV power plant concepts
- Wind energy converters
- Grid-integration and power system stability with grid-forming converters
- Grid codes and inverter testing
- Sustainability of power electronics

Examination achievement

See module

Course achievement

See module

Literature

R. W. Erickson and D. Maksimović, Fundamentals of Power Electronics, 3rd ed. 2020 Edition. Cham: Springer, 2020.

R. Teodorescu, M. Liserre, and P. Rodríguez, Grid Converters for Photovoltaic and Wind Power Systems, 1st ed. Chichester: Wiley-
IEEE Press, 2011.

P. S. Kundur and O. P. Malik, Power System Stability and Control, Second Edition. McGraw- Hill Education, 2022. J. Böcker, “Leistungselektronik / Power Electronics,” Universität Paderborn, Paderborn, Skript zur Vorlesung / Lecture Notes, Mar. 2020. [Online]. Available: https://ei.uni-paderborn.de/fileadmin- eim/elektrotechnik/fg/lea/Lehre/LE/Dokumente/ Skript_LE_2020-03-24.pdf Design of Switch Mode Power Supplies – Online Calculation Tool http://schmidt-walter- schaltnetzteile.de/smps_e/smps_e.html Energy Charts https://energy-charts.info/ Fraunhofer ISE Study 2021: Paths to a Climate-Neutral Energy System https://www.ise.fraunhofer.de/en/publications/studies/paths-to-a-climate-neutral-energy-system.html
Compulsory requirement
None
Recommended requirement
Knowledge in Electrical Components (Semiconductors, Inductors, Capacitors). The lecture “Energy-efficient power electronics” is strongly recommended as a prerequisite.
Teaching method
Lecture

↑

Name of module	**Number of module**
Memory Device Technology	11LE50MO-5726 PO 2021
Responsible	
JProf. Dr. Alwin Stefan Daus	
Organizer	
Department of Microsystems Engineering, Professorship in Sensors	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
None
Recommended requirement
Basic knowledge on semiconductor physics and semiconductor devices. Having completed the module micro-electronics before taking this module is recommended.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Memory Device Technology	lecture course	Core elective	6.0	2.0	180 Stunden / hours
Memory Device Technology	excercise course	Core elective		2.0	

Qualification

After completion of the module, -

- the students know various classical memory and storage device types, technologies and working principles.
- the students can explain the working principle of various emerging memory device types.
- the students know about the different memory performance parameters, how they are measured and how different memory device technologies compare in those metrics
- the students know how the physical integration and realization of different memory device types is realized
- the students can explain limitations of different memory device technologies
- the students can explain how the basic material properties of each memory device type enable and affect the memory behavior

▪ the students can explain how emerging memristive devices are beneficial to enable in-memory computing and neuromorphic hardware
Examination achievement
Prüfungsgespräch / oral examination
Course achievement
Referat, Vortrag / Presentation

↑

Name of module	**Number of module**
Memory Device Technology	11LE50MO-5726 PO 2021
course	
Memory Device Technology	
Event type	Number
lecture course	11LE50V-5726 PO 2021
Organizer	
Department of Microsystems Engineering, Professorship in Sensors	

ECTS-Points	6.0
Workload	180 Stunden / hours
Attendance	52 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	2
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
This course provides an overview on different memory device technologies. The classical memory and storage device types include static random-access memory, dynamic random-access memory, flash, hard disk drive and tape storage. The emerging memory device types include magnetic memory, phase-change memory, resistive random-access memory, ferroelectric memory and electrochemical memory. Along with the basic device concepts, the underlying physics and material properties enabling the memory functionality are explained. The various important performance parameters for memory devices are discussed. New application directions such as in-memory computing and neuromorphic computing hardware are introduced and the requirements for memory devices to be used in such scenarios are discussed.
Examination achievement
Course achievement
Presentation on implemented memory device model and functionality in circuit
Literature
1. Daniele Ielmini, Rainer Waser, "Resistive Switching: From Fundamentals of Nanoionic Redox Processes to Memristive Device Applications", 2016 Wiley-VCH, DOI: 10.1002/9783527680870 2. Jennifer Rupp, Daniele Ielmini, Ilia Valov, "Resistive Switching: Oxide Materials, Mechanisms, Devices and Operations", Springer, DOI: 10.1007/978-3-030-42424-4 3. Andrea Redaelli, Fabio Pellizzer, "Semiconductor Memories and Systems", Elsevier, ISBN 9780128209462
Compulsory requirement
None

Recommended requirement
Basic knowledge on semiconductor physics and semiconductor devices. Having completed the module micro-electronics before taking this module is recommended.

↑

Name of module	**Number of module**
Memory Device Technology	11LE50MO-5726 PO 2021
course	
Memory Device Technology	
Event type	Number
excercise course	11LE50Ü-5726 PO 2021

ECTS-Points	
Hours of week	2.0
Recommended semester	2
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The exercise will recap and deepen on most important aspects of the lecture. In addition, the students will learn how to develop and incorporate emerging memory device models in a compact modeling environment. They will then simulate the behavior of such devices in simple circuits.
Examination achievement
Course achievement
Compulsory requirement

↑

Name of module	**Number of module**
Mixed-Signal CMOS Circuit Design	11LE50MO-5208 ESE PO 2021
Responsible	
Dr.-Ing. Matthias Keller Prof. Dr.-Ing. Matthias Kuhl	
Organizer	
Department of Microsystems Engineering, Microelectronics	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
This course is a continuation of module 5202 Analog CMOS Circuit Design, since the layout for the microelectronic circuit designed at transistor level in module 5202 is to be designed in module 5208. Therefore, successful completion of the module Analog CMOS Circuit Design (offered in the summer term) is mandatory for participation in this module.
Recommended requirement
see above

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Entwurf von CMOS Mixed-Signal Schaltungen / Mixed-Signal CMOS Circuit Design - Laboratory	practical course	Core elective	3.0	2.0	90 hours

Qualification
This practical exercise deals with the layout of the two-stage amplifier with RC compensation which was designed on transistor level in the practical exercise Analog CMOS Circuit Design. It thus represents the second major task in the chain of the design flow of an integrated circuit consisting of “Design on transistor level”, “Layout” and “Fabrication and Verification”. Students are able to apply basic layout techniques for transistors, resistors, capacitors, and metal layers using industry standard layout und simulation software. They can employ techniques for the reduction of mismatch such as unit elements, multi-finger transistors, interdigitation, common centroid, or guard rings. At the end of the course, the students are able to compare the results of simulations on transistor and layout level so that they can extract the influence of parasitic resistors and capacitors on the overall performance of the amplifier. At the same time, they learn to optimize the layout with respect to these non-idealities.

Examination achievement
■ 5x graded reports (10% of the final grade each) ■ 1x graded presentation (50% of the final grade)
Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of module	**Number of module**
Mixed-Signal CMOS Circuit Design	11LE50MO-5208 ESE PO 2021
course	
Entwurf von CMOS Mixed-Signal Schaltungen / Mixed-Signal CMOS Circuit Design - Laboratory	
Event type	Number
practical course	11LE50P-5208
Organizer	
Department of Microsystems Engineering, Microelectronics	

ECTS-Points	3.0
Workload	90 hours
Attendance	30 hours
Independent study	60 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

- Layout of analog CMOS integrated circuits (basics)
- Introduction of the layout tool Cadence VirtuosoXL (industry standard)

Examination achievement

see module details

Course achievement

none

Literature

- Script
- R. J. Baker, CMOS Circuit Design, Layout, and Simulation, IEEE Press Series, 2008
- A. Hastings, The Art of Analog Layout, Pearson Education 2005

Compulsory requirement

This course is a continuation of module 5202 Analog CMOS Circuit Design, since the layout for the microelectronic circuit designed at transistor level in module 5202 is to be designed in module 5208. Therefore, successful completion of the module Analog CMOS Circuit Design (offered in the summer term) is mandatory for participation in this module.

Recommendation

In case of comments and/or questions regarding the practical exercise "Mixed Signal CMOS Circuit Design", please contact Dr.-Ing. M. Keller (mkeller@tf.uni-freiburg.de).

↑

Name of module	**Number of module**
Mikroaktorik für Mikrosystemtechniker	11LE50MO-5707 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Ulrike Wallrabe	
Organizer	
Department of Microsystems Engineering, Microactuators	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Basiswissen in Physik, Elektronik, Mechanik und MST Technologien | Basic knowledge in physics, electronics, mechanics and MSE technologies

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Micro-actuators für Mikrosystemtechniker - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden
Micro-actuators für Mikrosystemtechniker - Exercises	excercise course	Core elective		2.0	

Qualification
Das Modul baut auf die Inhalte des Moduls "MST Bauelemente" aus dem Bachelorstudiengang Mikrosystemtechnik auf. Die Studierenden kennen nach Abschluss dieses Moduls die in der Mikrosystemtechnik am meisten verbreiteten Aktorprinzipien. Dies umfasst die zugehörigen physikalischen Grundkenntnisse und Grundgleichungen, die Umsetzung der Prinzipien in der Mikrotechnik, die für das jeweilige Prinzip notwendigen spezifischen Prozesse und typische Anwendungen. Weiterhin haben sie die Fähigkeit zur kritischen Auseinandersetzung mit den diversen Prinzipien. Die Studierenden kennen die Vor- und Nachteile der einzelnen Prinzipien und sind dadurch in der Lage, für eine neuartige zu entwickelnden Anwendung das richtige Prinzip auszuwählen. Sie berücksichtigen dabei typische Kenngrößen wie Kraft und Stellweg, aber auch Prozessaufwand, Integrierbarkeit und Zuverlässigkeit.

| The module builds on the contents of the module "MST Devices" from the bachelor's degree program in Embedded Systems Engineering or the module "MSE Technologies and Processes" form this master's program. After completing this module, students will be familiar with the actuator principles most commonly used in microsystems technology. This includes the associated basic physical knowledge and basic equations, the implementation of the principles in microtechnology, the specific processes required for the respective principle and typical applications. Furthermore, they have the ability to critically examine the diverse principles. The students know the advantages and disadvantages of the individual principles and are thus able to select the correct principle for a novel application to be developed. They take into account typical parameters such as force and travel, but also process effort, integrability and reliability.
Examination achievement
Klausur (120 Minuten) | written exam (120 minutes)
Course achievement
keine | none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of module	Number of module
Mikroaktorik für Mikrosystemtechniker	11LE50MO-5707 ESE PO 2021
course	
Micro-actuators für Mikrosystemtechniker - Lecture	
Event type	Number
lecture course	11LE50V-5707
Organizer	
Department of Microsystems Engineering, Microactuators	

ECTS-Points	6.0
Workload	180 Stunden
Attendance	60 Stunden
Independent study	120 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	german

Contents
Mikroaktoren sind integrierte Bestandteile in vielen Mikrosystemen, z.B. in Mikrooptik, Mikrofluidik oder Sensorik und basieren auf verschiedensten physikalischen Funktionsprinzipien. Daher bedarf es in der Regel individuellen, maßgeschneiderten technischen Lösungen. In der Vorlesung wird dem zweigleisig Rechnung getragen: Theorieteil: Die Studierenden werden in die Lage versetzt, geeignete Aktorprinzipien auszuwählen und neuartige maßgeschneiderte Mikroaktoren zu entwickeln. Hierfür lernen sie die Kräfte, Stellwege und das dynamische Verhalten von Mikroaktoren ausgehend vom physikalischen Funktionsprinzip und dem geometrischen Aufbau schnell und effizient analytisch herzuleiten. Zudem lernen sie die relevanten funktionellen Materialien kennen. Darauf aufbauend entwickeln die Studierenden die Eigenschaften und Funktion der gängigsten Aktorprinzipien. Daher können sie schnell die Realisierbarkeit und Dimensionierung von Mikroaktoren abschätzen und diese dann im Detail weiter entwickeln. Anwendungsteil: Dieser Teil wird jährlich überarbeitet und um aktuelle Beispiele ergänzt. Es werden Anwendungsbeispiele aus unterschiedlichen Bereichen sowie deren Umsetzung und deren spezifischen Prozesse vorgestellt. Basierend auf dem zuvor vermittelten theoretischen Wissen, können die Studierenden die Vor- und Nachteile der verwendeten Materialien und Prozesse verschiedener Aktoren kritisch zu beleuchten und damit intuitiv eine Vorauswahl geeigneter Aktorprinzipien zu treffen. Grundlagenthemenn: A. Grundlagen, Motivation: Euler-Lagrange Gleichungen; Prinzip der virtuellen Arbeit; woher kommt es. Wiederholung: Mechanisches Verhalten von Federn und Balken B. Elektrostatische Aktoren: Herleitung der Kraft von virtueller Arbeit, pull-in Effekt C. Electrowetting, dielektrische elektroaktive Polymere, Elastizität/thermische Dehnung, Piezoeffekt/Piezokeramiken D. Verstärkungsmechanismen: Biegewandler, Knickaktoren E. Elektromagnetismus: Herleitung, Maxwellgleichungen, unterschiedliche Arten von magnetischen Kräften, magnetische Materialien

F. Magnetischer Kreis, Reluktanzaktoren H. Shape Memory Effekt und Superleastizität I. Einführung in die Strömngslehre Anwendungsthemen 1. Elektrostatik, hauptsächlich Electrowetting für Optical MEMS und Lab on Chip 2. Elektromagnetik, hauptsächlich Reluktanzaktoren für Optical MEMS 3. Piezoelektrische Aktoren für adaptive Optik 4. Thermische Aktoren und Shape Memory Anwendungen aus der Medizintechnik 5. Highlights aus aktueller Forschung: „Best of IEEE MEMS“
Examination achievement
siehe Modulebene
Course achievement
keine
Literature
Begleitend zur Vorlesung wird ein Folien-Skriptum zur Verfügung gestellt und regelmäßig aktualisiert.
Compulsory requirement
keine
Recommended requirement
Basiswissen in Physik, Elektronik, Mechanik und MST Technologien

↑

Name of module	Number of module
Mikroaktorik für Mikrosystemtechniker	11LE50MO-5707 ESE PO 2021
course	
Micro-actuators für Mikrosystemtechniker - Exercises	
Event type	Number
excercise course	11LE50Ü-5707
Organizer	
Department of Microsystems Engineering, Microactuators	

ECTS-Points	
Attendance	32 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	german

Contents
Die im Theorieteil erlernten Inhalte werden auf einfache Anwendungsbeispiele übertragen und geeignete Aktorgeometrien berechnet und dimensioniert. Es gibt verschiedene Übungen, z.B. zu mehrstufigem Kammaktor, electrowetting Linse, Reluktanz, FEM Simulation, Poiseuille-Strömung sowie zu kombinierten Problemen.
Examination achievement
Siehe Vorlesung
Course achievement
keine
Compulsory requirement
keine
Recommended requirement
Basiswissen in Physik, Elektronik, Mechanik und MST Technologien

↑

Name of module	**Number of module**
Micro-actuators	11LE50MO-7300 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Ulrike Wallrabe	
Organizer	
Department of Microsystems Engineering, Microactuators	
Faculty	
Department of Microsystems Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge in Physics, Electrical Engineering, Engineering Mechanics and Microsystems Technologies and Processes

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Micro-actuators	lecture course	Core elective	6.0	2.0	180 hours
Micro-actuators	excercise course	Core elective		2.0	

Qualification
The students should get acquainted with the most common actuation principles. This includes the basic knowledge of the physical principles and equations, the integration into micro technology and the specific fabrication processes and applications. Furthermore the critical examination of the different actuation principles is also encouraged. After the course, the students should be familiar with the advantages and disadvantages of the different actuation principles and be able to choose the right mechanism for a novel application with respect to the typical parameters like force and displacement, but also complexity of the fabrication process, ease of integration and reliability.

Examination achievement
written examination with a duration of 120 minutes If the number of participants is small (< 20), an oral examination of 45 minutes may be held instead. The students will be informed in good time.
Course achievement
Each student has to present one exercise solution on the black board. This is not marked, but counted as "Studienleistung" (coursework).
Recommendation
It is strongly recommended to pass the coursework before taking the exam.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), in Advanced Microsystems ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of module	Number of module
Micro-actuators	11LE50MO-7300 ESE PO 2021
course	
Micro-actuators	
Event type	Number
lecture course	11LE50V-7300
Organizer	
Department of Microsystems Engineering, Microactuators	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

The lecture starts off with a short recapitulation of the principles of mechanical engineering that are especially relevant for actuators: Newtonian mechanics, force, impulse, energy, torque, friction, forced oscillation with and without damping, resonance, waves and the wave equation.
Then the actuation principles mentioned below are worked through. For each principle the specific basic physical equations are presented. Afterwards the integration of that principle into micro technology and typical examples of scientific literature or commercial products are shown. The actuation principles are:

Electrostatics
First the plate capacitor with one direction of motion perpendicular to the plate is introduced. The special pull-in characteristic is derived.
Then the direction of motion parallel to the plate is covered, which resembles a comb actuator leading to a linear or tilting motion, depending on the design of the actuator.
Lastly rotating motors are covered.

Electromagnetics
The easiest actuator uses the Lorentz force. Here the possibility of using bi-stable and snap-action mechanisms arises.
After the Lorentz-force actuators, magnetic reluctance actuators with the challenge of coil winding, the use of eddy currents and the assembly of small electromagnetic motors are discussed.

Piezoelectricity
Piezoelectric behavior is first introduced using the example of SiO_2, followed by PZT. Since piezo actuators are commonly obtained as modular parts, typical commercially available designs are presented and standard applications are discussed.
As a special case, surface waves excited within a piezoelectric substrate are shown. The applications of these devices include RFID-tags and friction-controlled rotary motors.

Shape Memory Metals
The special behavior of NiTi is introduced concerning the aspect of shape memory and super elasticity. The method of shape settings is illustrated, followed by numerous examples, especially super elasticity used in medical engineering.

Polymer actuators
Less known for hydroactive polymers, polymer actuators are a common synonym for dielectric elastomer actuators. The importance of the choice of the actuator material and the influence of the material on percolation and the dielectric constant is exemplified. Typical challenges and applications for polymer actuators are identified.

Hydrodynamic
After a theoretical introduction to fluid dynamics, two types of turbines are presented: Firstly actual micro turbines, where the challenge of friction can be exemplified and secondly turbines in the millimeter range for surgical applications.
This is followed by active multi-pathway valves and a short overview over micro pumps.

Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
none
Recommended requirement
Basic knowledge in Physics, Electrical Engineering, Engineering Mechanics and Microsystems Technologies and Processes

↑

Name of module	**Number of module**
Micro-actuators	11LE50MO-7300 ESE PO 2021
course	
Micro-actuators	
Event type	Number
excercise course	11LE50Ü-7300
Organizer	
Department of Microsystems Engineering, Microactuators	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
Micro Acoustical Transducers	11LE50MO-5257 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Alfons Dehe	
Organizer	
Department of Microsystems Engineering, Professorship in Smart Systems Integration	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	each term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Mikroakustische Wandler / Micro Acoustical Transducers	lecture course	Core elective	3.0	2.0	90 hours

Qualification
This lecture introduces into the fundamentals of air born sound propagation and effects in conjunction with the interaction of MEMS systems. You familiarize with the principles of sound transducers such as microphones and microspeakers as well as their design, key performance parameters and fabrication. Silicon microphones are the most widely spread MEMS systems worldwide and keep growing in volume as well as applications. As a role model for an integrated system, the Si microphone development will open insight into the needs and constraints of consumer product development.
Examination achievement
Oral examination (20 minutes)
Course achievement
None

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of module	**Number of module**
Micro Acoustical Transducers	11LE50MO-5257 ESE PO 2021
course	
Mikroakustische Wandler / Micro Acoustical Transducers	
Event type	Number
lecture course	11LE50V-5257
Organizer	
Department of Microsystems Engineering, Professorship in Smart Systems Integration	

ECTS-Points	3.0
Workload	90 hours
Attendance	28 hours
Independent study	62 hours
Hours of week	2.0
Recommended semester	
Frequency	each term
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
Lectures on: 1. Acoustic field and effects 2. General acoustical transducer principles 3. Modeling in acoustical, mechanical and electrical domain 4. Example of capacitive transducer and identification of key performance parameters 5. Different MEMS microphone concepts and their pros and cons 6. MEMS fabrication 7. Aspects of assembly and packaging 8. Acoustical measurement techniques 9. From microphone to microspeaker 10. Future trends 11. Applications of MEMS acoustical transducers
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement
None
Recommended requirement
None

Teaching method
Will be taught in English if there is at least one international participant.

↑

Name of module	**Number of module**
Microcontroller Techniques - Praktikum	11LE50MO-760MScPr ESE PO 2021
Responsible	
Prof. Dr. Stefan Rupitsch	
Organizer	
Department of Microsystems Engineering, Professorship in Electrical Instrumentation and Embedded Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge of electronics, binary arithmetics, C programming and the structure of microcontrollers

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Mikrocomputertechnik / Microcomtroller Techniques - Laboratory	practical course	Core elective	3.0	2.0	90 hours

Qualification

Students have obtained practical knowledge in using microcontrollers. By means of Texas Instrument's MSP430 microcontroller as an example, the students have learned the basics of low-level C programming and the usage of the most important peripheral modules such as I/Os, analog-to-digital converters, timers, etc. Finally, the students will be able to use microcontroller hard- and software concepts in their own projects.

Examination achievement

The exam consists in the submission of 9 practically-oriented exercise sheets throughout the semester. The grade of each exercise sheet is 1/9 of the final module grade.

Explanation: This lab course is a hands-on course with an emphasis on the continuous development of microprocessor programming. Since these development processes represent the essential course work, their results will be collected and evaluated throughout the semester. In case of failure to hand in one of these deliverables due to illness, an extention of the deadline will be granted.

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of module	**Number of module**
Microcontroller Techniques - Praktikum	11LE50MO-760MScPr ESE PO 2021
course	
Mikrocomputertechnik / Microcomtroller Techniques - Laboratory	
Event type	Number
practical course	11LE50P-760MScPr
Organizer	
Faculty of Engineering Department of Microsystems Engineering, Professorship in Electrical Instrumentation and Embedded Systems	

ECTS-Points	3.0
Workload	90 hours
Attendance	30 hours
Independent study	60 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Based on a custom hardware learning platform being developed by the Laboratory for Electrical Instrumentation and using a TI MSP430G2553 microcontroller, the students will gain insight into the following topics:
• Low-level C programming
• Hard- and software debugging
• Using microcontroller inputs and outputs
• Using internal and external peripheral hardware
• Using communication interfaces
The students will autonomously perform the practical exercises at home. This is facilitated by a hardware kit containing the microcontroller board as well as required equipment, which can be obtained from the library of the technical faculty (the kit is labeled “µ-Controller-Praktikum I”). The support is given by the tutors on the ILIAS online platform, laboratory lessons will only be given as required. Mandatory events are two short colloquiums (students have to explain their exercise solution to a tutor twice, the deadlines and appointments will be made on demand).

Examination achievement

see module details

Course achievement

none

Literature

MSP430 Microcontroller Basics: John H. Davies
Electronic Circuits - Handbook for Design and Application: Tietze, Schenk, Gamm

Compulsory requirement
None
Recommended requirement
Basic knowledge of electronics, binary arithmetics, C programming and the structure of microcontrollers.
Recommendation
The successful completion of this module is mandatory for the participation in the module “Advanced Laboratory in Microcontroller”.

↑

Name of module	**Number of module**
Model Predictive Control and Reinforcement Learning	11LE50MO-5720 ESE PO 2021
Responsible	
Prof. Dr. Joschka Bödecker Prof. Dr. Moritz Diehl	
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization Department of Computer Science, Professorship in Neurorobotics	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Prior knowledge in Systems and Control, State Space Control Systems, Numerical Optimization, Numerical Optimal Control, Reinforcement Learning and Machine Learning is an advantage.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Model Predictive Control and Reinforcement Learning	lecture course	Core elective	3.0	1.0	90 h
Model Predictive Control and Reinforcement Learning	excercise course	Core elective		1.0	

Qualification
Participants understand the concepts of model predictive control (MPC) and reinforcement learning (RL) as well the similarities and differences between the two approaches. They are able to apply the methods to practical optimal control problems from science and engineering.

Examination achievement
Towards the end of the course, participants will work on application projects which apply at least one of the MPC and RL methods to self-chosen application problems from any area of science or engineering. The results of the projects, that can be performed in teams, will be presented in a public presentation on the last day of the course and a short report to be submitted two weeks after the course. The final course grade (Prüfungsleistung) is based on the final project report.
Course achievement
A mandatory requirement for passing the coursework (Studienleistung) is based on the written microexam at the end of the course.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc. Informatik / Computer Science (2020) in in Spezialvorlesung | Specialization Courses

↑

Name of module	**Number of module**
Model Predictive Control and Reinforcement Learning	11LE50MO-5720 ESE PO 2021
course	
Model Predictive Control and Reinforcement Learning	
Event type	Number
lecture course	11LE50V-5720_PO20091
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization Department of Computer Science, Professorship in Neurorobotics	

ECTS-Points	3.0
Workload	90 h
Attendance	26
Independent study	64
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Lectures cover: optimal control problem formulations (constrained, infinite horizon, discrete time, stochastic, robust), dynamic programming, model predictive control formulations and stability, reinforcement learning formulations, MPC algorithms, RL algorithms, similarities and differences between MPC and RL

Towards the end of the course, participants will work on application projects which apply at least one of the MPC and RL methods to self-chosen application problems from any area of science or engineering. The results of the projects, that can be performed in teams, will be presented in a public presentation on the last day of the course and a short report to be submitted two weeks after the course. The report will determine the final grade of the course.

Examination achievement

see module details

Course achievement

see module details

Literature

“Reinforcement Learning: An Introduction” by Richard S. Sutton and Andrew G. Barto
“Model Predictive Control: Theory, Computation, and Design” by James B. Rawlings, David Q. Mayne, and Moritz M. Diehl
“Optimal Control and Reinforcement Learning" by Dimitri Bertsekas

Compulsory requirement

None

Recommended requirement
Prior Knowledge in Systems and Control, State Space Control Systems, Numerical Optimization, Numerical Optimal Control, Reinforcement Learning and Machine Learning is an advantage.

↑

Name of module	**Number of module**
Model Predictive Control and Reinforcement Learning	11LE50MO-5720 ESE PO 2021
course	
Model Predictive Control and Reinforcement Learning	
Event type	Number
excercise course	11LE50Ü-5720_PO20091
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization Department of Computer Science, Professorship in Neurorobotics	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Computer exercises based on MATLAB, Octave or Python will accompany the lectures in order to gain hands-on-knowledge on method of MPC and RL
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Model Predictive Control for Renewable Energy Systems	11LE50MO-5723 PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden / hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Prior knowledge in the following fields is an advantage: - Mathematics 1 and 2 for engineers (or basic linear algebra and calculus courses) - Linear systems theory - State space control - Numerical optimization - Modeling and system identification (MSI)

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Model Predictive Control for Renewable Energy Systems	lecture course	Core elective	3.0	2.0	90 Stunden

Qualification
The students will be familiar with the control-oriented modelling of different renewable energy systems. They can analyze and formulate linear and nonlinear model predictive control problems for these systems. They can use state-of-the-art software tools to efficiently compute a numerical solution to these problems.
Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes)
Course achievement
The course work is completed if students pass the mid-term online quiz.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Concentration Area Circuits and Systems

↑

Name of module	Number of module
Model Predictive Control for Renewable Energy Systems	11LE50MO-5723 PO 2021
course	
Model Predictive Control for Renewable Energy Systems	
Event type	Number
lecture course	11LE50V-5723 PO 2021
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	32 Stunden
Independent study	58 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents

Model predictive control (MPC) is an advanced control technique that is able to flexibly deal with complex, multivariable systems with high performance demands operating under constraints.
MPC becomes more and more important in the field of renewable energy systems because it can account systematically for the complex and varying system demands while maximizing resource efficiency during operation.

During the lectures the following topics will be treated:

- Introduction to MPC for energy systems
- Overview of traditional and advanced control concepts
- Basics of simulation and optimization
- Fundamentals and solution methods of linear MPC
- Fundamentals and solution methods of nonlinear MPC
- Modeling and control of building energy systems
- Modeling and control of solar energy plants
- Modeling and control of wind energy plants

Bi-weekly voluntary exercises will be provided in order to help the student to understand the theory better.

Examination achievement

see module details

Course achievement

see module details

Literature

"Model Predictive Control: Theory, Computation, and Design" by James B. Rawlings, David Q. Mayne, and Moritz M. Diehl

Compulsory requirement
None

Recommended requirement
Prior knowledge in the following fields is an advantage: - Mathematics 1 and 2 for engineers (or basic linear algebra and calculus courses) - Linear systems theory - State space control - Numerical optimization - Modeling and system identification (MSI)

↑

Name of module	**Number of module**
Numerical Optimal Control in Science and Engineering	11LE50MO-5249 ESE PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	6.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses. Numerical Optimization (NUMOPT), Modelling and System Identification (MSI), Systems and Control Bachelor or Master lectures.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Numerical Optimal Control in Science and Engineering	lecture course	Core elective	6.0	6.0	180 hours
Numerical Optimal Control in Science and Engineering	excercise course	Core elective		2.0	

Qualification
The students can formulate optimal control problems and implement and analyze several numerical methods for solving them.
Examination achievement
Written exam (180 minutes)
Course achievement
The course work is completed if students pass the mid-term online quiz.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems **OR** in Elective Courses in Computer Science ■ M.Sc. Informatik / Computer Science (PO 2020), in Spezialvorlesung | Specialization Courses Part of the specialization Cyber-Physical Systems in Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	Number of module
Numerical Optimal Control in Science and Engineering	11LE50MO-5249 ESE PO 2021
course	
Numerical Optimal Control in Science and Engineering	
Event type	Number
lecture course	11LE50V-5249
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	6.0
Workload	180 hours
Attendance	78 hours
Independent study	102 hours
Hours of week	6.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

- 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

Examination achievement

see module details

Course achievement

see module details

Literature

1. Manuscript "Numerical Optimal Control" by M. Diehl and S. Gros
2. Biegler, L.T., Nonlinear Programming, SIAM, 2010

Compulsory requirement

None

Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses. Numerical Optimization (NUMOPT), Modelling and System Identification (MSI), Systems and Control Bachelor or Master lectures.

↑

Name of module	**Number of module**
Numerical Optimal Control in Science and Engineering	11LE50MO-5249 ESE PO 2021
course	
Numerical Optimal Control in Science and Engineering	
Event type	Number
excercise course	11LE50Ü-5249
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
In the tutorial, the contents of the lecture will be deepened by means of theoretical examples and computer exercises.
Examination achievement
see moodule details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses. Numerical Optimization (NUMOPT), Modelling and System Identification (MSI), Systems and Control Bachelor or Master lectures.

↑

Name of module	**Number of module**
Numerical Optimal Control in Engineering - Project	11LE50MO-5250 ESE PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	1.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Numerical Optimal Control - Project	Alle Arten, soweit keine ständige Betreuung der Studierenden erforderlich ist	Core elective	3.0	1.0	90 hours

Qualification
Students will be able to independently program, analyze, and apply numerical methods of optimal control.
Examination achievement
Submission of a report incl. a documented computer code.
Course achievement
A short oral presentation at the end of the semester.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of module	**Number of module**
Numerical Optimal Control in Engineering - Project	11LE50MO-5250 ESE PO 2021
course	
Numerical Optimal Control - Project	
Event type	Number
Alle Arten, soweit keine ständige Betreuung der Studierenden erforderlich ist	11LE50Pro-5250
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	3.0
Workload	90 hours
Attendance	14 hours
Independent study	76 hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
The project consists of implementing one or more self-selected optimal control methods on the computer and applying them to one or more self-selected application problems. The focus may be more on algorithms and performance comparisons or on modeling a specific problem. The result of the project is a documented computer code, a report, and a public presentation.
Examination achievement
see module details
Course achievement
see module details
Literature
http://syscop.de/teaching/
Compulsory requirement
None
Recommendation
It is strongly recommended to attend the Numerical Optimal Control lecture offered in the same semester.

↑

Name of module	**Number of module**
Numerical Optimization	11LE50MO-5243 ESE PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	6.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Numerische Optimierung / Numerical Optimization - Lecture	lecture course	Core elective	6.0	4.0	180 hours
Numerische Optimierung / Numerical Optimization - Exercises	excercise course	Core elective		2.0	

Qualification
The students know different types of optimization problems and can discuss their theoretical background and implement and analyze numerical methods for solving them.
Examination achievement
Written exam (180 minutes)
Course achievement
The course work is completed if students pass the mid-term online quiz.

Usability
As compulsory elective in ■ M.Sc. Embedded Systems Engineering (ESE) in Microsystems Engineering Concentrations Area: Circuits and Systems **OR** in Elective Courses in Computer Science ■ M.Sc. Microsystems Engineering in Microsystems Engineering Concentrations Area: Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses Part of the specialization Cyber-Physical Systems in Master of Science Informatik/Computer Science resp. M.Sc. Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Numerical Optimization	11LE50MO-5243 ESE PO 2021
course	
Numerische Optimierung / Numerical Optimization - Lecture	
Event type	Number
lecture course	11LE50V-5243
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	6.0
Workload	180 hours
Attendance	90 hours
Independent study	90 hours
Hours of week	4.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

The course is divided into four major parts:

1. Fundamental Concepts of Optimization: Definitions, Types, Convexity, Duality
2. Unconstrained Optimization and Newton Type Algorithms: Stability of Solutions, Gradient and Conjugate Gradient, Exact Newton, Quasi-Newton, BFGS and Limi- ted Memory BFGS, and Gauss-Newton, Line Search and Trust Region Methods, Algorithmic Differentiation
3. Equality Constrained Optimization Algorithms: Newton Lagrange and Generalized Gauss-Newton, Range and Null Space Methods, Quasi-Newton and Adjoint Based Inexact Newton Methods
4. Inequality Constrained Optimization Algorithms: Karush-Kuhn-Tucker Conditions, Linear and Quadratic Programming, Active Set Methods, Interior Point Methods, Se- quential Quadratic and Convex Programming, Quadratic and Nonlinear Parametric Optimization

Examination achievement

see module details

Course achievement

see module details

Literature

1. Jorge Nocedal and Stephen J. Wright, Numerical Optimization, Springer, 2006
2. Amir Beck, Introduction to Nonlinear Optimization, MOS-SIAM Optimization, 2014
3. Stephen Boyd and Lieven Vandenberghe, Convex Optimization, Cambridge Univ. Press, 2004

Compulsory requirement

None

Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses

↑

Name of module	**Number of module**
Numerical Optimization	11LE50MO-5243 ESE PO 2021
course	
Numerische Optimierung / Numerical Optimization - Exercises	
Event type	Number
excercise course	11LE50Ü-5243
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
In der Übung werden die Inhalte der Vorlesung anhand theoretischer Beispielaufgaben sowie mit Rechnerübungen vertieft.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses

↑

Name of module	**Number of module**
Numerical Optimization Project	11LE50MO-5244 ESE PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	1.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Numerische Optimierung / Numerical Optimization - Projekt	Alle Arten, soweit keine ständige Betreuung der Studierenden erforderlich ist	Core elective	3.0	1.0	90 hours

Qualification
Students will be able to independently program, analyze, and apply continuous optimization methods. The project consists of implementing one or more self-selected optimization methods on the computer and applying them to one or more self-selected application problems. The focus may be more on algorithms and performance comparisons or on modeling a specific problem. The result of the project is a documented computer code, a report, and a public presentation.
Examination achievement
Submission of a report incl. a documented computer code.
Course achievement
A short oral presentation at the end of the semester.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of module	**Number of module**
Numerical Optimization Project	11LE50MO-5244 ESE PO 2021
course	
Numerische Optimierung / Numerical Optimization - Projekt	
Event type	Number
Alle Arten, soweit keine ständige Betreuung der Studierenden erforderlich ist	11LE50Pr-5244
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	3.0
Workload	90 hours
Attendance	15 hours
Independent study	75 hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
None
Recommendation
It is strongly recommended to attend the Numerical Optimization lecture offered in the same semester.

↑

Name of module	**Number of module**
Power Electronics for E-Mobility	11LE50MO-4106 ESE PO 2021
Responsible	
Stefan Reichert	
Organizer	
Department of Sustainable Systems Engineering, Professorship in Photovoltaic Energy Conversion	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
Power Electronic Circuits and Devices (compulsory elective module)
Recommended requirement
see above

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Power Electronics for E-Mobility	lecture course	Core elective	3.0	2.0	Attendance: 24 h lecture + 6 h exercise = 30 hSelf-study: 60 h90 h

Qualification
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.
Examination achievement
Oral examination *(Prüfungsgespräch)*, approx. 30 min. The examination takes place at the end of the winter semester.

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ Master of Science in Sustainable Systems Engineering, Energiesysteme / Energy Systems ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systeme

↑

Name of module	**Number of module**
Power Electronics for E-Mobility	11LE50MO-4106 ESE PO 2021
course	
Power Electronics for E-Mobility	
Event type	Number
lecture course	11LE68V-4106
Organizer	
Department of Sustainable Systems Engineering-VB	

ECTS-Points	3.0
Workload	Attendance: 24 h lecture + 6 h exercise = 30 h Self-study: 60 h 90 h
Attendance	30 h
Independent study	60 h
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english
Group size	25

Contents

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 (3 exercises x 2 h, conducted by Akshay Mahajan in the winter term 2021/22).
- Simulation of basic topologies and control structures (Simulationsoftware: PLECS)

Qualification

See module

Examination achievement

See module

Course achievement

See module

Literature
■ Teodorescu R., Liserre M., Rodriguez P.; Grid Converters for Photovoltaic and Wind Power Systems, Wiley-IEEE, 2011
Compulsory requirement
Recommended requirement
Module *Energy Efficient Power Electronics* (only summer term!); Basic Knowledge in (Power) Electronics and Control
Teaching method
Lecture with embedded exercise
Recommendation
This course is **not** available for exchange students.

↑

Name of module	**Number of module**
Rennautoregelung Praktikum / Race Car Control Laboratory	11LE50MO-5224 PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
None
Recommended requirement
The lab course includes topics as part of the Race Car project (Simulation, Optimization and Control of small race cars). The project offers a large variety of project topics, students may be assigned topics meeting their interests and academic background. Prior studies of “Modelling and System Identification” and/or “Optimal Control and Estimation” are recommended.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Rennautoregelung Praktikum / Race Car Control Laboratory	practical course	Core elective	6.0	4.0	180 Stunden

Qualification
Aim of this lab course is to use the theoretical background for real applications in a scientific project. Finding creative solutions to problems as well as hands-on testing/verification of soft- and hardware will be part of the projects. The lab course will also offer experience of working in an international team.
Examination achievement
Project work: 1. A working project result 2. project documentation and oral presentation
Course achievement
none

Grading
The final module grade is determined from an average of the grades of the project work.
Examination weight
■ 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 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 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.
Usability
Elective Module for students of the study program ■ Bachelor of Science in Embedded Systems Engineering ■ Master of Science in Informatik - Application Field Microsystems Engineering ■ Master of Science in Embedded Systems Engineering - Design and simulation - Circuits and systems - Sensors and actuators - Personal Profile ■ Master of Science in Mikrosystemtechnik - Design and simulation - Circuits and systems - Sensors and actuators - Personal Profile ■ Master of Science in Microsystems Engineering - Design and simulation - Circuits and systems - Sensors and actuators - Personal Profile ■ Master of Science in Sustainable Systems Engineering - Informationstechnik / Information Processing Technology

↑

Name of module	**Number of module**
Rennautoregelung Praktikum / Race Car Control Laboratory	11LE50MO-5224 PO 2021
course	
Rennautoregelung Praktikum / Race Car Control Laboratory	
Event type	Number
practical course	11LE50P-5224
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	6.0
Workload	180 Stunden
Attendance	56 hours
Independent study	126 hours
Hours of week	4.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Focus of the lab course is setting up a race track and control system for autonomous driving cars. The set up consists of a track, cars, a color camera, which is tracking the cars and a computer, controling the cars. The communication between the race cars and the computer will be carried out by hacking the remote control. The color camera can be seen as the sensor of the car, communicating its actual position to the computer. The course will be accompanied by weekly meetings with one or more team members working on complementary projects addressing the same real world control problem. In the last two to three weeks of the lab course, when the main project aims are achieved, the participants will start to work on a short report for documentation and give a final oral presentation to share their findings with all team members.
Examination achievement
Written composition and oral presentation of the project results.
Course achievement
None
Compulsory requirement
None
Recommended requirement
The lab course includes topics as part of the Race Car project (Simulation, Optimization and Control of small race cars). The project offers a large variety of project topics, students may be assigned topics meeting their interests and academic background. Prior studies of “Modelling and System Identification” and/or “Optimal Control and Estimation” are recommended.

↑

Name of module	**Number of module**
RF- and Microwave Devices and Circuits	11LE50MO-5215 ESE PO 2021
Responsible	
Prof. Dr. Rüdiger Quay	
Organizer	
Department of Sustainable Systems Engineering, Professorship in Energy-Efficient High-Frequency Electronics	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
RF- and Microwave Devices and Circuits	lecture course	Core elective	3.0	2.0	90 h

Qualification
The students will be able 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.
Examination achievement
Oral examination, duration: approx. 30 min.
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of module	Number of module
RF- and Microwave Devices and Circuits	11LE50MO-5215 ESE PO 2021
course	
RF- and Microwave Devices and Circuits	
Event type	Number
lecture course	11LE68V-5215
Organizer	
Department of Sustainable Systems Engineering, Professorship in Energy-Efficient High-Frequency Electronics-VB	

ECTS-Points	3.0
Workload	90 h
Attendance	26 h
Independent study	64 h
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
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 microsystems. 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.
Examination achievement
See module
Course achievement
See module
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

Compulsory requirement
None
Recommended requirement
None
Teaching method
Electronic handout will be provided during the lecture. Visit to the Fraunhofer IAF.
Recommendation
Electronic handout will be provided during the lecture. Visit to the Fraunhofer IAF.

↑

Name of module	**Number of module**
RF- and Microwave Circuits and Systems	11LE50MO-5232 ESE PO 2021
Responsible	
Prof. Dr. Rüdiger Quay	
Organizer	
Department of Sustainable Systems Engineering, Professorship in Energy-Efficient High-Frequency Electronics	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
RF- und Mikrowellen Schaltungen und Systeme / RF- and Microwave Circuits and Systems - Lecture	lecture course	Core elective	3.0	2.0	90 h

Qualification
The students will be able 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 are 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.
Examination achievement
Oral examination, duration: approx. 30 min.

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of module	Number of module
RF- and Microwave Circuits and Systems	11LE50MO-5232 ESE PO 2021
course	
RF- und Mikrowellen Schaltungen und Systeme / RF- and Microwave Circuits and Systems - Lecture	
Event type	Number
lecture course	11LE68V-5232
Organizer	
Department of Sustainable Systems Engineering-VB	

ECTS-Points	3.0
Workload	90 h
Attendance	30 h
Independent study	60 h
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

The lecture RF- and Microwave circuits and systems deals with the fundamentals and concepts of RF-circuits and systems. It comprises three parts: fundamental RF-concepts with focus on communications and sensing, more complex RF-circuits, and actual RF systems. At the interface
of modern electronics, wave propagation, circuit design, and advanced communication and sensing, advanced analysis and characterisation techniques are introduced in order to bridge the gap from modern integrated circuits to the understanding of RF-communication and sensing systems with all aspects of frequency conversion, amplification, noise, distortion, and detection. The methodologies of RF-analysis, design of circuits, complex signal flows, their modelling and their characterisation are introduced along with the demonstration of their relevance to real RFcomponents and (micro)-systems. Typical applications include a mobile handset such as the SmartPhone, automotive radar, and wireless data communication links for high-data-rate transmission.

Examination achievement

See module

Course achievement

See module

Literature

RF- and Microwave passives
- Zinke/Brunswig, Hochfrequenztechnik, Band 1, Springer, 1999

Further literature for systems are presented during the lecture

Compulsory requirement

None

Recommended requirement
None
Teaching method
Electronic handout will be provided during the lecture. Visit to the Fraunhofer IAF.
Recommendation
No prior knowledge of the software is required.

↑

Name of module	**Number of module**
RF- and Microwave Systems - Design Course	11LE50MO-5344 ESE PO 2021
Responsible	
Prof. Dr. Rüdiger Quay	
Organizer	
Department of Sustainable Systems Engineering, Professorship in Energy-Efficient High-Frequency Electronics	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
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.
Recommended requirement
see above

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
RF- und Mikrowellen Systeme - Design Kurs / RF- and Microwave Systems - Design Course	practical course	Core elective	3.0	2.0	90 h

Qualification
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.
Examination achievement
The grade is calculated based on the average of the submitted exercises (5 out of 6). There is no exam.

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of module	**Number of module**
RF- and Microwave Systems - Design Course	11LE50MO-5344 ESE PO 2021
course	
RF- und Mikrowellen Systeme - Design Kurs / RF- and Microwave Systems - Design Course	
Event type	Number
practical course	11LE68P-5344
Organizer	
Department of Sustainable Systems Engineering, Professorship in Energy-Efficient High-Frequency Electronics-VB	

ECTS-Points	3.0
Workload	90 h
Attendance	26 h
Independent study	64 h
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The Design Course: RF- and Microwave Systems deals with the analysis and creation of RFdevices, 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 non-linear 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 LTE and modern radar.
Examination achievement
See module
Course achievement
See module
Literature
■ Keysight Design System User Manual www.keysight.com ■ Script: Design Course: RF- and Microwave Systems, R. Quay, (will be provided at the beginning of the lecture)

Compulsory requirement
The prior or parallel participation in either module *RF- and microwave devices and circuits* or *RF- and microwave circuits and system*s is required. No prior knowledge of the software is required.
Recommended requirement
None

↑

Name of module	**Number of module**
Sensor-Aktor-Schaltungstechnik	11LE50MO-5725 ESE PO 2021
Responsible	
Prof. Dr. Peter Woias	
Organizer	
Department of Microsystems Engineering, Design of Microsystems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Wissen und Kenntnisse der vermittelten Lehrmodule "Einführung in die Elektrotechnik" und "Messtechnik" des Bachelor-Studiengang, alternativ aus vergleichbaren Lehrveranstaltungen anderer Hochschulen. Vertiefte Grundkenntnisse zu elektronischen Bauelementen.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Sensor-Aktor-Schaltungstechnik	lecture course	Core elective	6.0	2.0	180 Stunden
Sensor-Aktor-Schaltungstechnik	excercise course	Core elective		2.0	

Qualification
Das Modul vermittelt grundlegendes Wissen zur elektronischen Schaltungstechnik der signalverarbeitenden Elektronik für verschiedene Mikrosensoren und Mikroaktuatoren. Es werden in einer Abfolge von Kapiteln zunächst die Grundlagen einiger wesentlicher elektronischer Bauelemente und Funktionsgruppen vermittelt. Anschließend werden kapitelweise verschiedene Sensor- und Aktormechanismen kurz vorgestellt, gefolgt von einer Erläuterung der wichtigsten Schaltungskonzepte für ihren Betrieb. Die Übung vertieft den Lehrstoff anhand der Präsentation und Diskussion exemplarischer Designbeispiele von elektronischen Schaltungen.
Examination achievement
Oral exam (usually 30 or 45 minutes)

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of module	Number of module
Sensor-Aktor-Schaltungstechnik	11LE50MO-5725 ESE PO 2021
course	
Sensor-Aktor-Schaltungstechnik	
Event type	Number
lecture course	11LE50V-5725
Organizer	
Department of Microsystems Engineering, Design of Microsystems	

ECTS-Points	6.0
Workload	180 Stunden
Attendance	52 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	german

Contents
Inhalte sind: • Einführung in elektronische Bauelemente und Funktionsblöcke (Diode, Bipolartransistor, Stromquellen, Stromspiegel, Bandgap-Referenz, Operationsverstärker) • Stromliefernde Sensoren (Photodiode, amperometrische Elektrode) • Spannungsliefernde Sensoren (Ionensensitiver Feldeffekttransistor) • Resistive Sensoren nach dem Wheatstone-Brückenprinzip (Druck, Beschleunigung) • Kapazitive Sensoren (Druck, Beschleunigung, Feuchte) • Kapazitive Aktoren (elektrostatisch, piezo)
Examination achievement
siehe Modulebene
Course achievement
keine
Literature
Tietze, Schenk, Gamm, Halbleiter-Schaltungstechnik, 15. Auflage, 2016, Springer, Berlin, ISBN 978-3-662-48354-1. Schrüfer, Reindl, Zagar, Elektrische Messtechnik, 11. Auflage, 2014, Carl-Vieweg-Verlag, München, ISBN 978-3-446-44208-5.
Compulsory requirement

Recommended requirement
Wissen und Kenntnisse der vermittelten Lehrmodule "Einführung in die Elektrotechnik" und "Messtechnik" des Bachelor-Studiengangs Mikrosystemtechnik, alternativ aus vergleichbaren Lehrveranstaltungen anderer Hochschulen. Vertiefte Grundkenntnisse zu elektronischen Bauelementen.

↑

Name of module	**Number of module**
Sensor-Aktor-Schaltungstechnik	11LE50MO-5725 ESE PO 2021
course	
Sensor-Aktor-Schaltungstechnik	
Event type	Number
excercise course	11LE50Ü-5725
Organizer	
Department of Microsystems Engineering, Design of Microsystems	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	german

Contents
Die Übung vertieft den Lehrstoff anhand der Präsentation und Diskussion von exemplarischen Problemstellungen und Designbeispielen elektronischer Schaltungen.
Examination achievement
siehe Modulebene
Course achievement
keine
Compulsory requirement

↑

Name of module	**Number of module**
State Space Control Systems	11LE50MO-5267 ESE PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Students are expected to have an undergraduate knowledge in mathematics. It is furthermore recommended to have a good knowledge of differential equations, system theory and control. Kenntnisse/Kompetenzen aus Mathematik I und II werden VORAUSGESETZT. Kenntnisse aus Differentialgleichungen, Systemtheorie und Regelungstechnik werden EMPFOHLEN.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
State Space Control Systems	lecture course	Core elective	6.0	3.0	180 hours
State Space Control Systems	excercise course	Core elective		1.0	

Qualification
The students understand the mathematical foundations of state space control systems and are able to design and use state space control systems in engineering applications.
Examination achievement
Written exam (120 minutes)
Course achievement
Keine | none
Recommendation
Work on the weekly exercise sheets and participation in the exercises is voluntary.

Usability
As compulsory elective in ■ M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) in Microsystems Engineering Concentrations Area: Circuits and Systems ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Microsystems Engineering, Concentration area Circuits and Systems Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ Bachelor of Science in Mikrosystemtechnik (PO 2018), im Wahlpflichtbereich, Bereich Mikrosystemtechnik ■ B.Sc. in Informatik (PO 2018)

↑

Name of module	**Number of module**
State Space Control Systems	11LE50MO-5267 ESE PO 2021
course	
State Space Control Systems	
Event type	Number
lecture course	11LE50V-5267-
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	6.0
Workload	180 hours
Attendance	52 Stunden
Independent study	128 Stunden
Hours of week	3.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Review of linear system theory in continuous time and ordinary differential equations; nonlinear and linear systems; discrete time and continuous time systems; eigenvalues and stability; Lyapunov functions; controllability, stabilizability, observability and detectability; control and observer normal form, Kalman normal form; pole placement, linear quadratic regulator (LQR); Luenberger observer, Kalman filter (KF); linear quadratic Gaussian (LQG) control and separation principle; disturbance modelling and offset free control; model predictive control (MPC); robustness; Extended and Unscented Kalman Filter (EKF/UKF); moving horizon estimation (MHE)
Examination achievement
see module details
Course achievement
see module details
Literature
■ Karl J. Åström and Richard M. Murray, Feedback Systems, Princeton University Press, 2011 ■ Stengel, R. Optimal Control and Estimation, Dover Publications, 1994 ■ S. Skogestad, I. Postlethwaite: Multivariable Feedback Control. Analysis and Design. Chichester/ New York, 2006. ■ G.F. Franklin, J.D. Powell, A. Emami-Naeini: Feedback Control of Dyna- mic Systems, Pearson (ISBN-13: 978-0-13-601969-5) Rawlings, J. B., Mayne, D. Q., and Diehl, M. M. Model Predictive Control: Theory, Computation, and Design, 2nd edition ed. Nob Hill, 2017.
Compulsory requirement
None

Recommended requirement
Students are expected to have an undergraduate knowledge in mathematics. It is furthermore recommended to have a good knowledge of differential equations, system theory and control. Kenntnisse/Kompetenzen aus Mathematik I und II werden VORAUSGESETZT. Kenntnisse aus Differentialgleichungen, Systemtheorie und Regelungstechnik werden EMPFOHLEN.

↑

Name of module	Number of module
State Space Control Systems	11LE50MO-5267 ESE PO 2021
course	
State Space Control Systems	
Event type	Number
excercise course	11LE50Ü-5267
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The weekly exercise sheets allows students to apply their acquired knowledge. During the voluntary weekly exercise sessions the content of both the lecture and the exercise sheets will be discussed in-depth and consolidated.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
Students are expected to have an undergraduate knowledge in mathematics. It is furthermore recommended to have a good knowledge of differential equations, system theory and control. Kenntnisse/Kompetenzen aus Mathematik I und II werden VORAUSGESETZT. Kenntnisse aus Differentialgleichungen, Systemtheorie und Regelungstechnik werden EMPFOHLEN.

↑

Name of module	**Number of module**
Wind Energy Systems	11LE50MO-5256 ESE PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Undergraduate knowledge in physics, mathematics as well as in systems and control.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Windenergiesysteme / Wind Energy Systems	lecture course	Core elective	6.0	3.0	180 hours
Windenergiesysteme / Wind Energy Systems	excercise course	Core elective		1.0	-

Qualification
Students understand the physical principles of wind energy and the technology of modern wind energy systems.
Examination achievement
Written exam (180 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of module	Number of module
Wind Energy Systems	11LE50MO-5256 ESE PO 2021
course	
Windenergiesysteme / Wind Energy Systems	
Event type	Number
lecture course	11LE50V-5256
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	6.0
Workload	180 hours
Attendance	52 hours
Independent study	128 hours
Hours of week	3.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Global wind energy resource - aerodynamic principles of wind turbines - design of modern wind turbines - control of modern wind turbines - the electrical system of wind turbines - alternative concepts and high-altitude wind energy.
Examination achievement
See module level
Course achievement
See module level
Literature
"Wind Energy Handbook" by T. Burton, N. Jenkins, D. Sharpe, E. Bossanyi, 2nd edition, Wiley, 2011
Compulsory requirement
Recommended requirement
Undergraduate knowledge in physics, mathematics as well as in systems and control.

↑

Name of module	Number of module
Wind Energy Systems	11LE50MO-5256 ESE PO 2021
course	
Windenergiesysteme / Wind Energy Systems	
Event type	Number
excercise course	11LE50Ü-5256
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	
Workload	-
Attendance	-
Independent study	-
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	german

Contents
The tutorials deepen the understanding of the material of the lecture.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement
None

↑

Name of module	**Number of module**
Wearable and Implantable Computing (WIC)	11E13MO-1402_PO 2020
Responsible	
Prof. Dr. Oliver Amft	
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Attendance	32 Stunden / Hours
Independent study	116 Stunden / Hours
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Basic timeseries analysis methods, basic programming skills, coding in Python

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Wearable and Implantable Computing (WIC)	lecture course	Core elective	6.0	2.0	180 Stunden / Hours
Wearable and Implantable Computing (WIC)	excercise course	Core elective		2.0	

Qualification
Students are able to ■ Understand design concepts and apply/analyse wearable and implantable system design methods. ■ Analyse physical principles, select and optimise on-body energy harvesting and power management techniques. ■ Create context recognition and energy-efficient pattern analysis pipelines using sparse sampling and pattern processing methods. ■ Build wearable system prototypes and apply system evaluation methods, including design for biocompatibility.

Examination achievement
mündliche Prüfung (i.d.R. 30 oder 45 Minuten) | Oral exam (usually 30 or 45 minutes) If there are too many students for a reasonably organized oral exam, it will be held as a written exam instead, announced well in advance.
Course achievement
Durchführung von Versuchen und Ergebnisprotokoll | Execution of experiments and written report of results
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung **|** Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science **OR** in Microsystems Engineering Concentrations Area Circuits and Systems/Biomedical Engineering ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems/Biomedical Engineering ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme/Biomedizinische Technik Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. M.Sc. Embedded Systems Engineering **and** Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. M.Sc. Embedded Systems Engineering

↑

Name of module	**Number of module**
Wearable and Implantable Computing (WIC)	11E13MO-1402_PO 2020
course	
Wearable and Implantable Computing (WIC)	
Event type	Number
lecture course	11E13V-1402_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Attendance	32 Stunden / Hours
Independent study	116 Stunden / Hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The course provides students with a comprehensive overview and in-depth skills on system design of sensor-based wearable and implantable computing systems. Course covers frequent sensors and actuators and their system integration, context recognition methods and selected algorithms, powering and energy management concepts (task scheduling, sparse sampling, and on-demand signal processing), energy harvesting methods, and system design topics (flexible electronics, electronics textile integration, multiprocess additive manufacturing), as well as principles of system validation.
Examination achievement
see module details
Course achievement
see module details
Literature
Up-to-date literature recommendations are provided during the lectures.
Compulsory requirement
None
Recommended requirement
Basic timeseries analysis methods, basic programming skills, coding in Python

↑

Name of module	**Number of module**
Wearable and Implantable Computing (WIC)	11E13MO-1402_PO 2020
course	
Wearable and Implantable Computing (WIC)	
Event type	Number
excercise course	11E13Ü-1402_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	
Attendance	32 Stunden / Hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Student groups will investigate concrete cases including context recognition, energy-efficient signal processing, and digital design of wearable systems. A wearable device prototype will be realised per student group.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
MSE Study Project in Concentration Circuits and Systems	11LE50MO-5996 ESE SP-CS
Responsible	
Prof. Dr.-Ing. Bastian Rapp	
Faculty	
Faculty of Engineering	

ECTS-Points	9.0
Workload	270 Studen / hours
Hours of week	
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
allgemeine mathematische Grundlagen, praktische und theoretische Grundlagen der Ingenieurswissenschaften, Programmierkenntnisse, themenspezifische Vorkenntnisse für den gewählten Themenbereich | general fundamental mathematical knowledge, practical and theoretical foundations in Engineering Sciences, programming skills, subject-specific knowledge for the chosen topics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload

Qualification
In this module students get involved in the actual research process of the chosen work group/chair in the area of Circuits and Systems. Depending on their personal field of interest and their expertise in various research and teaching areas offered at the Department of Microsystems Engineering, they decide on a specific topic and deepen their knowledge and skills in this area as well as their overall proficiency in academic work and research. They learn to work on the different tasks required for the specific project under given technical specifications, to develop appropriate systems and to work experimentally and constructively in projects. Students acquire the ability to familiarize themselves with new engineering problems and do independent background research. They will work with modern development environments and adhere to the generally accepted quality standards. During the project, working in a team as well as observing the rules of good scientific work will be trained.
Examination achievement
The graded assessment is (depending on the topic) either a written research paper (if it is rather a theoretical or fundamentally based topic; length usually maximum 40 pages) or the creation of a software or a demonstrator including a sufficient documentation (according to the scientific standards) and subsequent discussion. Details are agreed upon with the supervisor (usually a person authorized to conduct examinations at the Department of Microsystems Engineering) when the topic is assigned.

Course achievement
As a rule, the course work consists of the following components: - regular attendance of (team) meetings or discussions with the supervisor - oral presentation (usually 20 - 30 minutes) with subsequent discussion
Recommendation
Language is usually English, but might be negotiable (changed to German). Please learn about the procedure of finding a topic and registering for the project in good time. (For instance, see "A to Z - Study FAQ" under "Studies and Teaching" on our faculty website.) Students are expected to self-organize the given tasks and do background research.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of node	**Number of node**
Materials and Fabrication	11LE50KT-MSc-787-2021-MSE-MaF
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Compulsory

↑

Name of module	Number of module
Advanced Silicon Technology	11LE50MO-5112 ESE PO 2021
Responsible	
Prof. Dr. Oliver Paul	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge in microsystems technology and semiconductor physics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Fortgeschrittene Siliziumtechnologie / Advanced Silicon Technology - Lecture	lecture course	Core elective	3.0	2.0	90 hours

Qualification
This module provides a more detailed description of silicon technologies exceeding the modules in Microsystemtechnology I and II. The basics in silicon technologies will be accomplished by the most recent results found in literature. Whenever possible, we will organize a visit of the Micronas GmbH in Freiburg and their CMOS Fab.
Examination achievement
Oral examination if there are 20 or fewer than 20 registered participants; written examination if there are more than 20 registered participants (minimum 60 and maximum 240 minutes). Details will be announced by the examiner in due time.
Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of module	**Number of module**
Advanced Silicon Technology	11LE50MO-5112 ESE PO 2021
course	
Fortgeschrittene Siliziumtechnologie / Advanced Silicon Technology - Lecture	
Event type	Number
lecture course	11LE50V-5112
Organizer	
Department of Microsystems Engineering, Microsystem Materials	

ECTS-Points	3.0
Workload	90 hours
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Substrate materials, oxidation, diffusion, implantation, polysilicon and epitaxy, silisides, metallisation, dielectric layers, SiGe, strained silicon, low- und high-k-dielectrics, photo lithography (immersion lithography, phase shift mask, EUV, chemical-mechanical polishing, process integration, CMOS-compatible micro mechanics
Examination achievement
see module details
Course achievement
none
Literature
■ Chang/Sze: ULSI Technology, Wiley ■ Semiconductor International: monatliche Technologie-Zeitschrift
Compulsory requirement
Recommended requirement
Basic knowledge in microsystems technology and semiconductor physics

↑

Name of module	**Number of module**
Bioinspired functional materials	11LE50MO-5125 ESE PO 2021
Responsible	
Dr. Anayancy Osorio-Madrazo	
Organizer	
Department of Microsystems Engineering-VB Department of Microsystems Engineering, Professorship in Sensors	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Bioinspirierte Funktionsmaterialien / Bioinspired functional materials - Lecture	lecture course	Core elective	3.0	2.0	90 Stunden

Qualification
In this lecture 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 theoretical principle of these methods; and describe the physical-chemistry of the processing of different bioinspired materials studied in the course.
Examination achievement
written examination (90 minutes) (Part of the Exam "Advanced Macromolcular Materials and Nanostructural Engineering" of the study program M.Sc. Sustainable Materials - Polymer Science.)

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication (Part of the Exam "Advanced Macromolcular Materials and Nanostructural Engineering" of the study program M.Sc. Sustainable Materials - Polymer Science.)

↑

Name of module	Number of module
Bioinspired functional materials	11LE50MO-5125 ESE PO 2021
course	
Bioinspirierte Funktionsmaterialien / Bioinspired functional materials - Lecture	
Event type	Number
lecture course	11LE50V-5125

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
- 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 testing; 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
Examination achievement
see module details
Course achievement
none
Literature
- Materials Design Inspired by Nature. Function through Inner Architecture. Edited by: P. Fratzl, J. WC Dunlop and R. Weinkamer. RSC Publishing (2013) - Nature's hierarchical materials P. Fratzl and R. Weinkamer Progress in Materials Science , Volume 52, pages 1263-1334, (2007) - Bioinspiration and biomimetics. Learning from Nature. Edited by: P. Fratzl, T. Speck and S. Gorb. IOP Publishing (2016) Besides, it will be provided an script accompanying each lecture, which will be updated with recent literature.

Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
Clean Room Laboratory for Engineers	11LE50MO-5804 ESE PO 2021
Responsible	
Prof. Dr. Claas Müller Prof. Dr.-Ing. Bastian Rapp	
Organizer	
Department of Microsystems Engineering, Process Technology	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	3.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Reinraumlaborkurs für Ingenieure / Clean Room Laboratory for Engineers	practical course	Core elective	3.0	3.0	

Qualification
The Goal of the Cleanroom Lab Course is to learn Cleanroom behaviour and processing and the creation of a high quality lab report.
Examination achievement
The grade of the lab course is derived from the average of 6 short tests with evaluation of the practical skill of the student by the supervisor (50%) and a lab report (50%).
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication **or** the Customized Course Selection: Courses offered by IMTEK ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Circuits and Systems/Materials and Fabrication

↑

Name of module	**Number of module**
Clean Room Laboratory for Engineers	11LE50MO-5804 ESE PO 2021
course	
Reinraumlaborkurs für Ingenieure / Clean Room Laboratory for Engineers	
Event type	Number
practical course	11LE50P-5804

ECTS-Points	3.0
Attendance	42 Stunden
Hours of week	3.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Cleanroom behavior and processing:
1. Wafer handling
2. Lithography sequence
3. Cleaning
4. Metal deposition (physical vapour deposition)
5. Profilometry
6. Lift-Off
7. Wafer backside processing
8. Electroplating
9. Characterization
10. Acquisition of relevant processing data and recording

Examination achievement

see module details

Course achievement

see module details

Literature

A script is provided and kept up-to-date.
- C. Müller, MST Technologies and Processes, lecture
- W. Menz, J. Mohr, O. Paul, Microsystems Technology, Wiley VCH
- M. Madou, Fundamentals of Microfabrication, CRC Press
- S. M. SZE, Physics of Semiconductor Devices, Wiley VCH
- J. W. Dini, Electrodeposition, Noyes Publications

Compulsory requirement

↑

Name of module	**Number of module**
Computational physics: material science	11LE50MO-5270 ESE PO 2021
Responsible	
Prof. Dr. Joachim Dzubiella	
Faculty	
Faculty of Engineering	

ECTS-Points	9.0
Workload	270 Stunden | hours
Hours of week	
Recommended semester	
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge in programming (Python, C/C++) as well as statistical mechanics.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Computational Physics: Materials Science	lecture course	Core elective	9.0	4.0	270

Qualification
Application of computational simulation methods can help to discover or design new materials and investigate (microscopic) structure- (macroscopic) property relationships of a wide range of materials classes, such as metals, composites, nanostructures, ice/water, as well as polymers, surfactants, or colloidal dispersions. This course will introduce basic statistical concepts as well as programming and simulations techniques with particular focus on methods based on classical Hamiltonians spanning orders of length and time scales, such as Molecular Dynamics and coarse-grained Langevin Dynamics simulations. The students will become familiar with some examples for the different types of interatomic and coarse-grained potentials: e.g., Lennard-Jones, Born-Mayer, Embedded-Atom, (screened) Coulomb, Hamaker, etc. as well as bonded potentials for molecules and polymers. The course will consist of lectures and hands-on programming exercises and small projects, simulating mostly complex (interacting) fluids and molecules, using own written code.
Examination achievement
The Prüfungsleistung consists of a written exam, and only the result of the written exam contributes to the Prüfungsleistung.

Course achievement
Criteria for passing: For successfully completing the Studienleistung (SL), students must (i) obtain, at least, an average of 50% over all the tutorial sheets , (ii) not miss more than two tutorials (either digital or in presence), and (iii) present their results at least twice during the semester.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of module	**Number of module**
Computational physics: material science	11LE50MO-5270 ESE PO 2021
course	
Computational Physics: Materials Science	
Event type	Number
lecture course	07LE33V-ADV_THEO_COMP-MAT

ECTS-Points	9.0
Workload	270
Attendance	90
Independent study	180
Hours of week	4.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
This lecture provides an introduction into basic concepts of atomistic computational materials science. 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 physical problems extending over too many scales for one single method alone. We will start with a brief introduction to density functional theory and more approximate methods such as tight binding. Quantum derived forces can be extracted from these methods and the short term dynamics of small nanosystems can be studied. For the simulation of larger systems and longer time scales, classical interatomic potentials are required. The students will become familiar with some examples for the different types of interatomic potentials: e.g. Lennard-Jones, Born-Mayer, Embedded-Atom, Bond-Order-potentials as well as bead-spring potentials for polymers. A brief introduction into the basic methodology of micro-canonical and thermostated molecular dynamics simulations will be given. The lecture is accompanied by a hands-on programming course. Classical molecular dynamics simulations will be used to study metallic and covalently bonded materials.
Examination achievement
Course achievement
Literature
lecture script: A brief Introduction into Computational Materials Science
Compulsory requirement

↑

Name of module	**Number of module**
Continuum mechanics I with exercises	11LE50MO-4302 ESE PO 2021
Responsible	
Dirk Helm	
Organizer	
Department of Sustainable Systems Engineering-VB	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Advanced mathematics; engineering mechanics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Continuum Mechanics I	lecture course	Core elective	6.0	2.0	180 h
Continuum Mechanics I	excercise course	Core elective		2.0	

Qualification
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.
Examination achievement
Oral examination with a max. duration of 45 min. The oral examination covers the content of the lecture and exercises. Important info for exchange students: the examination must be taken at the official examination date!

Course achievement
none
Usability

Compulsory elective module for students of the study program
■ Master of Science in Sustainable Systems Engineering (2021 version of the exam regulations):
  ■ Resilience Engineering
  ■ Sustainable Materials Engineering
■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication
■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse
■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area:Materials and Fabrication

↑

Name of module	**Number of module**
Continuum mechanics I with exercises	11LE50MO-4302 ESE PO 2021
course	
Continuum Mechanics I	
Event type	Number
lecture course	11LE68V-4302
Organizer	
Department of Sustainable Systems Engineering-VB	

ECTS-Points	6.0
Workload	180 h
Attendance	52 h
Independent study	128 h
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

- Mathematical foundations of continuum mechanics (specialized to orthonormal base systems) consisting of tensor algebra and tensor analysis
- Introduction to the basic structure 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.

Examination achievement

See module

Course achievement

See module

Literature

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

Compulsory requirement

None

Recommended requirement

Advanced mathematics; engineering mechanics

Teaching method

Lecture + exercise

↑

Name of module	**Number of module**
Continuum mechanics I with exercises	11LE50MO-4302 ESE PO 2021
course	
Continuum Mechanics I	
Event type	Number
excercise course	11LE68Ü-4302
Organizer	
Department of Sustainable Systems Engineering-VB	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
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.
Examination achievement
See module
Course achievement
See module
Literature
See lecture
Compulsory requirement
None
Recommended requirement
See lecture

↑

Name of module	**Number of module**
Continuum mechanics II with exercises	11LE50MO-4304 ESE PO 2021
Responsible	
Dirk Helm	
Organizer	
Department of Sustainable Systems Engineering-VB	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Module Continuum Mechanics I with Exercises

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Continuum Mechanics II	lecture course	Core elective	6.0	2.0	180 h
Continuum mechanics II - Exercises	excercise course	Core elective		2.0	See lecture

Qualification
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.
Examination achievement
Oral examination with a max. duration of 45 min. The oral examination covers the content of the lecture and exercises. Important info for exchange students: the examination must be taken at the official examination date.
Course achievement
none

Usability

Compulsory elective module for students of the study program
■ Master of Science in Sustainable Systems Engineering (2021 version of the exam regulations):
  ■ Resilience Engineering
  ■ Sustainable Materials Engineering
■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication
■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse
■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area:Materials and Fabrication

↑

Name of module	**Number of module**
Continuum mechanics II with exercises	11LE50MO-4304 ESE PO 2021
course	
Continuum Mechanics II	
Event type	Number
lecture course	11LE68V-4303
Organizer	
Department of Sustainable Systems Engineering-VB	

ECTS-Points	6.0
Workload	180 h
Attendance	60 h
Independent study	120 h
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

- 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. linear-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

Examination achievement

See module

Course achievement

See module

Literature

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

Compulsory requirement

None

Recommended requirement

Module *Continuum Mechanics I with Exercises*

Teaching method
Lecture + exercise

↑

Name of module	**Number of module**
Continuum mechanics II with exercises	11LE50MO-4304 ESE PO 2021
course	
Continuum mechanics II - Exercises	
Event type	Number
excercise course	11LE68Ü-4304
Organizer	
Department of Sustainable Systems Engineering-VB	

ECTS-Points	
Workload	See lecture
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
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.
Examination achievement
See module
Course achievement
See module
Literature
See lecture
Compulsory requirement
See lecture
Recommended requirement
See lecture
Teaching method
See lecture

↑

Name of module	**Number of module**
Dynamics of Materials: Material Characterization	11LE50MO-5118 ESE PO 2021
Responsible	
Prof. Dr. Stefan Hiermaier	
Organizer	
Department of Sustainable Systems Engineering, Professorship in Sustainable Engineering Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Dynamics of Materials: Material Characterization	lecture course	Core elective		2.0	180 h
Dynamics of Materials: Material Characterization - Exercise	excercise course	Core elective		2.0	

Qualification
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.
Examination achievement
Written supervised exam, duration: 90 min.
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication ■ M.Sc. in Sustainable Systems Engineering (PO 2021) in the technical concentration area *Resilience Engineering*

↑

Name of module	**Number of module**
Dynamics of Materials: Material Characterization	11LE50MO-5118 ESE PO 2021
course	
Dynamics of Materials: Material Characterization	
Event type	Number
lecture course	11LE68V-5118
Organizer	
Department of Sustainable Systems Engineering, Professorship in Sustainable Engineering Systems	

ECTS-Points	
Workload	180 h
Attendance	52 h
Independent study	128 h
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

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

Examination achievement

See module

Course achievement

See module

Literature

- S. Hiermaier, "Structures under Crash and Impact", Springer, 2008.

Compulsory requirement
None
Recommended requirement
None
Teaching method
Lecture + exercise

↑

Name of module	**Number of module**
Dynamics of Materials: Material Characterization	11LE50MO-5118 ESE PO 2021
course	
Dynamics of Materials: Material Characterization - Exercise	
Event type	Number
excercise course	11LE68Ü-5118
Organizer	
Department of Sustainable Systems Engineering, Professorship in Sustainable Engineering Systems	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Exercises will utilize freely available Finite-Element codes (currently: Ansys Student) to study specific applications of the theoretical knowledge established in the lectures. We will work through a series of applied examples demonstrating different material behaviour, e.g. reversible elastic or permanent plastic deformation. Different solution methods for quasi-static and time-dependent phenomena will be explored. The need for simulation as a tool to interpret experimental data will be demonstrated in case of elastic wave propagation for the Split-Hopkinon Bar Method. Students are expected to present solutions to exercises in front of the class.
Examination achievement
See module
Course achievement
See module
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Electrochemical energy applications: fuel cells and electrolysis	11LE50MO-5278 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Roland Zengerle	
Organizer	
Department of Microsystems Engineering, MEMS Applications	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	each term

Compulsory requirement
keine | none
Recommended requirement
Knowledge in material science

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Electrochemical energy applications: fuel cells and electrolysis	lecture course	Core elective	3.0	2.0	90 Stunden

Qualification
understanding/knowledge of - basic electrochemistry - hydrogen fuel cell working principle, materials, systems - electrolysis working principle, materials, systems - redox flow batteries - electrochemical and ex-situ characterization methods
Examination achievement
Written exam (duration 90 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of module	**Number of module**
Electrochemical energy applications: fuel cells and electrolysis	11LE50MO-5278 ESE PO 2021
course	
Electrochemical energy applications: fuel cells and electrolysis	
Event type	Number
lecture course	11LE50V-5278
Organizer	
Department of Microsystems Engineering, MEMS Applications	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	each term
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
Examination achievement
siehe Modulebene
Course achievement
keine
Compulsory requirement
none
Recommended requirement
Knowledge in material science

↑

Name of module	Number of module
Electrochemical Methods for Engineers	11LE50MO-5719 ESE PO 2021

Responsible
Prof. Dr. Stefan Rupitsch Prof. Dr. Gerald Urban
Organizer
Department of Microsystems Engineering, Professorship in Sensors Department of Microsystems Engineering, Professorship in Electrical Instrumentation and Embedded Systems
Faculty
Faculty of Engineering

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
■ Introductory lecture to chemistry or similar knowledge ■ Introductory lecture to electronics or similar knowledge

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Elektrochemische Methoden für Ingenieure / Electrochemical Methods for Engineers - Lecture	lecture course	Core elective	3.0	2.0	90 hours

Qualification
The students know the essential concepts and fundamental equations of electrochemical theory. The participants from different subjects link together the knowledge from physical chemistry and several engineering disciplines to get a sound understanding of the classical electrochemical methods and electrochemical impedance spectroscopy. The students can apply their knowledge and understanding of the electrochemical methods to tasks in the field of material science, microtechnology, microsystems and energy application.
Examination achievement
written examination (90 minutes)

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of module	Number of module
Electrochemical Methods for Engineers	11LE50MO-5719 ESE PO 2021
course	
Elektrochemische Methoden für Ingenieure / Electrochemical Methods for Engineers - Lecture	
Event type	Number
lecture course	11LE50V-5719
Organizer	
Department of Microsystems Engineering, Professorship in Sensors Department of Microsystems Engineering, Professorship in Electrical Instrumentation and Embedded Systems	

ECTS-Points	3.0
Workload	90 hours
Attendance	30
Independent study	60
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

- Electrochemical theory (cells, electrodes, fundamental equation and concepts)
- Instrumentation (focus on the interplay between electrochemistry and electronics/data acquisition), equipment (electrodes, cells), and electrolytes
- Classical methods (potentiometry, amperometry, CV, DPV, SWV, HDME, RDE, RRDE)
- Electrochemical impedance spectroscopy (EIS)
- Selected aspects: Material science (corrosion, hierarchical micro-/nanostructures)
- Selected aspects: Microtechnology (electrodeposition, failure mechanism)
- Selected aspects: Microsystems (electrochemical sensors and actuators)
- Selected aspects: Energy application (fuel cells, batteries, super caps)

Examination achievement

see module details

Course achievement

none

Literature

- Bard, Faulkner: Electrochemical Methods – Fundamentals and Applications, 2nd ed., 2001, Wiley, library: SB/I.1/1
- Hamann, Hamnett, Vielstich: Electrochemistry, 2nd ed., Wiley-VCH 2007, library: SB/H.2/13
- Zoski: Handbook of electrochemistry, 1st ed., Elsevier, 2007, available as ebook (campus license)

Compulsory requirement

Recommended requirement
Introductory lecture to chemistry or similar knowledge Introductory lecture to electronics or similar knowledge

↑

Name of module	**Number of module**
Energiespeicherung und Wandlung mittels Brennstoffzellen	11LE50MO-5203 ESE PO 2021
Responsible	
Prof. Dr. Claas Müller	
Organizer	
Department of Microsystems Engineering, Process Technology	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Energiespeicherung und Wandlung mittels Brennstoffzellen / Energy storage and conversion using fuel cells - Lecture	lecture course	Core elective	3.0	2.0	90 Stunden

Qualification
Ziel des Moduls ist die Vermittlung der vertieften theoretischen Grundlagen und der spezifischen Kenntnisse zur Speicherung und Wandlung von Energie mittels Brennstoffzellen in mikrotechnischen Systemen. | The aim of the module is to convey the in-depth theoretical principles and specific knowledge of the storage and conversion of energy using fuel cells in microtechnical systems.
Examination achievement
written exam (duration of 90 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of module	Number of module
Energiespeicherung und Wandlung mittels Brennstoffzellen	11LE50MO-5203 ESE PO 2021
course	
Energiespeicherung und Wandlung mittels Brennstoffzellen / Energy storage and conversion using fuel cells - Lecture	
Event type	Number
lecture course	11LE50V-5203
Organizer	
Department of Microsystems Engineering, Process Technology	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	german

Contents

- Physikalisch chemische Grundlagen Brennstoffzellen
- Aufbau und Funktion von Brennstoffzellen
- Vorstellung unterschiedlicher Brennstoffzellentypen
- Physikalisch chemische Grundlagen der Wasserstoffspeicherung
- Vorstellung von Wasserstoffspeichertypen und -mechanismen
- Diskussion von Vor- und Nachteilen der Wasserstoffspeicher
- Brennstoffzellensysteme im Automobil
- PEM
- DMFC
- Miniaturisierung von Brennstoffzellen
- Mikrobrennstoffzelle
- Chipintegrierte Brennstoffzelle (I^2Brenn)
- Brennstoffzellenakkumulator
- Miniaturisierung der Wasserstofferzeugung
- Einsatz von Brennstoffzellensystemen in der MST

Examination achievement

siehe Modulebene

Course achievement

keine

Literature

Zur Vorlesung wird ein Skriptum zur Verfügung gestellt und regelmäßig aktualisiert.

Compulsory requirement

↑

Name of module	**Number of module**
From Microsystems to the Nanoworld	11LE50MO-5101 ESE PO 2021
Responsible	
Prof. Dr. Jürgen Rühe	
Organizer	
Department of Microsystems Engineering, Chemistry and Physics of Interfaces	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Von Mikrosystemen zur Nanowelt / From Microsystems to the Nanoworld - Lecture	lecture course	Core elective	3.0	2.0	90 Stunden

Qualification
This module describes the issues encountered at the transition from the world of Microsystems to the nanoworld. It aims at an understanding of the principle concepts for both worlds and describes current trends and problems in the field. It is also attempted to give an outlook for future research within the boundaries of physics.
Examination achievement
written exam with a duration of 90 minutes
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	**Number of module**
From Microsystems to the Nanoworld	11LE50MO-5101 ESE PO 2021
course	
Von Mikrosystemen zur Nanowelt / From Microsystems to the Nanoworld - Lecture	
Event type	Number
lecture course	11LE50V-5101
Organizer	
Department of Microsystems Engineering, Chemistry and Physics of Interfaces	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	30
Independent study	60
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
1. INTRODUCTION What is nanotechnology? The long way of science to nanotechnology and nanoengineering: a survey. The current aspects of nanoengineering: beyond terabyte hard drives. Future aspects: Molecular motors and engines. Nano robots and nano machinery. 2. FOUNDATIONS The physics governing properties of objects on the micro- and nano-scale. Principles of manufacturing nanometer scale devices: Nature's strategy: biomotors based on proteins - something the human body already does, top-down approach: miniaturization of macro-world principles to ever smaller scales, bottom-up strategy: from synthesizing simple compounds consisting of a few atoms to nanoengines. Examples of man-made nanostructures. Properties of novel materials, Strategies for visualization and object handling in the nano world. 3. PROBLEMS From Micro to Nano: what's different. Physical and societal limits of nano engineering.
Examination achievement
siehe Modulebene
Course achievement
keine
Compulsory requirement
none

Recommended requirement
none

↑

Name of module	Number of module
Functional Safety, Security and Sustainability: Active Resilience	11LE68MO-5120 ESE PO 2021
Responsible	
Prof. Dr. Stefan Hiermaier	
Organizer	
Department of Sustainable Systems Engineering, Professorship in Sustainable Engineering Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement

keine | none

Recommended requirement

Any basics in any of the following areas would be helpful but are not mandatory:

- system description and modelling
- graphical/ semiformal modelling
- product and development life cycles
- classical system analysis
- reliability analysis for any engineering discipline, e.g. electronics, computer science, mechanical, civil and aerospace engineering
- Machine Learning/Artificial Intelligence (ML/AI) methods

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Functional Safety, Security and Sustainability: Active Resilience	lecture course	Core elective	3.0	2.0	90 h

Qualification

Main goals include:
1. Know main (emerging) application domains, e.g. digitalized production, transport, aerospace, AI safety, and renewable energy
2. Knowledge how to achieve acceptable overall safety (risk control), security, sustainability, and resilience of socio-technical (safety relevant and critical) systems through reliable functions
3. Knowledge and tailoring of definitions, types and effects of reliability functions
4. Relation of functional safety to related concepts for security and sustainability generation

5. Knowledge and tailoring of safety life cycle, development processes and process steps to plan, develop, verify and validate reliability or safety functions
6. Knowledge, tailoring, process-driven application, quantification and evaluation, executive conclusions development, and litigable documentation of mainly quantitative system analysis methods
7. Knowledge of required development methods and how to combine and tailor them for achieving functional safety
8. Know failure types and how to avoid and control them with techniques and measures for hardware and software
9. Knowledge and application of assessment quantities for reliable functions, e.g. safety integrity level (on demand or continuous), hardware failure tolerance, diagnostic coverage, safe failure fraction, complexity level
10. Understanding of the role of ML/AI approaches as part of considered systems or of the functional safety process and methods, and related emerging options
11. Knowledge of reliability prediction methods and related standards
12. Applicable knowledge of related standardization landscape

Examination achievement
Written supervised examination at the end of the semester covering the content of the lecture and its embedded exercises contributing 100% to the final grade. Duration: 90 minutes. Important info for exchange students: the exam must be taken at the official examination date.
Course achievement
None
Usability
Elective module for students of the study program ■ M.Sc. in Sustainable Systems Engineering (PO 2021) in the technical concentration area *Resilience Engineering* ■ M.Sc. in Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. in Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. in Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of module	Number of module
Functional Safety, Security and Sustainability: Active Resilience	11LE68MO-5120 ESE PO 2021
course	
Functional Safety, Security and Sustainability: Active Resilience	
Event type	Number
lecture course	11LE68V-5120 PO 2021
Organizer	
Department of Sustainable Systems Engineering-VB	

ECTS-Points	3.0
Workload	90 h
Attendance	26 h
Independent study	64 h
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Main content:

1. Definition of functional safety, safety functions, safety integrity level (SIL), safety related systems and related key quantities, e.g. hardware failure tolerance (HFT), complexity, diagnostic coverage (DC), safe failure fraction (SFF)
2. Relation and transfer of functional safety to reliability, availability, security, IT-security, sustainability, and resilience
3. Functional safety, security, sustainability and resilience life cycle models (management and development processes): general and phase-specific requirements
4. System definition and graphical/semi-formal modelling for system analysis, e.g. with UML and SysML
5. Inductive analytical tabular system analysis methods: e.g. hazard analyses (PHL, PHA, SSH, O and SHA, HAZOP), hazard log, failure mode and effects analysis (FMEA, FMEDCA), double failure matrix
6. (Deductive) Graphical system analysis methods: Fishbone diagram, Event Tree Analysis, Reliability block diagram (RBDs), Fault tree analysis (FTA, TDFTA)
7. Markov models and Petri nets
8. (Semi) Quantification and evaluation of system analysis methods, e.g. using risk priority numbers, parts count and parts stress, reliability prediction standards, Boolean algebra and importance measures for FTA, quantitative measures for graph-based methods, computation and simulation approaches for Markov and Petri models
9. Overview on methods for requirements determination, e.g. SIL: graphical, numerical, analytical, statistical, simulation based using individual and collective risk criteria
10. Safety and reliability function architecture allocation, e.g. MooN, MooND
11. Overview on techniques and measures for hardware and software to avoid and control systematic errors of hardware and software and to avoid and control statistic errors of hardware
12. Combination and tailoring of processes and methods
13. Application domains and examples: e.g. automation, production, automotive, transport, energy generation, systems with ML/AI, e.g. autonomous driving

14. Use of ML/AI for safety assessment and development
15. Standardization landscape, e.g. functional safety standards IEC 61508, ISO 26262 and safety of intended functionality ISO/PAS 21448
16. Emerging standards, future risk control and resilience generation challenges, e.g. AI and superintelligence control

Students are encouraged to volunteer to present a recently published journal article of their choice. The article selection according to their interests is supported.

Qualification

Examination achievement

See module

Course achievement

See module

Literature

Sample literature:

1. Satisfying safety goals by probabilistic risk analysis, Hiromitsu Kumamoto, Springer 2007
2. Modern statistical and mathematical methods in reliability, Alyson Wilson et. al. (eds.), World Scientific, 2005
3. Mathematical and statistical methods in reliability, Bo H Lindqvist and Kyell A Doksum, World Scientific, 2003
4. Hazard analysis techniques for system safety, Clifton A. Ericson, Wiley, 2015
5. FRAM: the functional resonance analysis method, Erik Hollnagel, Ashgate, 2012
6. Synesis: The Unification of Productivity, Quality, Safety and Reliability, Erik Hollnagel, Ashgate, 2020
7. Control systems safety evaluation and reliability, William M. Gobe, 2010
8. System reliability theory: models, statistical methods and applications, Marvin Rausand, Arnljot Hoyland, Wiley-Interscience, 2004
9. Risk assessment: theory, methods, and application, Marvin Rausand, Wiley, 2011
10. Reliability of safety-critical systems: theory and applications, Marvin Rausand, Wiley, 2014
11. Risk and resilience: methods and application in environment, cyber and social domains, Eds.: Igor Linkov, Jose Manuel Palma-Oliviera, Springer, 2017
12. Functional safety for road vehicles: new challenges and solutions for e-mobility and automated driving, Hans-Leo Ross, Springer, 2016
13. Functional Safety of Machinery: Sample Questions and Solutions, Jagadeesh-Pandiyan, author’s edition, 2019
14. Functional safety in practice, Harvey T Dearden, CreateSpace Independent Publishing Platform, 2018
15. Modeling for reliability analysis: Markov modeling for reliability, maintainability, safety, and supportability analyses of complex systems, Jan van Pukite, Paul Pukite, Wiley-IEEE Press, 1998
16. Applied reliability engineering and risk analysis: probabilistic models and statistical inference, Editor(s): Ilia B. Frenkel, Alex Karagrigoriou, Anatoly Lisnianski, Andre Kleyner, John Wiley & Sons, 2013
17. Reliability engineering: theory and practice, Alessandro Birolini, Springer, 2013
18. Electronic safety systems: hardware concepts, models, calculations, Josef Börcsök, Hüthig, 2004
19. Functional Safety: Basic Principles of Safety-related Systems, Josef Börcsök, Hüthig, 2020
20. Zuverlässigkeitstechnik, Arno Meyna and Bernhard Pauli, Hanser, 2010
21. The safety critical systems handbook, David J. Smith, Butterworth-Heinemann, 2010
22. Reliability and availability engineering: modeling, analysis, and applications, Kishor S. Trivedi, Andrea Bobbio, Cambridge University Press, 2017
23. Embedded Software Development for Safety-Critical Systems, Chris Hobbs, CRC Press, 2019
24. Dynamic Probabilistic Systems, Volume I: Markov Models, Ronand A. Howard, Dover publications, 2012

25. Dynamic Probabilistic Systems, Volume II: Semi-Markov and Decision Processes, Ronand A. Howard, Dover publications, 2013
26. Fault-Tolerant Systems, Israel Koren, C. Mani Krishna, Morgan Kaufmann Publisher, 2020
27. Semi-Markov Processes: Applications in System Reliability and Maintenance, Franciszek Grabski, Elesevier, 2014
28. Risk analysis and management: engineering resilience, Ivo Häring, Springer 2015
29. A Primer in Petri Net Design, Wolfgang Reisig, Springer, 1992
30. Ereignisdiskrete Systeme: Modellierung und Analyse dynamischer Systeme mit Automaten, Markovketten und Petrinetzen, Jan Lunze, De Gruyter, 2017
31. System Modeling and Control with Resource-Oriented Petri Nets, MengChu Zhou, Routledge, 2017
32. Formal Methods in Computer Science, Jiacun Wang, William Tepfenhart, Taylor & Francis, 2019
33. Technical Safety, Reliability and Resilience: Methods and Processes, I. Häring, Springer, 2021
34. From event to performance function-based resilience analysis and improvement processes for more sustainable systems, I. Häring, J. Schäfer, et al., International Journal of Sustainable Materials and Structural Systems, 5(1/2), 2021, pp.90 - 120
35. Functional safety assessment of distributed predictive heating and cooling systems for electric delivery vehicles, Y. Satsrisakul, I. Häring, et al., ESREL 2021

Further information:
Sample related standards for information
- https://www.iec.ch/functionalsafety/
- https://www.iso.org/standard/68383.html
- https://www.iso.org/standard/70939.html

Recent publications: https://scholar.google.com/citations?user=luyHvrkAAAAJ&hl=en

Compulsory requirement
None
Recommended requirement
Any basics in any of the following areas would be helpful but are not mandatory: ■ system description and modelling ■ graphical/ semiformal modelling ■ product and development life cycles ■ classical system analysis ■ reliability analysis for any engineering discipline, e.g., ■ electronics, computer science, mechanical, civil and aerospace ■ engineering ■ Machine Learning/Artificial Intelligence (ML/AI) methods
Teaching method
Lecture with integrated exercises.

↑

Name of module	**Number of module**
Hardware-Entwicklung mit der Finite-Elemente-Methode	11LE50MO-5503 ESE PO 2021
Responsible	
Prof. Dr. Jürgen Wilde	
Organizer	
Department of Microsystems Engineering, Assembly and Packaging Technology	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Kenntnisse in Assembly and Packaging Technology oder Aufbau- und Verbindungstechnik | Knowledge of assembly and packaging technology or packaging and interconnection technology

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Hardware-Entwicklung mit der Finite-Elemente-Methode / Hardware Design with the Finite-Element-Method - Praktische Übung	practical course	Core elective	6.0	4.0	180 Stunden

Qualification
It is the aim, that after this module, the student will know the fundamental physical problems in electronic hardware based on own numerical investigations. The student will have elementary capabilities to solve praxis-relevant design problems in assembly and packaging of MEMS using a professional finite-element-system. He/she will know how experiments can be replaced by simulation and what the necessary input data are. He/she will be able to work with the Finite-Element-Code and to modify complex existing models. Furthermore it is expected that the student will have improved capabilities in the analysis of industrial problems and on reporting of the corresponding results.

Examination achievement
Graded protocols and a written examination based on the protocols. If the number of participants is very small, an oral examination may be held instead of the written exam. The students will be informed in good time.
Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of module	**Number of module**
Hardware-Entwicklung mit der Finite-Elemente-Methode	11LE50MO-5503 ESE PO 2021
course	
Hardware-Entwicklung mit der Finite-Elemente-Methode / Hardware Design with the Finite-Element-Method - Praktische Übung	
Event type	Number
practical course	11LE50P-5503

ECTS-Points	6.0
Workload	180 Stunden
Attendance	60
Independent study	120
Hours of week	4.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	german

Contents
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement
none
Recommended requirement
Knowledge in Assembly and Packaging Technology or Aufbau- und Verbindungstechnik

↑

Name of module	**Number of module**
High-performance computing: Distributed-memory parallelization on GPUs and accelerators	11LE50MO-5284 ESE PO 2021
Responsible	
Prof. Dr. Lars Pastewka	
Organizer	
Department of Microsystems Engineering, Simulation	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden/hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
None
Recommended requirement
Experience with programing in C++ or Fortran or Python; knowledge of common hardware architectures will be useful

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Höchstleistungsrechnen: Parallelisierung auf verteilten GPUs und Acceleratoren / High-performance computing: Distributed-memory parallelization on GPUs and accelarators	lecture course	Core elective	6.0	2.0	180 hours
Höchstleistungsrechnen: Parallelisierung auf verteilten GPUs und Acceleratoren / High-performance computing: Distributed-memory parallelization on GPUs and accelarators	excercise course	Core elective		2.0	

Qualification
After completing this class, the student will be able to… * …understand the difference between vectorization, shared-memory and distributed-memory parallelization * …write vectorized code for GPUs or accelerators using a hardware abstraction layer (such as Kokkos, Fortran, JAX or others) * …write distributed-memory code using the Message Passing Interface (MPI)

* …understand the foundations of the Lattice Boltzmann Method and how to parallelize it
Examination achievement
mündlicher Vortrag / oral examination Erstellung von Demonstratoren oder Software / Development of demonstrators or software
Course achievement
keine / none
Usability
As compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering and M.Sc. Mikrosystemtechnik ■ M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	Number of module
High-performance computing: Distributed-memory parallelization on GPUs and accelerators	11LE50MO-5284 ESE PO 2021
course	
Höchstleistungsrechnen: Parallelisierung auf verteilten GPUs und Acceleratoren / High-performance computing: Distributed-memory parallelization on GPUs and accelarators	
Event type	Number
lecture course	11LE50V-5284 PO 2021
Organizer	
Department of Microsystems Engineering, Simulation	

ECTS-Points	6.0
Workload	180 hours
Attendance	60 on site
Independent study	120 self study
Hours of week	2.0
Recommended semester	2
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
* Hardware architectures * Vectorization, shared-memory and distributed memory parallelization * Low-level interfaces to GPUs and accelerators: CUDA, HIP * Abstraction layers for GPUs and accelerators: Kokkos, SYCL, Fortran and Python * Message Passing Interface (MPI) * Fluid Dynamics * Lattice Boltzmann Method * Domain decomposition
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement
None
Recommended requirement
Experience with programing in C++ or Fortran or Python; knowledge of common hardware architectures will be useful

↑

Name of module	**Number of module**
High-performance computing: Distributed-memory parallelization on GPUs and accelerators	11LE50MO-5284 ESE PO 2021
course	
Höchstleistungsrechnen: Parallelisierung auf verteilten GPUs und Acceleratoren / High-performance computing: Distributed-memory parallelization on GPUs and accelarators	
Event type	Number
excercise course	11LE50Ü-5284 PO 2021
Organizer	
Department of Microsystems Engineering, Simulation	

ECTS-Points	
Hours of week	2.0
Recommended semester	2
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
Throughout the term, the students will implement a parallel Lattice Boltzmann solver that can run on heterogeneous architectures. Students will be divided in groups that use different programming languages and programming models.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
High-Performance Computing: Fluid Mechanics with Python	11LE50MO-5285 ESE PO 2021
Responsible	
Prof. Dr. Lars Pastewka	
Organizer	
Department of Microsystems Engineering, Simulation	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Höchstleistungsrechnen mit Python / High-Performance Computing with Python	lecture course	Core elective	6.0	2.0	180 Stunden
Höchstleistungsrechnen mit Python / High-Performance Computing with Python - Project	excercise course	Core elective		2.0	

Qualification
The student ■ can use Python for solving numerical problems using the numpy and scipy libraries and knows 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.
Examination achievement
Written examination. The students have to submit a written report, describing numerical results and scaling tests obtained with their simulation code.

Course achievement
none
Usability
■ Students enrolled in the Master of Science in Sustainable Systems Engineering (2021 version of the exam regulations) can complete this elective module in the technical concentration area *Sustainable Materials Engineering* or *Interdisciplinary Profile - Modules related to the Subject Area.*

↑

Name of module	**Number of module**
High-Performance Computing: Fluid Mechanics with Python	11LE50MO-5285 ESE PO 2021
course	
Höchstleistungsrechnen mit Python / High-Performance Computing with Python	
Event type	Number
lecture course	11LE50V-5285
Organizer	
Department of Microsystems Engineering, Simulation	

ECTS-Points	6.0
Workload	180 Stunden
Attendance	52 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective

Contents
This class teaches parallel scientific computing with Python using the numpy library for fast array operations. Parallelization strategies that use the Message Passing Interface (MPI) will be presented. These technical concepts will be applied to the solution of fluid mechanical problems using the lattice Boltzmann method. Scientific computing: 1. Efficient Python: basics, numpy arrays, numpy operations, scipy 2. Translating mathematical expressions into efficient array operations 3. The Message Passing Interface (MPI) 4. Parallelization strategies 5. Practical aspects of working with High-Performance clusters Fluid mechanics and the Lattice Boltzmann method: 6. Phenomenology of fluid mechanics 7. Lattice gas and lattice Boltzmann 8. Boundary conditions
Examination achievement
See module level
Course achievement
See module level
Literature
A. Scopatz, K.D. Huff, "Effective Computation in Physics" (O'Reilly 2015) W.A. Wolf-Gladrow, "Lattice-Gas Cellular Automata and Lattice Boltzmann Models" (Springer 2000)

T. Krüger, H. Kusumaatmaja, A. Kuzmin, O. Shardt, G. Silva, E.M. Viggen, "The Lattice Boltzmann Method" (Springer 2017)
Compulsory requirement
None
Recommended requirement
Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)

↑

Name of module	**Number of module**
High-Performance Computing: Fluid Mechanics with Python	11LE50MO-5285 ESE PO 2021
course	
Höchstleistungsrechnen mit Python / High-Performance Computing with Python - Project	
Event type	Number
excercise course	11LE50Ü-5285
Organizer	
Department of Microsystems Engineering, Simulation	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The students will implement their own parallel Lattice Boltzmann simulation code in the computer lab accompanying this lecture series.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement
None
Recommended requirement
Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)

↑

Name of module	**Number of module**
High-Performance Computing: Molecular Dynamics with C++	11LE50MO-5288 ESE PO 2021
Responsible	
Prof. Dr. Lars Pastewka	
Organizer	
Department of Microsystems Engineering, Simulation	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
None
Recommended requirement
Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
High-Performance Computing: Molecular Dynamics with C++	lecture course	Core elective	6.0	2.0	180 hours
Molekularstatik und Molekulardynamik / Molecular Statics and Molecular Dynamics Veranstaltung_2	excercise course	Core elective		2.0	-

Qualification
The student ■ understands the physics of interatomic bonds, potential energy landscapes and the statistical foundations of thermodynamics ■ can transfer these concepts to molecular simulations, in particular interatomic potentials, transition paths, thermostats and barostats ■ can select initial conditions and interatomic potentials, run a molecular dynamics simulation and evaluate and interpret the simulation results
Examination achievement
Written report

Course achievement
There are exercises at regular intervals that have to be worked on and handed in.These are corrected and assessed with points. The course work is passed if 50% of the excercise sheets have been successfully completed.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentrations Area: Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) in Microsystems Engineering Concentrations Area: Materials and Fabrication ■ Students enrolled in the Master of Science in Sustainable Systems Engineering (2021 version of the exam regulations) can complete this elective module in the technical concentration area *Sustainable Materials Engineering.*

↑

Name of module	**Number of module**
High-Performance Computing: Molecular Dynamics with C++	11LE50MO-5288 ESE PO 2021
course	
High-Performance Computing: Molecular Dynamics with C++	
Event type	Number
lecture course	11LE50V-5286
Organizer	
Department of Microsystems Engineering, Simulation	

ECTS-Points	6.0
Workload	180 hours
Attendance	56 Stunden
Independent study	124 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
This lecture introduces atomic-scale simulation techniques with a focus on solid mechanics. 1. Materials physics 2. Interatomic potentials 3. Molecular statics and potential energy landscapes 4. Molecular dynamics 5. Classical statistical mechanics 6. Thermostats and barostats 7. Analysis and visualization
Examination achievement
see module details
Course achievement
see module details
Literature
Understanding Molecular Simulation: From Algorithms to Applications, Daan Frenkel and Berend Smit (Academic Press, 2001) Computer simulation of liquids, M. P. Allen and Dominic J. Tildesley (Clarendon Press, Oxford, 1996)
Compulsory requirement
None

Recommended requirement
Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)

↑

Name of module	**Number of module**
High-Performance Computing: Molecular Dynamics with C++	11LE50MO-5288 ESE PO 2021
course	
Molekularstatik und Molekulardynamik / Molecular Statics and Molecular Dynamics Veranstaltung_2	
Event type	Number
excercise course	11LE50Ü-5286
Organizer	
Department of Microsystems Engineering, Simulation	

ECTS-Points	
Workload	-
Attendance	-
Independent study	-
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The students will solve problems from materials science with a widely used molecular simulation code. Successful completion of >=50% of exercise sheets
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)

↑

Name of module	**Number of module**
Introduction to (Bioinspired) Programmable Meta Materials	11LE50MO-5287 PO 2021
Responsible	
Prof. Dr. Christoph Eberl	
Organizer	
Department of Microsystems Engineering, Micro and Materials Mechanics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden / hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
Keine / none
Recommended requirement
Bachelor in engineering or natural sciences and related studies.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Introduction to (Bioinspired) Programmable Meta Materials	lecture course	Core elective	6.0	2.0	180 Stunden / hours
Introduction to (Bioinspired) Programmable Meta Materials	excercise course	Core elective		2.0	

Qualification
Concluding this course enables you to design programmable mechanical metamaterials. You will know how to prototype such materials and be able to characterize their behavior. You will be able to relate algorithms from biological model systems which can be implemented into programmable materials. You will understand the mechanics behind it.
Examination achievement
Prüfungsgespräch / oral examination

Course achievement
Referat, Vortrag / presentation There will be lab courses where characterization methods will be introduced. Students will design, simulate or manufacture programmable metamaterials and present their project at the end.

↑

Name of module	**Number of module**
Introduction to (Bioinspired) Programmable Meta Materials	11LE50MO-5287 PO 2021
course	
Introduction to (Bioinspired) Programmable Meta Materials	
Event type	Number
lecture course	11LE50V-5287 PO 2021
Organizer	
Department of Microsystems Engineering, Micro and Materials Mechanics	

ECTS-Points	6.0
Workload	180 Stunden / hours
Attendance	52 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	2
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

1. Programmable Materials: from properties to abilities (should we combine the first two?)
2. The introduction of mechanical metamaterials and their manufacturing and possible applications
3. Learning from nature – plant mechanics and function integration in biological role models
4. Semantic description of materials
5. Calculating analytical relationships for the mechanical properties of 2D and 3D metamaterials
6. Simulation of the mechanical metamaterials unit cells and lattices under periodic boundary condition.
7. Introducing nonlinearities and instabilities such as buckling and bistability in metamaterials (Mechanisms, Simulations and experimental examples)
8. Structural and mechanical characterization: how to measure complex structurers as well as nonlinear and discontinuous behavior
9. How to introduce algorithms into programmable mechanical meta materials (Simulation and Experiments)
10. Programming mechanical metamaterials for specific functionalities
11. An introduction to forward and inverse design with machine learning
12. Manufacturing of (programmable) meta materials and the semantic description of manufacturing
13. Wrap-up

Examination achievement

Course achievement

Compulsory requirement

Keine / none

Recommended requirement

Bachelor in engineering or natural sciences and related studies.

↑

Name of module	**Number of module**
Introduction to (Bioinspired) Programmable Meta Materials	11LE50MO-5287 PO 2021
course	
Introduction to (Bioinspired) Programmable Meta Materials	
Event type	Number
excercise course	11LE50Ü-5287 PO 2021
Organizer	
Department of Microsystems Engineering, Micro and Materials Mechanics	

ECTS-Points	
Hours of week	2.0
Recommended semester	2
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Students learn the application of the courses content in the excercises. Students will design, simulate or manufacture programmable metamaterials and present their project at the end.
Examination achievement
Course achievement
Compulsory requirement

↑

Name of module	**Number of module**
Keramische Werkstoffe der Mikrotechnik	11LE50MO-5102 ESE PO 2021
Responsible	
Prof. Dr. Thomas Hanemann	
Organizer	
Department of Microsystems Engineering, Materials Processing	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Kenntnisse der Werkstoffwissenschaft, z.B. Zustandsdiagramme, physikalische Eigenschaften verschiedener Materialklassen, Kristallsysteme, thermodynamische Eigenschaften und Kinetik kristalliner und nichtkristalliner Festkörper | Knowledge of materials science, e.g., state diagrams, physical properties of various classes of materials, crystal systems, thermodynamic properties and kinetics of crystalline and non-crystalline solids

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Keramische Werkstoffe der Mikrotechnik / Ceramic Materials for microsystems - Lecture	lecture course	Core elective	3.0	2.0	90 Stunden

Qualification
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. | The aim of the module is to teach the technological and physical fundamentals of ceramic materials and the associated processing methods. Aspects of ceramic materials and their processing methods relevant to microsystems technology will be demonstrated.

Examination achievement
Written exam (90 minutes) If the number of participants is small, an oral examination (30 minutes) may be held instead. The students will be informed in good time.
Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area:Materials and Fabrication

↑

Name of module	Number of module
Keramische Werkstoffe der Mikrotechnik	11LE50MO-5102 ESE PO 2021
course	
Keramische Werkstoffe der Mikrotechnik / Ceramic Materials for microsystems - Lecture	
Event type	Number
lecture course	11LE50V-5102
Organizer	
Department of Microsystems Engineering, Materials Processing	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	german

Contents
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 Vorlesung schließt mit einer Einführung in Sinterprozesse. Es besteht die Möglichkeit, im Anschluss an die Vorlesung ein ca. 2-wöchiges Blockpraktikum zu absolvieren. Dieses dient dazu die in der Vorlesung theoretisch behandelten Themen praktisch umzusetzen.
Examination achievement
siehe Modulebene
Course achievement
keine
Literature
Begleitend zur Vorlesung wird ein Skriptum und werden Handzettel der Vorlesungsfolien zur Verfügung gestellt.
Compulsory requirement
keine

Recommended requirement
Kenntnisse der Werkstoffwissenschaft, z.B. Zustandsdiagramme, physikalische Eigenschaften verschiedener Materialklassen, Kristallsysteme, thermodynamische Eigenschaften und Kinetik kristalliner und nichtkristalliner Festkörper

↑

Name of module	**Number of module**
Lithographie	11LE50MO-5603 ESE PO 2021
Responsible	
Prof. Dr. Claas Müller	
Organizer	
Department of Microsystems Engineering, Process Technology	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Lithographie / Lithography - Lecture	lecture course	Core elective	3.0	2.0	90 Stunden

Qualification
Ziel des Moduls ist die Vermittlung der Kenntnisse, die für ein ganzheitliches Verständnis der lithographischen Verfahren, die in der Mikrosystemtechnik eingesetzt werden, notwendig sind. The aim of the module is to provide the knowledge necessary for a holistic understanding of the lithographic processes used in microsystems technology.
Examination achievement
Oral exam (approx. 20 - 30 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area:Materials and Fabrication

↑

Name of module	Number of module
Lithographie	11LE50MO-5603 ESE PO 2021
course	
Lithographie / Lithography - Lecture	
Event type	Number
lecture course	11LE50V-5603
Organizer	
Department of Microsystems Engineering, Process Technology	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	german

Contents

- Optische Mikroskopie
- Hellfeld Beleuchtung
- Dunkelfeld Beleuchtung
- Aperturblende
- Geschichtsfeldblende
- Aufbau und Funktion von Photoresisten
- Positiv und negativ Resiste
- Chemischer Aufbau der Resiste
- Lithographische Masken
- Herstellung
- Materialien
- Aufbau
- Grenzen
- Aufbau und Funktion von Maskaligner
- Justage Vorderseite und Rückseite
- Belichtungsmodi
- Prozessablauf und Prozessketten
- Charakterisierung von lithographisch hergestellten Strukturen
- Weiterführende Prozessvarianten

Examination achievement

siehe Modulebene

Course achievement

keine

Literature
Begleitend zur Vorlesung wird ein Skriptum zur Verfügung gestellt und regelmäßig aktualisiert.
Compulsory requirement
keine

↑

Name of module	**Number of module**
Machine Learning Approaches in Structural Mechanics	11LE50MO-5722 PO 2021
Responsible	
Prof. Dr. Lars Pastewka Dr. Viacheslav Slesarenko	
Organizer	
Department of Microsystems Engineering, Simulation	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Machine Learning Approaches in Structural Mechanics	lecture course	Core elective	6.0	2.0	
Machine Learning Approaches in Structural Mechanics	excercise course	Core elective		2.0	

Qualification
After the completion of the module, students will be able to: 1. Understand different neural network topologies and their possible applications in mechanical engineering and structural mechanics; 2. Understand the interplay between optimization and machine learning; 3. Analyze and augment datasets obtained via experiments or simulations; 4. Program simple architectures and make predictions on the mechanical behavior of materials and structures; 5. Understand the limitations of proposed approaches and the ways to overcome them using state-of-art publications.
Examination achievement
Prüfungsgespräch / oral examination (idR 30-45 Minuten/usually 30 or 45 minutes)

Course achievement
Protokoll / written lab report: ■ Each student has to solve one practical problem using appropriate studied machine learning techniques, analyze obtained results, and provide a written report accompanying the code. Sample problems will be provided, however, students are encouraged to explore other problems from mechanical engineering after prior approval by the lecturer. Among provided problems are: predicting the properties in mechanical lattices, detecting the crack; obtaining the critical load of the heterogeneous column.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	**Number of module**
Machine Learning Approaches in Structural Mechanics	11LE50MO-5722 PO 2021
course	
Machine Learning Approaches in Structural Mechanics	
Event type	Number
lecture course	11LE50V-5722 PO 2021
Organizer	
Department of Microsystems Engineering, Simulation	

ECTS-Points	6.0
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
This course is designed mainly for students with an engineering background who want to understand machine learning and get hands-on experience in programming artificial neural networks. Using examples from mechanical engineering (primarily structural mechanics), students will learn the main ML approaches (NN, SVM, anomaly detection, DL, etc.). They will understand how to implement corresponding ML architectures in popular frameworks, such as TensorFlow and scikit-learn. Students will learn how to obtain initial datasets, process them, choose the best-suited approaches and what to do with obtained results. The classical forward (structure - properties) and inverse (properties - structure) problems will be discussed.
Examination achievement
see module details
Course achievement
see module details
Literature
Ryan G. McClarren, Machine Learning for Engineers. Springer, 2021 Andriy Burkov, The Hundred-Page Machine Learning Book. 2019 Aurélien Géron, Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow. O'Reilly Media Inc., 2019
Compulsory requirement
None
Recommended requirement
Programming skills and basic knowledge of Python. Understanding of Solid Mechanics will be beneficial.

↑

Name of module	**Number of module**
Machine Learning Approaches in Structural Mechanics	11LE50MO-5722 PO 2021
course	
Machine Learning Approaches in Structural Mechanics	
Event type	Number
excercise course	11LE50Ü-5722 PO 2021
Organizer	
Department of Microsystems Engineering, Simulation	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
During the course, students will complete four practice programming exercises devoted to different aspects of machine learning in mechanical engineering and solid mechanics. Students must score at least 50% on each of these practice exercises. Additionally, a detailed report on one of these exercises will be requested as a prerequisite for admission to the examination.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Memory Device Technology	11LE50MO-5726 PO 2021
Responsible	
JProf. Dr. Alwin Stefan Daus	
Organizer	
Department of Microsystems Engineering, Professorship in Sensors	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
None
Recommended requirement
Basic knowledge on semiconductor physics and semiconductor devices. Having completed the module micro-electronics before taking this module is recommended.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Memory Device Technology	lecture course	Core elective	6.0	2.0	180 Stunden / hours
Memory Device Technology	excercise course	Core elective		2.0	

Qualification

After completion of the module, -

- the students know various classical memory and storage device types, technologies and working principles.
- the students can explain the working principle of various emerging memory device types.
- the students know about the different memory performance parameters, how they are measured and how different memory device technologies compare in those metrics
- the students know how the physical integration and realization of different memory device types is realized
- the students can explain limitations of different memory device technologies
- the students can explain how the basic material properties of each memory device type enable and affect the memory behavior

▪ the students can explain how emerging memristive devices are beneficial to enable in-memory computing and neuromorphic hardware
Examination achievement
Prüfungsgespräch / oral examination
Course achievement
Referat, Vortrag / Presentation

↑

Name of module	**Number of module**
Memory Device Technology	11LE50MO-5726 PO 2021
course	
Memory Device Technology	
Event type	Number
lecture course	11LE50V-5726 PO 2021
Organizer	
Department of Microsystems Engineering, Professorship in Sensors	

ECTS-Points	6.0
Workload	180 Stunden / hours
Attendance	52 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	2
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

This course provides an overview on different memory device technologies. The classical memory and storage device types include static random-access memory, dynamic random-access memory, flash, hard disk drive and tape storage. The emerging memory device types include magnetic memory, phase-change memory, resistive random-access memory, ferroelectric memory and electrochemical memory. Along with the basic device concepts, the underlying physics and material properties enabling the memory functionality are explained. The various important performance parameters for memory devices are discussed. New application directions such as in-memory computing and neuromorphic computing hardware are introduced and the requirements for memory devices to be used in such scenarios are discussed.

Examination achievement

Course achievement

Presentation on implemented memory device model and functionality in circuit

Literature

1. Daniele Ielmini, Rainer Waser, "Resistive Switching: From Fundamentals of Nanoionic Redox Processes to Memristive Device Applications", 2016 Wiley-VCH, DOI: 10.1002/9783527680870
2. Jennifer Rupp, Daniele Ielmini, Ilia Valov, "Resistive Switching: Oxide Materials, Mechanisms, Devices and Operations", Springer, DOI: 10.1007/978-3-030-42424-4
3. Andrea Redaelli, Fabio Pellizzer, "Semiconductor Memories and Systems", Elsevier, ISBN 9780128209462

Compulsory requirement

None

Recommended requirement
Basic knowledge on semiconductor physics and semiconductor devices. Having completed the module micro-electronics before taking this module is recommended.

↑

Name of module	**Number of module**
Memory Device Technology	11LE50MO-5726 PO 2021
course	
Memory Device Technology	
Event type	Number
excercise course	11LE50Ü-5726 PO 2021

ECTS-Points	
Hours of week	2.0
Recommended semester	2
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The exercise will recap and deepen on most important aspects of the lecture. In addition, the students will learn how to develop and incorporate emerging memory device models in a compact modeling environment. They will then simulate the behavior of such devices in simple circuits.
Examination achievement
Course achievement
Compulsory requirement

↑

Name of module	**Number of module**
Methoden der Materialanalyse / Methods of Material Analysis	11LE50MO-5126 ESE PO 2021
Responsible	
Prof. Dr. Margit Zacharias	
Organizer	
Department of Microsystems Engineering, Nanotechnology	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Methoden der Materialanalyse / Methods of Material Analysis	lecture course	Core elective	3.0	2.0	90 hours

Qualification
The module gives an overview of all state of the art measurement and analysis methods for thin films and nanoscopic structures. Special emphasis will be placed on the prospects and drawbacks of each method as well as on typical limits and potential measurement artifacts. Educational objective is to enable students to find a suitable and appropriate method to measure or detect a certain material property of interest.
Examination achievement
Written exam (usually 90 to 180 minutes) If the number of participants is small, an oral examination may be held instead. The students will be informed in good time.
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area:Materials and Fabrication

↑

Name of module	Number of module
Methoden der Materialanalyse / Methods of Material Analysis	11LE50MO-5126 ESE PO 2021
course	
Methoden der Materialanalyse / Methods of Material Analysis	
Event type	Number
lecture course	11LE50V-5126
Organizer	
Department of Microsystems Engineering, Nanotechnology	

ECTS-Points	3.0
Workload	90 hours
Attendance	26 SS; 30 WS
Independent study	64 SS; 60 WS
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
The treated measurement and analysis techniques include optical, electrical, chemical and structural methods which detect and probe material properties like morphology/shape, film thickness, crystallinity, chemical composition, trace impurities, bonding configurations, bandgap, etc. Namely methods like AFM, SEM / TEM, APT, SIMS, XPS, SE, PL, FTIR, Raman, XRD, C-V / I-V, RBS and many more will be dealt with.
Examination achievement
siehe Modulebene
Course achievement
keine
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
Microstructured Polymer Components	11LE50MO-5604 ESE PO 2021
Responsible	
Prof. Dr. Thomas Hanemann	
Organizer	
Department of Microsystems Engineering, Materials Processing	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Mikrostrukturierte Kunststoffkomponenten / Microstructured Polymer Components - Lecture	lecture course	Core elective	3.0	2.0	90 Stunden

Qualification
Besides silicon and the established MEMS/MOEMS technology polymer materials and the related microreplication technologies are becoming more and more important for the realization and commercial success of new microcomponents and microsystems. New nanostructuring methods like 2-photon-stereolithography and others are at the threshold of leaving the laboratory status and entering market. The course will cover the large variety of polymer materials, their fundamental chemical and physical properties and the derived microstructuring and replication possibilities. Direct and indirect micro- and nanostructuring methods like deep X-ray lithography, stereolithography, laser machining, nanoimprinting and others as well as the large family of replication methods like hot embossing and injection molding will be described in detail. Master and tooling fabrication methods like electroplating, electro discharge machining as well as mechanical and laser micromachining will be presented and discussed intensely. A large number of application examples and case studies dealing with the accessible geometries, feasibility, and process characteristics will be used for the presentation of the polymer microfabrication importance.

Examination achievement
written examination (90 minutes) if number of participants is small, oral exam (30 minutes) instead students will be informed in good time
Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	Number of module
Microstructured Polymer Components	11LE50MO-5604 ESE PO 2021
course	
Mikrostrukturierte Kunststoffkomponenten / Microstructured Polymer Components - Lecture	
Event type	Number
lecture course	11LE50V-5604
Organizer	
Department of Microsystems Engineering, Materials Processing	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	30
Independent study	60
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Contents:

- Polymers: Fundamental chemical and physical properties
- Fabrication of molding tools: Fabrication principles and characteristics
- Rapid Prototyping in microsystem technology
- Polymer replication techniques: Reaction Molding, UV-Embossing, Hot Embossing and Injection Molding: Principles, equipment, applications and case studies
- From micro to nano: Nanoimprinting, soft lithography, nanostereolithography and other new developments

Examination achievement

see module details

Course achievement

none

Literature

- W. Ehrfeld, Handbuch Mikrotechnik, Hanser-Verlag, München, 2002, ISBN: 3-446-21506-9
- W. Menz, J. Mohr, O. Paul, Microsystem Technology, Wiley-VCH, Weinheim, 2001, ISBN: 3-527-29634-4

Compulsory requirement

↑

Name of module	**Number of module**
Optimierung	11LE13MO-720 ESE PO 2021
Responsible	
Prof. Dr. Thomas Brox	
Organizer	
Department of Computer Science, Pattern Recognition and Image Processing Department of Computer Science, Bioinformatics	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	3.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Grundlagenkenntnisse in Mathematik Grundlegende Kenntnisse zu Programmierung und Algorithmen Praktische Programmierkenntnisse in Python | Basic knowledge of mathematics Basic knowledge of programming and algorithms Practical programming knowledge in Python

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Optimization - Lecture	lecture course	Compulsory	3.0	2.0	90 Stunden
Optimization - Exercises	excercise course	Compulsory		1.0	

Qualification
Bei Optimierungsverfahren handelt es sich um Algorithmen, denen eine konkrete Zielfunktion zugrunde liegt, die es zu optimieren gilt. Für fast alle mathematisch fundierten Algorithmen ist dies der Fall. Studierende lernen, welche Optimierungsprobleme es gibt und wie sie gelöst werden können. Sie sollen die Schwierigkeit von Optimierungsproblemen analysieren und einschätzen lernen und in die Lage versetzt werden, die besprochenen Optimierungsverfahren in Anwendungsfällen einzusetzen. |

Optimization methods are algorithms that are based on a concrete objective function that has to be optimized. This is the case for almost all mathematically based algorithms. Students learn which optimization problems exist and how they can be solved. They will learn to analyze and assess the difficulty of optimization problems and be enabled to use the discussed optimization methods in application cases.
Examination achievement
Written exam (usually 90 to 180 minutes)
Course achievement
There are exercises at regular intervals that have to be worked on and handed in. These are corrected and assessed with points. The course work is passed if at least 50% of the total points are achieved in the semester.
Usability
As compulsory elective for students of the study pogram ■ M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Microsystems Engineering Concentrations Area: Materials and Fabrication ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ Master of Education Erweiterungsfach Informatik ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (Optionsbereich Individuelle Studiengestaltung) ■ Bachelor of Science in Mikrosystemtechnik (PO 2018), im Wahlpflichtbereich, Bereich Mikrosystemtechnik Compulsory course for students of the study pogram ■ B.Sc. in Embedded Systems Engineering (PO 2018) ■ B.Sc. in Informatik (PO 2018)

↑

Name of module	Number of module
Optimierung	11LE13MO-720 ESE PO 2021
course	
Optimization - Lecture	
Event type	Number
lecture course	11LE13V-720
Organizer	
Department of Computer Science, Algorithms and Data Structures Department of Computer Science, Algorithms and Complexity Department of Computer Science, Pattern Recognition and Image Processing Department of Computer Science, Bioinformatics	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	30
Independent study	45
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Language	german

Contents
Die Vorlesung gibt eine Einführung in die allgemeine Problematik und erklärt, wie sich viele Aufgaben der Informatik als Optimierungsprobleme formulieren lassen. Es werden die grundlegenden Verfahren und Konzepte der Optimierung vorgestellt; das Hauptaugenmerk liegt auf kontinuierlicher Optimierung. Anschließend werden Konvexität, lineare und quadratische Programme, Gradientenverfahren sowie einige approximative Verfahren behandelt. Die Vorlesung wird von größtenteils praktischen übungen begleitet. Durch theoretische und praktische Übungen wird der Stoff anschaulich vertieft.
Examination achievement
Siehe Modulebene
Course achievement
Siehe Modulebene
Literature
Nocedal-Wright: Numerical Optimization (Englisch)
Compulsory requirement
keine
Recommended requirement
Grundlagenkenntnisse in Mathematik Grundlegende Kenntnisse zu Programmierung und Algorithmen Praktische Programmierkenntnisse in Python

↑

Name of module	**Number of module**
Optimierung	11LE13MO-720 ESE PO 2021
course	
Optimization - Exercises	
Event type	Number
excercise course	11LE13Ü-720
Organizer	
Department of Computer Science, Algorithms and Data Structures Department of Computer Science, Algorithms and Complexity Department of Computer Science, Pattern Recognition and Image Processing Department of Computer Science, Bioinformatics	

ECTS-Points	
Attendance	15
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Language	german

Contents
In den Übungen werden einzelne Verfahren eigenständig in der Sprache Python implementiert, andere Verfahren werden anhand vorhandener Bibliotheken (z.B. SciPy) ausprobiert um praktische Erfahrungen in der Anwendung dieser Verfahren zu sammeln. Für einige der Übungen sind theoretische Vorleistungen zu erbringen, um das Verfahren umsetzen zu können. Das Überprüfen fremder Lösungen ist ebenfalls Teil der Übungen.
Examination achievement
Siehe Modulebene
Course achievement
Siehe Modulebene
Compulsory requirement

↑

Name of module	**Number of module**
Optimierung von Fertigungsverfahren	11LE50MO-5607 ESE PO 2021
Responsible	
Prof. Dr. Claas Müller	
Organizer	
Department of Microsystems Engineering, Process Technology	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
■ Statistical Basics ■ Fundamentals of Manufacturing Technology ■ Processes of microsystem technology (clean room fabrication and conventional environment)

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Optimierung von Fertigungsverfahren / Advanced engineering - Lecture	lecture course	Core elective	3.0	2.0	90 Stunden

Qualification
Statistische Grundlagen zur Regelung komplexer technischer Prozesse Optimierung von Fertigungsverfahren nach unterschiedlichen Zielgrößen Erweiterung statistischer Methoden auf Führungs-und Organisationsstrukturen | Statistical fundamentals for the control of complex technical processes Optimization of manufacturing processes according to different target variables Extension of statistical methods to management and organizational structures
Examination achievement
Written exam (duration 90 minutes) If number of participants is low, oral exam instead (duration 20 - max. 30 minutes)

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	Number of module
Optimierung von Fertigungsverfahren	11LE50MO-5607 ESE PO 2021
course	
Optimierung von Fertigungsverfahren / Advanced engineering - Lecture	
Event type	Number
lecture course	11LE50V-5607
Organizer	
Department of Microsystems Engineering, Process Technology	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	german

Contents

- Statistische Versuchsplanung
- Toleranzen und Toleranzketten
- FMEA
- Prozess und Maschinenfähigkeit
- Six Sigma
- Kaizen_PDCA
- One Piece Flow

Examination achievement

siehe Modulebene

Course achievement

keine

Literature

- George E. P. Box, Statistics for Experimenters: An Introduction to Design, Data Analysis, and Model Building (Wiley Series in Probability and Statistics)
- Manufacturing Processes & Materials Hardcover – July, 2000 by George F. Schrade
- Effective FMEAs: Achieving Safe, Reliable, and Economical Products and Processes using Failure Mode and Effects Analysis Hardcover – May 15, 2012 by Carl Carlson
- The Practical Application of the Process Capability Study: Evolving From Product Control to Process Control [Kindle Edition] Douglas B. Relyea
- The Process Improvement Handbook: A Blueprint for Managing Change and Increasing Organizational Performance Hardcover – October 15, 2013 by Tristan Boutros

Compulsory requirement
keine
Recommended requirement
Statistical Basics Fundamentals of Manufacturing Technology Processes of microsystem technology (clean room fabrication and conventional environment)

↑

Name of module	**Number of module**
Physics of Failure	11LE50MO-5121 ESE PO 2021
Responsible	
Prof. Dr. Stefan Hiermaier	
Organizer	
Department of Sustainable Systems Engineering, Professorship in Sustainable Engineering Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Physics of Failure	lecture course	Core elective	3.0	2.0	90 h

Qualification
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.
Examination achievement
Oral examination (Prüfungsgespräch), duration: approx. 20 min. per student. The oral exam covers the content of the lecture.
Course achievement
none

Usability

Compulsory elective module for students of the study program
 	
■ Master of Science in Sustainable Systems Engineering (2021 version of the exam regulations):
    ■ Resilience Engineering
    ■ Sustainable Materials Engineering
■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication
■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse
■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area:Materials and Fabrication

↑

Name of module	**Number of module**
Physics of Failure	11LE50MO-5121 ESE PO 2021
course	
Physics of Failure	
Event type	Number
lecture course	11LE68V-5121
Organizer	
Department of Sustainable Systems Engineering, Professorship in Sustainable Engineering Systems	

ECTS-Points	3.0
Workload	90 h
Attendance	30 h
Independent study	60 h
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Fracture mechanics
- crack propagation and opening modes
- energy release rate
- crack tip stress state (stress intensity factors, J integral)
- cohesive zone model

Failure of materials
- failure criteria models (Tresca, Hill…)
- failure surfaces
- stress triaxiality (e.g. Johnson-Cook)

Damage mechanics
- strength degradation
- damage accumulation models

The theoretical, experimental, numerical and empirical approaches to the topics are accompanied with many examples from science and industry.

Examination achievement

See module

Course achievement

See module

Literature

Information will be given during the lecture.

Compulsory requirement
None
Recommended requirement
None
Teaching method
Lecture

↑

Name of module	**Number of module**
Polymer Processing and Microsystems Engineering	11LE50MO-5124 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Bastian Rapp	
Organizer	
Department of Microsystems Engineering, Process Technology	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Polymer Processing and Microsystems Engineering - Lecture	lecture course	Core elective	3.0	2.0	90 hours

Qualification
This course will teach students the various types of polymers in practical use today, the methods required for characterizing them, the processing techniques that are used to shape these polymers including polymer molding as well as 3D Printing. The lecture will cover fundamental aspects of polymer science and characterization as well as industrial process technology both for microsystems as well as scalable manufacturing.
Examination achievement
Oral exam with a duration of 30 minutes
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication Wahlpflichtmodul für Studierende des Studiengangs ■ Master of Science in Sustainable Systems Engineering - Nachhaltige Materialien / Sustainable Materials

↑

Name of module	**Number of module**
Polymer Processing and Microsystems Engineering	11LE50MO-5124 ESE PO 2021
course	
Polymer Processing and Microsystems Engineering - Lecture	
Event type	Number
lecture course	11LE50V-5124
Organizer	
Department of Microsystems Engineering, Chemistry and Physics of Interfaces Department of Microsystems Engineering, Materials Processing Department of Microsystems Engineering, Process Technology	

ECTS-Points	3.0
Workload	90 hours
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Polymers are ubiquitous in the 21st century. As a material class, polymers have seen an astonishing gain in academic and industrial significance since their first introduction into the market more than 140 years ago. One of the most striking advantages of polymers is their ease of processing in which they outperform almost any other material known to humankind. This lecture introduces the fundamentals of polymer processing focusing on techniques such as injection molding, hot embossing, thermoforming and nanoimprinting. These techniques represent the most important reforming processes. We will also explore additive manufacturing and 3D Printing including stereo lithography, powder-based as well as inkjet printing and fused deposition modeling. The didactical concept underlying the lecture is built on a combination of material science and instrumentation development and thus represents a holistic view onto the broad field of technical polymer processing.
Examination achievement
see module details
Course achievement
none
Literature
Various materials will be provided through the ILIAS online learning tool.
Compulsory requirement

↑

Name of module	**Number of module**
Quantum Mechanics for Engineers	11LE50MO-5273 ESE PO 2021
Responsible	
Prof. Dr. Oliver Paul	
Organizer	
Department of Microsystems Engineering, Microsystem Materials	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Physik I + II / physics I + II Mathematik I + II / mathematics I + II Festkörperphysik / solid state physics Halbleiter / semiconductors Elektronik / electronics Differentialgleichungen / differential equations

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Quantenmechanik für Ingenieure / Quantum mechanics for engineers - Lecture	lecture course	Core elective	6.0	2.0	180 hours
Quantenmechanik für Ingenieure / Quantum mechanics for engineers - Exercises	excercise course	Core elective		2.0	

Qualification
The goal is to introduce the students to the main effects of quantum mechanics relevant in technical micro and nano devices. Current semiconductor components in which quantum mechanics plays a role are discussed. The course successively develops the basic mathematical methods required to solve problems in one, two, and three dimensions. The understanding is deepened by exercises.

Examination achievement
Oral examination if there are 20 or fewer than 20 registered participants; written examination if there are more than 20 registered participants (minimum 60 and maximum 240 minutes). Details will be announced by the examiner in due time
Course achievement
The course work ("Studienleistung") consists of (1) the documented, successful attempt to solve more than 60% of the homework problems (as checked weekly); "60% of the homework problems" means the fraction of the overall number of homework problems proposed during the course, not of each homework problem separately; "successful" means that the solution could be presented by the student in front of the class; (2) the presentation of a representative number of solutions of homework problems in front of the class.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	**Number of module**
Quantum Mechanics for Engineers	11LE50MO-5273 ESE PO 2021
course	
Quantenmechanik für Ingenieure / Quantum mechanics for engineers - Lecture	
Event type	Number
lecture course	11LE50V-5273
Organizer	
Department of Microsystems Engineering Department of Microsystems Engineering, Microsystem Materials	

ECTS-Points	6.0
Workload	180 hours
Attendance	52 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
1. Introduction: historical overview, probability amplitudes, uncertainty relation 2. Wave mechanics: Schrödinger equation, separation of variables, free particle, reflection at wall, potential step, transfer matrix method, wave packets 3. Tunneling: principle, semiconductor tunneling devices, potential barriers, WKB approximation, triangular potential wall 4. Bound states, resonances, and band structure: potential well, tunneling between wells, infinite series of potential wells, 1D harmonic oscillator nanoparticles, impurity levels in semiconductors 5. Operators and state spaces, commensurate operators and quantum numbers, perturbation theory, energy matrix diagonalization 6. 3D problems, angular momentum, hydrogen atom and 3D harmonic oscillator
Examination achievement
see module details
Course achievement
see module details
Literature
A script will be handed out during the course. Material for further reading will be indicated therein.
Compulsory requirement
None

Recommended requirement
Undergraduate knowledge in the field of physics, mathematics, solid state physics, semiconductors, electronics and differential equations.

↑

Name of module	**Number of module**
Quantum Mechanics for Engineers	11LE50MO-5273 ESE PO 2021
course	
Quantenmechanik für Ingenieure / Quantum mechanics for engineers - Exercises	
Event type	Number
excercise course	11LE50Ü-5273
Organizer	
Department of Microsystems Engineering, Microsystem Materials	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The exercises will deepen the topics treated during the lecture. They will allow the students to rethink and rework the more theoretical aspects and apply them to realistic examples inspired from real devices or use them to expand the theoretical framework of the lecture. Solution approaches to the homework problems will be presented weekly by the participants and discussed and elaborated upon with the group of colleagues under the guidance of the professor. This discursive, participative approach allows to learn more than by being presented with up-front oral or written solutions.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
Undergraduate knowledge in the field of physics, mathematics, solid state physics, semiconductors, electronics and differential equations.

↑

Name of module	**Number of module**
Quantification of Resilience	11LE50MO-4110 ESE PO 2021
Responsible	
Prof. Dr. Stefan Hiermaier	
Organizer	
Department of Sustainable Systems Engineering, Professorship in Sustainable Engineering Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement

none

Recommended requirement

Any basics in any of the following areas would be helpful but are not mandatory:
- system description and modelling
- graphical/ semiformal modelling
- product and development life cycles
- classical system analysis
- reliability analysis for any engineering discipline, e.g. electronics, computer science, mechanical, civil and aerospace engineering

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Quantification of Resilience	lecture course	Core elective	3.0	2.0	90 h

Qualification

Main learning objectives include:
1. Know main (emerging) application domains, e.g. digitalized production, transport, aerospace, AI safety, and renewable energy
2. Knowledge how to achieve acceptable overall safety (risk control), security, sustainability, and resilience of socio-technical (safety relevant and critical) systems through reliable functions
3. Knowledge and tailoring of definitions, types and effects of reliability functions
4. Relation of functional safety to related concepts for security and sustainability generation
5. Knowledge and tailoring of safety life cycle, development processes and process steps to plan, develop, verify and validate reliability or safety functions

6. Knowledge, tailoring, process-driven application, quantification and evaluation, executive conclusions development, and litigable documentation of mainly quantitative system analysis methods 7. Know how to efficiently combine and tailor modern system analysis methods 8. Know failure types and how to avoid and control them with techniques and measures for hardware and software 9. Knowledge and application of assessment quantities for reliable functions, e.g. safety integrity level (on demand or continuous), hardware failure tolerance, diagnostic coverage, safe failure fraction, complexity level 10. Knowledge of reliability prediction methods and related standards 11. Applicable knowledge of related standardization landscape
Examination achievement
The *Prüfungsleistung* is a written supervised examination at the end of the semester covering the content of the lecture and its embedded exercises contributing 100% to the final grade, duration: 90 min.
Course achievement
None
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	**Number of module**
Quantification of Resilience	11LE50MO-4110 ESE PO 2021
course	
Quantification of Resilience	
Event type	Number
lecture course	11LE68V-4110
Organizer	
Department of Sustainable Systems Engineering-VB	

ECTS-Points	3.0
Workload	90 h
Attendance	30 h
Independent study	60 h
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Main contents comprise:

1. Context, basic definitions, objectives and options of resilience quantification: resilience management processes, resilience quantification and development processes
2. System (service) performance based resilience quantification
3. Method types for resilience quantification, resilience dimensions, and resilience method taxonomy
4. Qualitative and semi-quantitative resilience assessments: ontologies, process schemes, quantification and evaluation
5. Resilience dimensional order expansions and resulting quantification bounds
6. Application of classical system analysis approaches, e.g. deterministic inductive and deductive system analysis methods
7. Advanced system analysis methods, in particular time, system phase and system trajectory dependent methods such as TDFT, non-classical Markov models, Petri nets and stochastic processes
8. System graph-based and topological approaches: system definition, identification of disruption vector, response and recovery determination and response strategy optimization
9. Resilience quantification based on multiple event propagation through resilience analysis layers: heuristics vs. formalization, resilience transition matrix elements, related statistical-empirical, probabilistic, engineering and physical-simulative methods, forward and backward propagation methods
10. Input-output models, operability models: discrete and continuous
11. Coupled agent-supported engineering grid-model approaches for overall system modelling, simulation and resilience determination: operator, prosumer and consumer models; organizational, policy and framing models
12. Combination of resilience quantification approaches
13. Optimization problems in resilience engineering
14. For all resilience quantification approaches: model assumptions, application domains, application examples, typical input and output data, acceptance of modeling approach

15. Use of Machine Learning (ML) and artificial intelligence (AI) as support and stand-alone approaches for resilience quantification of systems
16. Standards, emerging standards and ongoing standardization efforts

Examination achievement
See module
Course achievement
See module
Literature

Sample literature includes:

1. Vulnerable systems, Wolfgang Kröger and Enrico Zio, Springer, 2011
2. Catalogue of risks: natural, technical, social and health risks, Dirk Proske, Springer, 2008
3. Resilience engineering: models and analysis, Nii O. Attoh-Okine, Cambridge University Press, 2016
4. Exploring Resilience: A Scientific Journey from Practice to Theory, Siri Wiig, Springer, 2018
5. Urban resilience for emergency response and recovery: fundamental concepts and applications, Gian Paolo Cimellaro, Springer, 2016
6. Resilience quantification of urban areas: An integrated statistical-empirical-physical approach for man-made and natural disruptive events, Kai Fischer, Dissertation, Fraunhofer Verlag, 2018
7. Risk assessment and decision analysis with Bayesian networks, Norman Fenton and Martin Neil, CRC Press, 2013
8. Risk analysis and management: engineering resilience, Ivo Häring, Springer 2015
9. Principles of cyber-physical systems, Rajeev Alur, MIT Press, 2015
10. Cyber-physical systems: from theory to practice, Danda B. Rawat, Joel J.P.C. Rodrigues, and Ivan Stojmenovic (eds.), CRC Press, 2016
11. Cyber-physical systems: integrated computing and engineering design, Fei Hu, CRC Press, 2013
12. Agent-based modelling of socio-technical systems, Koen H. van Dam, Igor Nikolic and Zoifia Lukszo (eds.), 2012, Springer
13. Introduction to agent-based modeling, Uri Wilenski, Springer, 2015
14. Transdisciplinary Systems Engineering: Exploiting Convergence in a Hyper-Connected World, Azad M. Madni, Springer, 2018
15. Optimization Under Uncertainty with Applications to Aerospace Engineering, Massimiliano Vasile (editor), Springer, 2020
16. The science and practice of resilience, Igor Linkov, Benjamin Trump, Springer, 2020
17. Design of coastal hazard mitigation alternatives for rising seas, David Basco, World Scientific Publishers, 2020
18. Resilience and risk, methods and application in environment, cyber and social domains, Editors: Igor Linkov, José Manuel Palma-Oliveira, Springer, 2017
19. Resilience Engineering for Urban Tunnels, Editors: Michael Beer, Hongwei Huang, Bilal M. Ayyub, Dongming Zhang, Brian M. Philips, American Society of Civil Engineers, 2018
20. Resilience of Critical Infrastructure Systems: Emerging Developments and Future Challenges, Editors: Zhishen Wu, Xilin Lu, Mohammad Noori, CRC Press, 2020
21. Mathematical Modelling of System Resilience, Kanchan Das, Mangey Ram, River Publishers, 2019
22. Technical Safety, Reliability and Resilience: Methods and Processes, Ivo Häring, Springer, 2021
23. 2Critical Information Infrastructure Protection and Resilience in the ICT Sector, Editors: Sandro Bologna, Paul Theron, Information Science Reference, 2013
24. Industrial Control Systems Security and Resiliency: Practice and Theory, Editors: Craig Rieger, Indrajit Ray, Quanyan Zhu, Michael A. Haney, Springer 2019
25. Critical Infrastructures Resilience: Policy and Engineering Principles, Auroop Ratan, Ganguly, Udit Bhatia, Stephen E. Flynn, Taylor and Francis, 2018

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
https://ascelibrary.org/ajrua6/resilience_quantification_modeling_decision_making

Search for the term resilience on the following web sites of standardization organizations: http://www.din.de/en/, http://www.iso.org, http://www.iec.ch, https://ansi.org

Recent publications:
https://scholar.google.com/citations?user=luyHvrkAAAAJ&hl=en

Compulsory requirement
None
Recommended requirement
Basic knowledge in any single or more of the following domains would be helpful, without being mandatory: ■ system theory, modeling, analysis and simulation ■ finite state machine modelling, discrete system models ■ graphical/ semi-formal system modelling languages ■ failure, damage and physics of failure modelling ■ statistics, probability theory, stochastic processes ■ engineering models for adverse, damaging, disruptive or extreme loads or events ■ network and graph modeling, graph theory ■ physical-engineering modelling of critical infrastructure structures, components and systems, e.g. of electricity, water, wastewater, and green gas grids ■ coupled physical models ■ modeling and simulation of cyber-physical socio-technical systems, world models
Teaching method
Lecture with embedded exercises including contextualization and discussion of short students' journal paper presentations.

↑

Name of module	**Number of module**
Robot Mechanics	11LE50MO-5727 PO 2021
Responsible	
JProf. Dr. Edoardo Milana	
Organizer	
Department of Microsystems Engineering, Professorship in Soft Machines	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Foundations in mechanics, calculus, geometry

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Robot Mechanics	lecture course	Core elective	3.0	2.0	90 Stunden | hours
Robot Mechanics	excercise course	Core elective		2.0	

Qualification
This course provides students with the knowledge and tools needed to model and analyze robotic manipulators, with an emphasis on mechanical performance. Students will learn how to analyze robotic systems, model their kinematics and dynamics, and design manipulators based on operational requirements. Application of this knowledge includes designing, modeling, and evaluating robots using real-world examples. Students demonstrate their understanding by presenting real-world use cases and demonstrate their ability to select and evaluate robot types for specific manipulation tasks.
Examination achievement
Klausur | written exam
Course achievement
keine | none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Microsystems Engineering Concentrations Area Materials and Fabrication ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. in Sustainable Systems Engineering (PO 2021), Interdisciplinary Profile ■ M.Sc. Informatik / Computer Science (PO 2020), in Spezialvorlesung | Specialization Courses

↑

Name of module	**Number of module**
Robot Mechanics	11LE50MO-5727 PO 2021
course	
Robot Mechanics	
Event type	Number
lecture course	11LE50V-5727 PO 2021
Organizer	
Department of Microsystems Engineering, Professorship in Soft Machines	

ECTS-Points	3.0
Workload	90 Stunden | hours
Attendance	64 Stunden | hours
Independent study	26 Stunden | hours
Hours of week	2.0
Recommended semester	2
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Kinematic chains, joints, mobility, types of manipulators, reference frames, forward kinematics, inverse kinematics, Jacobian, trajectory planning, dynamics
Qualification
This course provides students with the knowledge and tools needed to model and analyze robotic manipulators, with an emphasis on mechanical performance. Students will learn how to analyze robotic systems, model their kinematics and dynamics, and design manipulators based on operational requirements. Application of this knowledge includes designing, modeling, and evaluating robots using real-world examples. Students demonstrate their understanding by presenting real-world use cases and demonstrate their ability to select and evaluate robot types for specific manipulation.
Examination achievement
siehe Moduleebene | see module level
Course achievement
siehe Moduleebene | see module level
Literature
Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, and Giuseppe Oriolo. 2008. Robotics: Modelling, Planning and Control (1st. ed.). Springer Publishing Company, Incorporated.
Compulsory requirement
keine | none
Recommended requirement
Foundations in mechanics, calculus, geometry

↑

Name of module	**Number of module**
Robot Mechanics	11LE50MO-5727 PO 2021
course	
Robot Mechanics	
Event type	Number
excercise course	11LE50Ü-5727 PO 2021
Organizer	
Department of Microsystems Engineering, Professorship in Soft Machines	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The exercises will reinforce the lecture material through practical sample problems. The lecture includes the theoretical framework of Robot Mechanics, whereas the exercise session provides the students with the possibility to apply their acquired knowledge to solve applied problems, such as calculating the number of degrees of freedom of a rigid-body mechanism, to compute rotation matrices and to solve direct kinematics of planar/3D robots. Exercise problems are not graded and do not count for the final course grade, they are meant to help the students preparing for the final exam.
Examination achievement
siehe Modulebene | see module level
Course achievement
siehe Modulebene | see module level
Compulsory requirement

↑

Name of module	Number of module
Soft Robotics	11LE50MO-5374 ESE PO 2021
Responsible	
JProf. Dr. Edoardo Milana	
Organizer	
Department of Microsystems Engineering, Professorship in Soft Machines	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden/hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Soft Robotics	lecture course	Core elective	6.0	2.0	180 hours
Soft Robotics - Projekt	Alle Arten, soweit keine ständige Betreuung der Studierenden erforderlich ist	Core elective		2.0	

Qualification
The objective of this course it to provide students of engineering with the basics of Soft Robotics. Thus, the following topics will be addressed: - design and modeling of soft robots - soft actuation principles - materials and fabrication processes - control of soft robots - multifunctional embodiement
Examination achievement
oral examination oral presentation The final grade will be a weighted average of the project presentation (30%) and oral exam (70%)

↑

Name of module	Number of module
Soft Robotics	11LE50MO-5374 ESE PO 2021
course	
Soft Robotics	
Event type	Number
lecture course	11LE50V-5374
Organizer	
Department of Microsystems Engineering, Professorship in Soft Machines	

ECTS-Points	6.0
Workload	180 hours
Hours of week	2.0
Recommended semester	3
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The students will learn how to design, fabricate and control robots made of soft and deformable materials. Models of soft manipulators based on beam theory and piecewise constant strain approximation will be introduced. We will study the main soft actuation mechanisms, such as inflatable actuators, electroactive polymers, magnetorheological elastomers, liquid crystal elastomers. Different manufacturing techniques will be analysed, in the context of polymer molding and additive manufacturing. Further, we will see some examples of model-based control for soft robots. Finally, the concept of multifunctional embodiement of sensing, actuation, control and energy will be discussed.
Examination achievement
See module level
Course achievement
See module level
Literature
Della Santina, Cosimo, et al. "Soft robots." Encyclopedia of Robotics 489 (2020). Rus, Daniela, and Michael T. Tolley. "Design, fabrication and control of soft robots." Nature 521.7553 (2015): 467-475. Gorissen, Benjamin, et al. "Elastic inflatable actuators for soft robotic applications." Advanced Materials 29.43 (2017): 1604977. Suzumori et al "The Science of Soft Robots: Design, Materials and Information Processing", Springer (2023)
Compulsory requirement
None
Recommended requirement
Continuum Mechanics (Solid and Fluid), Electromagnetism, Thermodynamics

↑

Name of module	**Number of module**
Soft Robotics	11LE50MO-5374 ESE PO 2021
course	
Soft Robotics - Projekt	
Event type	Number
Alle Arten, soweit keine ständige Betreuung der Studierenden erforderlich ist	11LE50P-5374
Organizer	
Department of Microsystems Engineering, Professorship in Soft Machines	

ECTS-Points	
Hours of week	2.0
Recommended semester	3
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
During the course there will be a project assignment, where the students will be divided in groups and will be given a design challenge for a soft robotic system with specific requirements in terms of operational environment and locomotion modes.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	Number of module
Solar Energy	11LE50MO-8060 ESE PO 2021
Responsible	
Prof. Dr. Stefan Glunz	
Organizer	
Department of Sustainable Systems Engineering, Professorship in Photovoltaic Energy Conversion	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Basic understanding of physics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Solar Energy	lecture course	Compulsory		4.0	180 h
Solare Energie / Solar Energy - Exercises	excercise course	Compulsory		1.0	

Qualification
Students will be able to understand the fundamentals and different technology variants of solar energy conversion such 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.
Examination achievement
Written supervised exam, duration: 120 min.
Course achievement
Regular attendance of the exercise workshops according to §13 (2) of the General Examination Regulations for the Master of Science and submission of exercise sheets.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication ■ M.Sc. in Sustainable Systems Engineering (PO 2021) in the technical concentration area *Energy Systems Engineering*

↑

Name of module	**Number of module**
Solar Energy	11LE50MO-8060 ESE PO 2021
course	
Solar Energy	
Event type	Number
lecture course	11LE68V-8060
Organizer	
Department of Sustainable Systems Engineering, Professorship in Photovoltaic Energy Conversion	

ECTS-Points	
Workload	180 h
Attendance	60 h
Independent study	120 h
Hours of week	4.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Language	english
Group size	50

Contents

- 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, condenser 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)

The lecture will be accompanied by weekly exercises and simulation workshops to deepen the lecture's content and to apply state-of-the-art simulation software to design and describe complete energy systems.

Examination achievement

See module

Course achievement
See module
Literature
■ 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 ■ 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
Compulsory requirement
None
Recommended requirement
Basic understanding of physics
Teaching method
Lecture with accompanied, weekly exercise

↑

Name of module	Number of module
Solar Energy	11LE50MO-8060 ESE PO 2021
course	
Solare Energie / Solar Energy - Exercises	
Event type	Number
excercise course	11LE68Ü-8060
Organizer	
Department of Sustainable Systems Engineering, Professorship in Photovoltaic Energy Conversion	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents
■ The lecture will be accompanied by a weekly exercise to deepen the understanding of the lecture's content and to discuss further details
Examination achievement
See module
Course achievement
See module
Compulsory requirement

↑

Name of module	**Number of module**
Surface Analysis	11LE50MO-5606-1 ESE PO 2021
Responsible	
Prof. Dr. Jürgen Rühe	
Organizer	
Department of Microsystems Engineering, Chemistry and Physics of Interfaces	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Oberflächenanalyse / Surface Analysis - Lecture	lecture course	Core elective	3.0	2.0	90 Stunden

Qualification
XPS, TEM, FTIR, UPS, SEM, AFM, SPR, GIR, ATR, STM?? Got it? The performance of microsystems is often dominated by the nature of the surfaces involved. This course honours the great importance of surfaces and interfaces in microsystems engineering by introducing the most common techniques for surface analysis. Examples will be presented which are typical to various fields of microsystems engineering.
Examination achievement
Written examination with a duration of 90 minutes
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	**Number of module**
Surface Analysis	11LE50MO-5606-1 ESE PO 2021
course	
Oberflächenanalyse / Surface Analysis - Lecture	
Event type	Number
lecture course	11LE50V-5606-1
Organizer	
Department of Microsystems Engineering, Chemistry and Physics of Interfaces	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
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.
Examination achievement
siehe Modulebene/see module details
Course achievement
keine/none
Literature
Various materials are available on the website.
Compulsory requirement
none

↑

Name of module	**Number of module**
Surface Analysis Laboratory	11LE50MO-5311 ESE PO 2021
Responsible	
Prof. Dr. Jürgen Rühe	
Organizer	
Department of Microsystems Engineering, Chemistry and Physics of Interfaces	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Oberflächenanalyse – Praktikum / Surface Analysis Laboratory	practical course	Core elective	3.0	2.0	90 hours

Qualification
In microsystems, especially those for microfluidics, surface effects can no longer be neglected due to the small volume. In many cases, the properties of the surface even dominate the behavior of the overall system. The same can be said for components that are brought into contact with biological fluids, for example, as sensors. Therefore, surface analysis is of central importance for many questions relevant in microsystems technology. In the practical course, selected surface analytical techniques will be presented and their respective strengths and limitations will be demonstrated by means of examples. As examples, problems are chosen that frequently occur in the "life sciences".
Examination achievement
For each experiment, students need to hand in a protocol which will be graded. The final grade is calculated according to the weighed arithmetic mean of the individual protocol grades.

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	**Number of module**
Surface Analysis Laboratory	11LE50MO-5311 ESE PO 2021
course	
Oberflächenanalyse – Praktikum / Surface Analysis Laboratory	
Event type	Number
practical course	11LE50P-5311

ECTS-Points	3.0
Workload	90 hours
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
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
Examination achievement
see module details
Course achievement
none
Literature
see script
Compulsory requirement
none

Recommendation
Findet am Lehrstuhl statt

↑

Name of module	**Number of module**
Surface coating Techniques	11LE50MO-5109 ESE PO 2021
Responsible	
Prof. Dr. Jürgen Rühe	
Organizer	
Department of Microsystems Engineering, Chemistry and Physics of Interfaces	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Techniken zur Oberflächenmodifizierung / Surface coating Techniques - Lecture	lecture course	Core elective	3.0	2.0	90 Stunden

Qualification
This module describes all aspects of surface modification as often used in microsystems engineering. It tackles questions on the chemistry of the various approaches and discusses the advantages and shortcomings of a number of methods. Among the techniques presented are high energy surface oxidation techniques (chemical modification, flame treatment, corona discharge or plasma) as well as more elaborate approaches such as sef-assembled monolayers. Special emphasis is given to the use of polymers for coatings.
Examination achievement
written examination with duration of 90 minutes
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	**Number of module**
Surface coating Techniques	11LE50MO-5109 ESE PO 2021
course	
Techniken zur Oberflächenmodifizierung / Surface coating Techniques - Lecture	
Event type	Number
lecture course	11LE50V-5109
Organizer	
Department of Microsystems Engineering, Chemistry and Physics of Interfaces	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	30
Independent study	60
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Among the techniques presented are high energy surface oxidation techniques (chemical modification, flame treatment, corona discharge or plasma) as well as more elaborate approaches such as self-assembled monolayers. Special emphasis is given to the use of polymers for coatings and techniques will be described that yield surface attached polymer monolayers and multilayer assemblies. Examples from current research topics will be discussed.
Examination achievement
siehe Modulebene
Course achievement
keine
Compulsory requirement
none

↑

Name of module	**Number of module**
Verbindungshalbleiter	11LE50MO-5111 ESE PO 2021
Responsible	
Prof. Dr. Oliver Ambacher	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Verbindungshalbleiter / Compound semiconductor devices - Lecture	lecture course	Core elective	3.0	2.0	90 Stunden

Qualification
The aim of the Compound Semiconductor Devices lecture is to promote a pictorial understanding of the physical relationships in semiconductor materials, enabling students to quickly familiarize themselves with unknown materials based on their lattice structure and electron configuration. Subsequently, the students know the differences between compound semiconductors and classical semiconductor materials such as silicon and can compare them with each other. Special material properties of compound semiconductors such as pyroelectricity and piezoelectricity have been understood and their relevance for devices is now known. In addition, after attending the lecture, students know the basics of compound semiconductor-based devices such as High Electron Mobility Transistors (HEMTs), Light Emitting Diodes (LEDs), Quantum Cascade Lasers (QCLs) and various detectors for infrared and UV light and can narrow down which compound semiconductors are suitable for which applications and can also justify this.
Examination achievement
oral exam (90 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	Number of module
Verbindungshalbleiter	11LE50MO-5111 ESE PO 2021
course	
Verbindungshalbleiter / Compound semiconductor devices - Lecture	
Event type	Number
lecture course	11LE50V-5111
Organizer	
Department of Sustainable Systems Engineering, Professorship in Power Electronics	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	30
Independent study	60
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective

Contents
Spannende und neue physikalische Eigenschaften ergeben sich aus den immer kleiner werdenden Abmessungen von mechanischen, elektrischen und optischen Bauelementen aus Verbindungshalbleitern (GaN, GaAs, InP). In einer Einführung in die Welt der Verbindungshalbleiter-Mikrosysteme wird die Physik sowie die Technologie zur Herstellung von kleinsten Leuchtdioden und Lasern, mikromechanischen Filtern und Resonatoren sowie kleinsten Sensoren zur Analyse biologischer Prozesse vorgestellt. Neuartige Bauelemente aus Verbindungshalbleitern werden in ihrer Funktionsweise erläutert und ihre Relevanz für unser tägliches Leben dargestellt.
Examination achievement
siehe Modulebene
Course achievement
keine
Literature
Nanoelectronics and Information Technology Rainer Waser (Ed.) 2003 WILEY-VCH Verlag GmbH & Co ISBN 3-527-40363-9 Nanophysik und Nanotechnologie Horst-Günter Rubahn 2002 Teubner GmbH ISBN 3-519-00331-7
Compulsory requirement
Grundkenntnisse in Halbleiter- und Festkörperphysik

Recommended requirement
Bachelor-Abschluss (Ingenieur- oder Naturwissenschaften)

↑

Name of module	**Number of module**
MSE Study Project in Concentration Materials and Fabrication	11LE13MO-5998 ESE SP-MF
Responsible	
Prof. Dr.-Ing. Bastian Rapp	
Faculty	
Faculty of Engineering	

ECTS-Points	9.0
Workload	270 Studen / hours
Hours of week	
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
none
Recommended requirement
allgemeine mathematische Grundlagen, praktische und theoretische Grundlagen der Ingenieurswissenschaften, Programmierkenntnisse, themenspezifische Vorkenntnisse für den gewählten Themenbereich | general fundamental mathematical knowledge, practical and theoretical foundations in Engineering Sciences, programming skills, subject-specific knowledge for the chosen topics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload

Qualification
In this module students get involved in the actual research process of the chosen work group/chair in the area of Materials and Fabrication. Depending on their personal field of interest and their expertise in various research and teaching areas offered at the Department of Microsystems Engineering, they decide on a specific topic and deepen their knowledge and skills in this area as well as their overall proficiency in academic work and research. They learn to work on the different tasks required for the specific project under given technical specifications, to develop appropriate systems and to work experimentally and constructively in projects. Students acquire the ability to familiarize themselves with new engineering problems and do independent background research. They will work with modern development environments and adhere to the generally accepted quality standards. During the project, working in a team as well as observing the rules of good scientific work will be trained.
Examination achievement
The graded assessment is (depending on the topic) either a written research paper (if it is rather a theoretical or fundamentally based topic; length usually maximum 40 pages) or the creation of a software or a demonstrator including a sufficient documentation (according to the scientific standards) and subsequent discussion. Details are agreed upon with the supervisor (usually a person authorized to conduct examinations at the Department of Microsystems Engineering) when the topic is assigned.

Course achievement
As a rule, the course work consists of the following components: - regular attendance of (team) meetings or discussions with the supervisor - oral presentation (usually 20 - 30 minutes) with subsequent discussion
Recommendation
Language is usually English, but might be negotiable (changed to German). Please learn about the procedure of finding a topic and registering for the project in good time. (For instance, see "A to Z - Study FAQ" under "Studies and Teaching" on our faculty website.) Students are expected to self-organize the given tasks and do background research.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of node	**Number of node**
Biomedical Engineering	11LE50KT-MSc-787-2021-MSE-BE
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Compulsory

↑

Name of module	**Number of module**
Biointerfaces I - Basics for Bioanalytical Systems	11LE50MO-5406_1 ESE PO 2021
Responsible	
Prof. Dr. Jürgen Rühe	
Organizer	
Department of Microsystems Engineering, Chemistry and Physics of Interfaces	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Grundlagen der Molekurlarbiologie für bioanalytische Systeme / Basics in Molecular Biology for Bioanalytical Systems	lecture course	Core elective	3.0	2.0	90 hours

Qualification
The learning objective is the understanding of the basic methods for the analysis of biomolecules and their technical requirements. The participant will acquire an understanding of methods of DNA analysis (e.g. PCR) and protein analysis (e.g. ELISA) and will be able to plan such analyses (equipment / execution).
Examination achievement
Written exam (90 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Biointerfaces I - Basics for Bioanalytical Systems	11LE50MO-5406_1 ESE PO 2021
course	
Grundlagen der Molekurlarbiologie für bioanalytische Systeme / Basics in Molecular Biology for Bioanalytical Systems	
Event type	Number
lecture course	11LE50V-5406_1
Organizer	
Department of Microsystems Engineering, Chemistry and Physics of Interfaces	

ECTS-Points	3.0
Workload	90 hours
Attendance	30 hours
Independent study	60 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

- DNA analytics (enzymes / methods / devices)
- Various PCR methods
- DNA Fingerprinting
- Protein analysis (enzymes / methods / devices)
- Antibody based detection systems (ELISA)

Examination achievement

see module details

Course achievement

None

Literature

Materials are provided via the ILIAS system. An ILIAS page will be created and made available to students before the start of lectures.

Compulsory requirement

None

Recommended requirement

None

↑

Name of module	**Number of module**
Biointerfaces II - Interfaces for Bioanalytical Systems	11LE50MO-5407_1 ESE PO 2021
Responsible	
Prof. Dr. Jürgen Rühe	
Organizer	
Department of Microsystems Engineering, Chemistry and Physics of Interfaces	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Grenzflächen für bioanalytische Systeme / Interfaces for Bioanalytical Systems - Lecture	lecture course	Core elective	3.0	2.0	90 hours

Qualification
Biochip technologies play an important role in the miniaturization and parallelization of bioanalytical techniques. They combine microbiological methods with microsystems technology. Students will understand the requirements for integrating modern bioanalytical methods into microsystems. Emphasis will be placed on the design of bioanalytical surfaces and surface architectures, and students will learn how such concepts can be applied to chip-based detection methods.
Examination achievement
Written examination (90 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Biointerfaces II - Interfaces for Bioanalytical Systems	11LE50MO-5407_1 ESE PO 2021
course	
Grenzflächen für bioanalytische Systeme / Interfaces for Bioanalytical Systems - Lecture	
Event type	Number
lecture course	11LE50V-5407_1
Organizer	
Department of Microsystems Engineering, Chemistry and Physics of Interfaces	

ECTS-Points	3.0
Workload	90 hours
Attendance	26 hours
Independent study	64 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective

Contents
■ Interaction of surfaces with biological environments ■ Design criteria for bioanalytical surfaces and interfaces ■ Methods and techniques of biochip fabrication ■ Biochips for the analysis of nucleic acids ■ Protein biochips ■ Complex biochip techniques
Examination achievement
see module details
Course achievement
None
Literature
Materials are provided via the ILIAS system. An ILIAS page will be created and made available to students before the start of lectures.
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Biologie für Ingenieurinnen und Ingenieure	11LE50MO-780 ESE PO 2021
Responsible	
Prof. Dr. Ulrich Egert	
Organizer	
Department of Microsystems Engineering, Biomicrotechnology	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Biology for Engineers - Lecture	lecture course	Core elective	3.0	2.0	90 Stunden
Biologie für Ingenieurinnen und Ingenieure	excercise course	Core elective		1.0	

Qualification
Das Ziel dieses Moduls ist es, das Verständnis für grundlegende biomedizinische Konzepte, Prozesse und Strukturen, die definieren, oder Einfluss auf die Funktion der technischen Komponenten für biomedizinische Anwendungen zu vermitteln. | The objective of this module is to provide an understanding of fundamental biomedical concepts, processes, and structures that define or influence the function of engineered components for biomedical applications.
Examination achievement
written examination (90 minutes)

Course achievement
keine | none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Biologie für Ingenieurinnen und Ingenieure	11LE50MO-780 ESE PO 2021
course	
Biology for Engineers - Lecture	
Event type	Number
lecture course	11LE50V-BScMST-780
Organizer	
Faculty of Engineering Department of Microsystems Engineering, Biomicrotechnology	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	30 Stunden
Independent study	60 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	german

Contents

Die Vorlesungsreihe vermittelt die Grundlagen der verschiedenen biologischen Prozesse und Strukturen mit dem Ziel, den Rahmen der Messung von Signalen und die Anwendung von Mikrosystemen in der Biologie und Medizin zu beschreiben. Wir legen Wert auf Prozesse, die

- Einfluss auf die Erzeugung und die Eigenschaften der Signale meßbar Mikrosysteme, z.B. klinisch relevanten Schlüsselmoleküle, elektrische Signale in Muskel- und Nervensysteme, Sauerstoffversorgung des Blutes usw.
- Einfluss auf die Nutzbarkeit von MST compontentes, beispielsweise Sensoren oder Implantaten, wie zB durch Korrosion, Gewebereaktionen, Verkapselung, Veränderungen der Messbedingungen usw.
- typische Anwendungsbereiche der MST-Komponenten sind, beispielsweise relevant implantierbare Sensoren, Prothesen, Neurotechnologie, usw.

Im Rahmen der Vorlesungen werden wir einen ziemlich breiten Überblick zu präsentieren, mit einer gewissen Vorliebe für elektrische Biosignale. Notwendigerweise die Tiefe, durch die wir diese Themen behandeln muss begrenzt werden.

Themenschwerpunkte sind:

- grundlegende Konzepte zugrunde liegenden biologischen Geweben und ihre Funktionen
- Zellstruktur und Wachstum, den Stoffwechsel, die Zelldifferenzierung und specilization
- Grundlagen der Genetik
- Funktionssysteme des menschlichen Körpers
- Biophysik elektrischer Potentiale
- Neuronale Netze und deren Signale
- sensorische Systeme
- Fundamente von Lernen und Gedächtnis
- Energiestoffwechsels und der Ausscheidung

- Atmung
- Herz-Kreislauf-System

Examination achievement
siehe Modulebene
Course achievement
keine
Compulsory requirement
keine
Recommended requirement
keine

↑

Name of module	**Number of module**
Biologie für Ingenieurinnen und Ingenieure	11LE50MO-780 ESE PO 2021
course	
Biologie für Ingenieurinnen und Ingenieure	
Event type	Number
excercise course	11LE50Ü-BScMST-780-PO 2018

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	german

Contents
Examination achievement
Course achievement
Compulsory requirement

↑

Name of module	**Number of module**
Biomedical Microsystems	11LE50MO-7900 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	
Faculty	
Faculty of Engineering Department of Microsystems Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
▪ Basic knowlege in mathematics and natural sciences, ▪ Fundamental knowledge in processes and components of microsystems engineering

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Biomedical microsystems	lecture course	Core elective	6.0	2.0	180 hours
Biomedical microsystems	excercise course	Core elective		2.0	

Qualification
Objective of the module is to teach the technological requirements of microsystems in biomedical applications. Aspects of material science, standards and directives as well as technological opportunities will be evaluated. Examples from a variety of applications of approved medical devices and research prototypes in clinical trials will be presented and assessed.The module teaches the students which particular requirements have to be taken into account if microsystems should be used as a medical device. It will give a broad overview of the possible extent of microsystems applications in medical devices. The accompanying exercises supplement the lecture with respectto further applications. They guide the students towards independent learning whereas literature research,application and transfer of already acquired technological knowledge strengthen the engineering skills forresearch and development tasks in new application fields.

Examination achievement
■ Written or oral examination ■ Graded exercises/practical exercises The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).
Course achievement
There are exercises at regular intervals which are corrected and assessed with points. The exercises are considered passed if 50% of maximum points will be achieved from the tests that are written in the exercises with prior notice.
Grading
The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).
Examination weight
■ 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 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.
Usability
Mandatory module for students of the program ■ Master of Science in Microsystems Engineering Elective module for students of the program ■ Master of Science in Mikrosystemtechnik: Personal Profile

↑

Name of module	**Number of module**
Biomedical Microsystems	11LE50MO-7900 ESE PO 2021
course	
Biomedical microsystems	
Event type	Number
lecture course	11LE50V-7900
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

The course presents exemplary applications of microsystems in biomedical engineering, discusses challenges and illustrates solutions to meet the requirements of biocompatibility, biostability and reliability in clinical applications. In detail, the following topic will be covered:

- Introduction to Biomedical Microdevices
- Medical Devices: Legal Framework and Classification
- Glaucoma Monitoring Implant
- Neual Implants to Restore Vision
- Neural Implants to Record from the Brain
- Sensors in Cardiac Pacemakers
- Imaging Pills
- Spectroscopic Billirubin Measurement
- Trends for Intelligent Endoprostheses
- Stability and Functionality Implantable MEMS
- Packaging and Housing Concepts
- Data and Energy Transmission in (Micro-)Implants

Finally, the content of the course and the learning targets will be summarized together with the students to facilitate the preparation of the examination.

Examination achievement

see module details

Course achievement

see module details

Literature
Actual copies of the slides will be delivered accompanying to the lectures. Literature: ■ G. A. Urban (ed.) BioMEMS. Dordrecht: Springer 2006.
Compulsory requirement
none

↑

Name of module	**Number of module**
Biomedical Microsystems	11LE50MO-7900 ESE PO 2021
course	
Biomedical microsystems	
Event type	Number
excercise course	11LE50Ü-7900
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
Biomedical Instrumentation I	11LE50MO-5301 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	3.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Biomedizinische Messtechnik I / Biomedical Instrumentation I - Lecture	lecture course	Compulsory	3.0	2.0	90 hours
Biomedizinische Messtechnik I / Biomedical Instrumentation I - Exercises	excercise course	Compulsory		1.0	

Qualification
The objective of the module is to teach students the fundamental knowledge of biological and medical as well as physical and engineering processes to be able to acquire bioelectrical signals from the human body. Scientific and engineering knowledge from the whole signal chain between the biological source over the recording system is introduced including aspects of interferences and patient safety. Applications from cardiology (ECG) and neurology (EEG) as most prominent applications in clinical medicine are used as examples. The module teaches the students of microsystems engineering the fundamental anatomical, physiological and technical terms of biomedical terms with respect to bioelectrical signals. The students will get an overview of the application areas of the different methods and the technical background of the underlying measurement principles and measurement systems. The accompanying exercises consolidate the theoretical background and guide the students to independent handling of topics in the field of biomedical engineering.

Examination achievement
Oral examination (30 minutes)
Course achievement
The exercises are considered passed if 50% of maximum points will be achieved in each of the three tests that are written in the exercises with prior notice.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Biomedical Instrumentation I	11LE50MO-5301 ESE PO 2021
course	
Biomedizinische Messtechnik I / Biomedical Instrumentation I - Lecture	
Event type	Number
lecture course	11LE50V-5301
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	

ECTS-Points	3.0
Workload	90 hours
Attendance	39 hours
Independent study	51 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents

The course introduces different aspects of the recording of bioelectrical signals starting with the nerve and including amplifier design. It presents the most important medical diagnosis methods in the field of bioelectrical signals. In detail, the following topics will be covered:

- Origin of bioelectrical signals
- Electrochemistry of electrodes
- Acute and chronic applications of electrodes
- Recording and amplification of bioelectrical signals
- Interference and artefacts
- Bioelectrical signals of peripheral nerves and the muscle
- Electrical signals of the heart (ECG)
- Cardiac pacemakers and implantable defibrillators
- Technical safety of medical devices

Finally, the content of the course and the learning targets will be summarized together with the students to facilitate the preparation of the examination.

Examination achievement

see module details

Course achievement

see module details

Literature

Actual copies of the slides will be delivered accompanying to the lectures.
Literature:
German

1. Schmidt, Robert F., Lang, Florian, Thews, Gerhard (Hrsg.): Physiologie des Menschen, 29. Auflage. Heidelberg: Springer Medizin Verlag, 2005

English

1. Bronzino, Joseph D. (Hrsg.): The Biomedical Engineering Handbook, Volume 1 (and 2), Second Edition. Boca Raton: CRC Press 2000 / Heidelberg: Springer-Verlag, 2000
2. Enderle, John, Blanchard, Susan, Bronzino, Joseph (Hrsg.): Introduction to Biomedical Engineering, Second Edition. Burlington, San Diego, London, Elsevier, 2005

Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Biomedical Instrumentation I	11LE50MO-5301 ESE PO 2021
course	
Biomedizinische Messtechnik I / Biomedical Instrumentation I - Exercises	
Event type	Number
excercise course	11LE50Ü-5301
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Biomedical Instrumentation II	11LE50MO-5302 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	3.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Biomedizinische Messtechnik II / Biomedical Instrumentation II - Lecture	lecture course	Compulsory	3.0	2.0	90 hours
Biomedizinische Messtechnik II / Biomedical Instrumentation II - Exercises	excercise course	Compulsory		1.0	

Qualification
The objective of the module is to teach students the fundamental knowledge of biological and medical as well as physical and engineering processes to be able to acquire non-electrical measurement categories out of the human body and to impart knowledge about the technical and medical background of the most important imaging methods in medicine. The module teaches the students of microsystems engineering the fundamental anatomical, physiological and technical terms of biomedical terms with respect to cardiovascular diagnosis and imaging techniques. The students will get an overview of the application areas of the different methods and the technical background of the underlying measurement principles and measurement systems. The accompanying exercises consolidate the theoretical background and guide the students to independent handling of topics in the field of biomedical engineering
Examination achievement
Oral examination (30 minutes)

Course achievement
The exercises are considered passed if 50% of maximum points will be achieved in each of the three tests that are written in the exercises with prior notice.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Biomedical Instrumentation II	11LE50MO-5302 ESE PO 2021
course	
Biomedizinische Messtechnik II / Biomedical Instrumentation II - Lecture	
Event type	Number
lecture course	11LE50V-5302
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	

ECTS-Points	3.0
Workload	90 hours
Attendance	45 hours
Independent study	45 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents

The course introduces and explains the methods to monitor non electrical cardiovascular parameters, as well as the medical imaging techniques that are used nowadays to diagnose and help to treat many critical diseases. In this course you will learn and know how to apply the following methods:

- Measurement of cardiovascular parameters: blood pressure, physiology, pressure, measurement according to Riva Rocci & oscillometric.
- Measurement of cardiovascular parameters: blood flow, electromagnetic measurement principle
- Measurement of cardiovascular parameters: blood flow, ultrasound measurement principle
- Imaging techniques: x-ray
- Imaging techniques: systems theory of imaging systems, digital signal processing
- Imaging techniques: computer tomography
- Biological effect of ionizing radiation / dosimetry
- Imaging techniques in nuclear medicinal diagnosis
- Imaging techniques: ultrasound
- Imaging techniques: thermography and impedance tomography
- Imaging techniques: electrical sources, optical tomography, endoscopy
- Imaging techniques: MR tomography

Finally, the content of the course and the learning targets will be summarized together with the students to facilitate the preparation of the oral examination.

Examination achievement

see module details

Course achievement

see module details

Literature
Actual copies of the slides will be delivered accompanying to the lectures. Literature: **German** 1. Dössel, Olaf: Bildgebende Verfahren in der Medizin. Berlin, Heidelberg: Springer-Verlag, 2000 2. Schmidt, Robert F., Lang, Florian, Thews, Gerhard (Hrsg.): Physiologie des Menschen, 29. Auflage. Heidelberg: Springer Medizin Verlag, 2005 **English** 1. Bronzino, Joseph D. (Hrsg.): The Biomedical Engineering Handbook, Volume 1 (and 2), Second Edition. Boca Raton: CRC Press 2000 / Heidelberg: Springer-Verlag, 2000 2. Enderle, John, Blanchard, Susan, Bronzino, Joseph (Hrsg.): Introduction to Biomedical Engineering, Second Edition. Burlington, San Diego, London, Elsevier, 2005
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Biomedical Instrumentation II	11LE50MO-5302 ESE PO 2021
course	
Biomedizinische Messtechnik II / Biomedical Instrumentation II - Exercises	
Event type	Number
excercise course	11LE50Ü-5302
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Biomedical Instrumentation - Laboratory	11LE50MO-5304 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
Successful completion of "Biomedical Instrumentation I" is a prerequisite for attending this module.
Recommended requirement
Basic knowledge of mathematics and natural sciences

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Biomedizinische Messtechnik - Praktikum / Biomedical Instrumentation - Laboratory	practical course	Core elective	3.0	4.0	90 hours

Qualification
The aim of the module is to perform the recording of bioelectrical signals by oneself, applying the theoretical knowledge of recording signals and suppressing disturbances and artifacts and supplementing it with practical skills. The module teaches microsystems engineering students how to handle surface electrodes, develop simple electronic circuits and the basics of digital signal processing of bioelectric signals, as well as how to use software to create automatic signal recording routines.
Examination achievement
Written documentation

Course achievement
The "Studienleistung" is considered passed if 50% of maximum points will be achieved in each of the four tests that are written with prior notice. For the lab sessions, attendance is mandatory. In case of illness an additional lab session is offered. It is also possible to ask for auxiliary dates and to have access to the chair's labs outside the lab sessions.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Biomedical Instrumentation - Laboratory	11LE50MO-5304 ESE PO 2021
course	
Biomedizinische Messtechnik - Praktikum / Biomedical Instrumentation - Laboratory	
Event type	Number
practical course	11LE50P-5304
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	

ECTS-Points	3.0
Workload	90 hours
Attendance	60 hours
Independent study	30 hours
Hours of week	4.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english
Group size	15

Contents
The practical exercises are performed in small groups of maximum three persons. In the first part, diagnostic procedures (e.g. blood pressure measurement, electrocardiogram, determination of motor nerve conduction velocity, electro-myogram) are learned and characteristic quantities are extracted from the signals. In the second part, students independently design and develop an electronic amplifier circuit to record muscle signals and a user interface to graphically display the signals and control a screen pointer using the recorded muscle signals. This development of a simple human-computer interface is finally tested under real-time conditions.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
passed exam in Biomedical Instrumentation I
Recommended requirement
Basic knowledge in mathematics and sciences. Successful completion of "Biomedical Instrumentation I" is highly recommended.

↑

Name of module	**Number of module**
BioMEMS	11LE50MO-5403 ESE PO 2021
Responsible	
Prof. Dr. Stefan Rupitsch	
Organizer	
Department of Microsystems Engineering, Professorship in Electrical Instrumentation and Embedded Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Knowledge from the "Sensors" module

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
BioMEMS - Lecture	lecture course	Core elective	3.0	2.0	90 hours

Qualification
After this lecture, the students will overview the application of MEMS in biology and medicine. They will know the recent microfabrication technologies for biomedical applications as well as the basics of cell biology and biochemistry. The attendees of this lecture will think about the social impact of engineering. Most importantly, they will understand the connections between biology, medicine, and engineering. Finally, the students can apply this understanding to future topics in this field.
Examination achievement
Written examination (90 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
BioMEMS	11LE50MO-5403 ESE PO 2021
course	
BioMEMS - Lecture	
Event type	Number
lecture course	11LE50V-5403
Organizer	
Department of Microsystems Engineering, Professorship in Sensors	

ECTS-Points	3.0
Workload	90 hours
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Content
1. Introduction
2. Biochemistry and cells
3. Cell culture monitoring
4. Organ-on-chip (OOC) systems
5. Cell mechanics
6. Single cell analysis
7. DNA, RNA and protein analytics on chip
8. Implantable devices, in vivo sensors
9. Wearables
10. Summary

Examination achievement

see module details

Course achievement

none

Compulsory requirement

none

Recommended requirement

Knowledge from the module "Sensors" or "Sensors/Acuators"

Teaching method
■ Lecture (recorded) ■ Q&A live sessions ■ Surveys (ethics, social impact) ■ Design task (cooperative, in a live session)

↑

Name of module	**Number of module**
Biophysics of cardiac function and signals	11LE50MO-5324 ESE PO 2021
Responsible	
Prof. Dr. Jens Timmer Dr. Viviane Timmermann	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Basic interest in biology and computational modeling Knowledge in Python (or equivalent) is beneficial

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Biophysics of cardiac function and signals	lecture course	Core elective		2.0	180 hours
Biophysics of cardiac function and signals - praktische Übung	excercise course	Core elective		2.0	

Qualification
The basic concept of this lecture is to examine a biological system, analyze it and define mathematical equations in order to describe the system. In this lecture, the heart is used as this system. The students learn the electrical and mechanical function of the heart and its modeling. Additionally, the bioelectrical signals that are generated in the human body are described and how these signals can be measured, interpreted and processed. The content is explained both on the biological level and based on mathematical modelling. Aligned to the lecture is the exercise in which students learn to implement and use these models, get a practical introduction to medical image processing and perform signal processing using python.
Examination achievement
oral examination (30 minutes)
Course achievement
regular participation according to §13 (2) of the framework examination regulations M.Sc.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Biophysics of cardiac function and signals	11LE50MO-5324 ESE PO 2021
course	
Biophysics of cardiac function and signals	
Event type	Number
lecture course	11LE50V-5324

ECTS-Points	
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
• Cell membrane and ion channels • Cellular electrophysiology • Conduction of action potentials • Cardiac contraction and electromechanical interactions • Optogenetics in cardiac cells • Image processing and numerical field calculation in the body • Measurement of bioelectrical signals • Electrocardiography • Imaging of bioelectrical sources (ECG imaging) • Biosignal processing
Examination achievement
see module details
Course achievement
see module details
Literature
Lecture slides (further literature is included in the slides)
Compulsory requirement
none
Recommended requirement
Knowledge in Python (or equivalent) is beneficial Basic interest in biology and computational modeling

↑

Name of module	**Number of module**
Biophysics of cardiac function and signals	11LE50MO-5324 ESE PO 2021
course	
Biophysics of cardiac function and signals - praktische Übung	
Event type	Number
excercise course	11LE50prÜ-5324

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
see module details
Course achievement
none
Literature
Python implementation of • Hodgkin-Huxley model • Ion channel model adjustment to measurement data • Simulation of cardiac electrophysiology using openCARP • Image processing • ECG signal processing
Compulsory requirement
none

↑

Name of module	**Number of module**
Digital Health (DH)	11LE50MO-1160 ESE PO 2021
Responsible	
Prof. Dr. Oliver Amft	
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
none
Recommended requirement
Basic timeseries analysis methods, basic programming skills, coding in Python

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Digital Health (DH)	lecture course	Core elective	6.0	2.0	180 hours
Digital Health (DH)	excercise course	Compulsory		2.0	

Qualification
* Understand the data sources and modalities in digital medicine and the processes of data integration in clinical information systems and DGAs * Understand the German DGA regulation and issues relating to data privacy * Apply ubiquitous technology (ambient, mobile, wearable, implantable) for digital health * Apply context recognition and personalisation methods to qualify ubiquitous system data * Apply data-based privacy preserving techniques (obfuscation) * Design and implement digital biomarkers based on multimodal data * Design and apply digital health twins and clinical data modelling * Design medical decision support systems based on multimodal data

Examination achievement
mündliche Prüfung (i.d.R. 30 oder 45 Minuten) | Oral exam (usually 30 or 45 minutes) If there are too many students for a reasonably organized oral exam, it will be held as a written exam instead, announced well in advance.
Course achievement
written composition Reports on exercises to be submitted
Literature
Up-to-date literature recommendations are provided during the lectures.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science **OR** in Microsystems Engineering Concentrations Area Biomedical Engineering ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering **and** Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

↑

Name of module	Number of module
Digital Health (DH)	11LE50MO-1160 ESE PO 2021
course	
Digital Health (DH)	
Event type	Number
lecture course	11LE13V-1160_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	6.0
Workload	180 hours
Attendance	32 hours
Independent study	116 hours
Hours of week	2.0
Recommended semester	1
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Digital health is a branch of digital medicine that integrates and leverages multisource and multimodal data for medical knowledge extraction and decision support across a wide range of preventive, diagnostic, and therapeutic applications. The course starts by introducing the basic properties of medically relevant data sources and their different modalities. The course introduces the medical benefits of using ubiquitous technologies for data collection, in particular, between hospital visits. The process of medical data integration in clinical information systems and in digital health applications ("Digitale Gesundheitsanwendungen", DGA) is discussed. The German DGA regulations and their consequences are introduced, in particular relating to digital health application qualification and data privacy. Privacy preserving techniques are discussed and applied. Subsequently, data interpretation in telemedicine and digital biomarker design are analysed regarding context recognition and personalisation methods and algorithms. Decision support systems are dissected regarding their components and data analysis algorithms. Finally, the concept, realisation, and application of digital health twins in medicine is developed. The exercises will include practical experiments and implementation tasks, e.g. smartphone apps, 3D digital twin modelling, and data analysis for decision support.
Examination achievement
see module level
Course achievement
see module level
Literature
Up-to-date literature recommendations are provided during the lectures.
Compulsory requirement
None

Recommended requirement
Basic timeseries analysis methods, basic programming skills, coding in Python

↑

Name of module	**Number of module**
Digital Health (DH)	11LE50MO-1160 ESE PO 2021
course	
Digital Health (DH)	
Event type	Number
excercise course	11LE13Ü-1160_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	
Attendance	32 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents
Students will investigate concrete data science methods related to medical data, including context recognition, data interpretation and abstraction.
Examination achievement
see module level
Course achievement
see module level
Compulsory requirement

↑

Name of module	**Number of module**
Electromagnetism in Biomedical Imaging	11LE50MO-5330 ESE PO 2021
Responsible	
PD Dr. Ali Caglar Özen	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden/Hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
Recommended requirement
Analog Electronics (i.e., Basic Electronics/ Introduction to Circuit Design or similar)

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Electromagnetism in Biomedical Imaging	lecture course	Core elective	3.0	2.0	90 Stunden / hours

Qualification
1. interpret Maxwell's equations and their application to magnetic resonance imaging 2. describe the interaction of the electromagnetic fields with living tissue and their adverse effects 3. derive transmission line equations and use Smith chart for impedance matching 4. explain basic antenna types used in NMR & MRI and their design approach 5. model an antenna, perform FDTD simulations and analyze computed electric and magnetic fields
Examination achievement
Klausur / written exam
Directive
none

↑

Name of module	**Number of module**
Electromagnetism in Biomedical Imaging	11LE50MO-5330 ESE PO 2021
course	
Electromagnetism in Biomedical Imaging	
Event type	Number
lecture course	11LE50V-5330 PO 2021

ECTS-Points	3.0
Workload	90 Stunden / hours
Attendance	26 Stunden
Independent study	64 Stunden
Hours of week	2.0
Recommended semester	2
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
detailed plan of the lectures is attached CourseContent_EMinBMI_2024_Vorleasung.docx. Week 1 - Introduction to engineering electromagnetics Week 2 - Transmission Lines Week 3 - Impedance Matching Week 4 - Electric Fields Week 5 - Magnetic Fields Week 6 - Electromagnetic Fields in MRI 1 Week 7 – Electromagnetic Fields in MRI 2 Week 8 – Wave Propagation Week 9 – Electromagnetic Radiation Week 10 - Radiofrequency Transmitters Week 11 - Radiofrequency Detectors Week 12 - Numerical Methods in Electromagnetism Week 13 - Hands on FDTD Week 14 – Recap
Examination achievement
Course achievement
Literature
1. Fundamentals of Electromagnetics with Engineering Applications by Stuart M. Wentworth 2. Electromagnetic Analysis and Design in Magnetic Resonance Imaging by Jianming Jin 3. Microwave Engineeringvon by David M. Pozar
Compulsory requirement
none

Recommended requirement
Analog Electronics (i.e., Basic Electronics/ Introduction to Circuit Design or similar)

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 ESE PO 2021
Responsible	
Prof. Dr. Oliver Amft	
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Embedded Computing Entrepreneurship (2ES)	lecture course	Core elective	6.0	1.0	180 Stunden / Hours
Embedded Computing Entrepreneurship (2ES)	seminar	Core elective		1.0	
Embedded Computing Entrepreneurship (2ES)	excercise course	Core elective		2.0	

Qualification
* Conceptualise and design embedded sensor systems along a specific application. * Develop and demonstrate key components of embedded sensor systems, including signal and pattern analysis and recognition algorithms. * Develop a basic market analysis and business plan. * Implement an agile development process.

Examination achievement
Presentation followed by an oral examination (10 minutes per person, total duration depends on group size)
Course achievement
Regular attendance of the course (seminar and exercise) according to §13 (2) of the General Examination Regulations for the Bachelor of Science/Master of Science, as otherwise the required group work and scientific discussion is not possible. Further elements of the course work are the creation of demonstrators or software as well as a written elaboration/protocol.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems **or** Concentration Biomedical Engineering **OR** Elective Courses in Computer Science ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering **and** Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 ESE PO 2021
course	
Embedded Computing Entrepreneurship (2ES)	
Event type	Number
lecture course	11LE13V-1404_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Attendance	16 Stunden / Hours
Independent study	116 Stunden / Hours
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The course combines technical and business-related lectures on embedded sensor systems with a practical system development project using agile development methods. Students will organise in groups and define together with their advisor(s) goals for the technical development, market analysis, etc. Student groups can enter their projects for an award of the VDE.
Examination achievement
see module details
Course achievement
see module details
Literature
Relevant literature will be provided during the lectures and consultations.
Compulsory requirement
None
Recommended requirement
Basic pattern recognition methods; basic programming skills

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 ESE PO 2021
course	
Embedded Computing Entrepreneurship (2ES)	
Event type	Number
seminar	11LE13S-1404_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	
Attendance	16 Stunden / Hours
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 ESE PO 2021
course	
Embedded Computing Entrepreneurship (2ES)	
Event type	Number
excercise course	11LE13Ü-1404_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	
Attendance	32 Stunden / Hours
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Ethical Aspects of Neurotechnology	11LE50MO-5320 ESE PO 2021
Responsible	
Prof. Dr. Ulrich Egert	
Organizer	
Department of Microsystems Engineering, Biomicrotechnology	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Interesse an interdisziplinärer Aufbereitung aktueller Fragestellungen | interest in interdisciplinary processing and analyzing of current issues

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Ethische Aspekte der Neurotechnologie / Ethical Aspects of Neurotechnology - Seminar	seminar	Core elective	3.0	2.0	90 Stunden

Qualification
Studierende der Philosophie und Studierende der Neurobiologie und der Ingenieurwissenschaften erarbeiten in diesem Seminar gemeinsam ethische und philosophische Perspektiven der aktuellen Eingriffsmöglichkeiten in das Gehirn und der derzeit entwickelten und in naher Zukunft entwickelbaren Mensch-Maschine-Komplexe, um auf dieser Grundlage die Herausforderungen für unser personales Selbstverständnis und unsere ethischen Kriterien für die Grenzen solcher Eingriffe zu diskutieren. Dabei soll versucht werden, philosophische Ansätze zum Verhältnis von Person sein und neurobiologischer „Determinierung“ als zentrale Aspekte in der ethischen Theoriebildung mit den empirischen und interagierenden Zugängen der Neurowissenschaften in einen konstruktiven und kontroversen Dialog gebracht werden. | In this seminar, students of philosophy and students of neurobiology and engineering will jointly elaborate ethical and philosophical perspectives on the current possibilities of intervention in the brain and on the human-machine complexes currently developed and those that can be developed in the near future, in order

to discuss, on this basis, the challenges to our personal self-understanding and our ethical criteria for the limits of such interventions. In doing so, we will attempt to bring philosophical approaches to the relationship between being a person and neurobiological "determinacy" as central aspects in ethical theorizing into a constructive and controversial dialogue with the empirical and interacting approaches of neuroscience.
Examination achievement
oral examination (30 minutes)
Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Ethical Aspects of Neurotechnology	11LE50MO-5320 ESE PO 2021
course	
Ethische Aspekte der Neurotechnologie / Ethical Aspects of Neurotechnology - Seminar	
Event type	Number
seminar	11LE50S-5320
Organizer	
Department of Microsystems Engineering, Biomicrotechnology	

ECTS-Points	3.0
Workload	90 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	german

Contents
Interdisziplinäres Seminar zu ethischen und philosophischen Aspekten der Neurotechnologie. Folgende Themenbereiche werden jeweils unter ethischen, neurowissenschaftlichen bzw. ingenieurwissenschaftlichen Gesichtspunkten bearbeitet: 1. Ethik der Neurowissenschaften als aktuelles Gebiet der Philosophie 2. Identität, Person und Persönlichkeit als Grundbegriffe der Ethik der Neurowissenschaften 3. Spezifische philosophische und ethische Aspekte folgender Anwendungsfelder: - Invasive und nicht-invasive Gehirn-Maschine-Schnittstellen - Neuroimaging- Emotionale Integration neuronaler Prothesen - Tiefe Hirnstimulation - Optogenetische Interaktion - Neuro-Enhancement - Zukunftstechnologien und deren Einsatz
Examination achievement
siehe Modulebene
Course achievement
keine
Compulsory requirement
keine
Recommended requirement
Interesse an interdisziplinärer Aufbereitung aktueller Fragestellungen

↑

Name of module	**Number of module**
Fundamentals of electrical stimulation	11LE50MO-5306 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Grundlagen der Elektrostimulation / Fundamentals of electrical stimulation - Lecture	lecture course	Core elective	3.0	2.0	90 hours

Qualification
The aim of the module is to teach the biological-medical and physicochemical-technical fundamentals in the electrostimulation of nerves and muscles, which are necessary for an engineer to understand the biological processes and to design aids and procedures in applications in the field of neuroprosthetics and neuromodulation. The module teaches students the theoretical background of mechanisms of action and damage of electrical stimulation in the peripheral and central nervous systems, as well as the electrochemical processes to be considered at neuro-engineering interfaces.
Examination achievement
Oral exam (30 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Fundamentals of electrical stimulation	11LE50MO-5306 ESE PO 2021
course	
Grundlagen der Elektrostimulation / Fundamentals of electrical stimulation - Lecture	
Event type	Number
lecture course	11LE50V-5306

ECTS-Points	3.0
Workload	90 hours
Attendance	30 hours
Independent study	60 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The course introduces the medical and biological as well as the physicochemical and technical aspects of electrical stimulation. In detail, students get familiar with the following topics: Overview of the history of electrical stimulation Anatomy and physiology of nerve and muscle Description of nerve excitation Electrical fields and electrochemical processes at electrodes Electrode designs and applications Charakteristic parameters during technical excitation of nerves Methods for selective stimulation Effects of chronic electrical stimulation Limits of safe electrical stimulation Systems theory aspects of control of neural prostheses Simulation of nerve excitation Stimulator design Overview of stimulation parameters in clinical applicationsFinally, the content of the course and the learning targets will be summarized together with the students to facilitate the preparation of the examination.
Examination achievement
see module details
Course achievement
None
Literature
A script will be provided to accompany the lecture and will be updated regularly. Further reading material: ▪ Horch, K.W., Dhillon, G.S. (Hrsg.): Neuroprosthetics – Theory and Practice. (Series on Bioengineering & Biomedical Engineering – Vol. 2)

■ River Edge: World Scientific Computing, 2004
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Implant Manufacturing Technologies	11LE50MO-5313 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	3.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Technologien der Implantatfertigung / Implant Manufacturing Technologies - Lecture	lecture course	Core elective	3.0	2.0	90 hours
Technologien der Implantatfertigung / Implant Manufacturing Technologies - Exercises	excercise course	Core elective		1.0	

Qualification
The aim of the module is to teach the physical and technological fundamentals for manufacturing electrically active implants, to become familiar with basic structures and elements as well as methods and processes for their manufacture. The theoretical engineering basis for understanding the function and failure modes of this type of implants is provided. The module teaches students of microsystems engineering the various, basic processes on the basis of which complex implants can be realized. The exercise supplements the theoretical knowledge with practical aspects and guides the independent application of the knowledge gained.
Examination achievement
Written examination (90 minutes)

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Implant Manufacturing Technologies	11LE50MO-5313 ESE PO 2021
course	
Technologien der Implantatfertigung / Implant Manufacturing Technologies - Lecture	
Event type	Number
lecture course	11LE50V-5313
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	

ECTS-Points	3.0
Workload	90 hours
Attendance	45 hours
Independent study	45 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

In the lecture Implant Manufacturing Technologies, knowledge and methods for the development of electrically active implants such as pacemakers or hearing prostheses (cochlear implants) are taught. Materials, components, systems and legal frameworks are presented. Clinically established (neuro-) implants as well as novel developments, which are still in the research phase, will be presented and critically discussed. The following topics will be covered during the lecture:

- Overview of active implants & neuroprostheses in clinical and research settings.
- Definitions and classification of electrically active implants
- Biocompatibility testing and biostability (corrosion and degradation)
- Electrodes
- Design of electrically active implants (components, interfaces)
- Silicone as material for encapsulation
- Materials for hermetically sealed housings
- Connections and joining techniques
- Requirements for implant development and production (risk management, FMEA, production rooms, documentation)
- Thin-film technology in implant development
- Manufacturing of microimplants using the example of a BION

Finally, the learning content will be repeated together with the students in order to facilitate the preparation for the examination.

Examination achievement

see module details

Course achievement
None
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Implant Manufacturing Technologies	11LE50MO-5313 ESE PO 2021
course	
Technologien der Implantatfertigung / Implant Manufacturing Technologies - Exercises	
Event type	Number
excercise course	11LE50Ü-5313
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
see module details
Course achievement
none
Compulsory requirement

↑

Name of module	**Number of module**
Implant Manufacturing Technologies - Laboratory	11LE50MO-5314 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
Successful completion of the module "Technologien der Implantfertigung / Implant manufacturing technologies"
Recommended requirement
Basic knowledge in mathematics and sciences

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Technologien der Implantatfertigung - Praktikum / Implant Manufacturing Laboratory	practical course	Core elective	3.0	4.0	90 hours

Qualification
The aim of the module is to train the skills for manufacturing electrically active implants, to become familiar with basic structures and elements as well as methods and processes for their manufacture. The theoretical engineering basis for understanding the function and failure modes of this type of implants is complemented by practical skills and experience during own manufacturing of a demonstrator of an active implant.
Examination achievement
Written test prior to each of the seven experiments. The module grade is the average of the marks obtained in the seven tests.
Course achievement
Regular attendance in the 12 sessions is required. In case of illness, an additional session is offered.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Implant Manufacturing Technologies - Laboratory	11LE50MO-5314 ESE PO 2021
course	
Technologien der Implantatfertigung - Praktikum / Implant Manufacturing Laboratory	
Event type	Number
practical course	11LE50P-5314
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	

ECTS-Points	3.0
Workload	90 hours
Attendance	52 hours
Independent study	38 hours
Hours of week	4.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

In the course of the practical exercises, the students re-build the first generation of a neuroptosthetic device, a cochlear implant. Groups with a maximum of three persons manufacture the implant in structured learning units on their own under supervision at different manufacturing setups. The learning units include:

- Laser marking and cutting
- Screen printing
- Hybrid implant assembly
- Design of pronted circuit boards
- Development and etching of printed circuit boards
- Cleansing and cleaning of substrates
- Silicone encapsulation or electronic circuits
- Packaging and sterilization
- Technical implant function test

Examination achievement

see module details

Course achievement

see module details

Compulsory requirement

Recommended requirement

Basic knowledge in mathematics and sciences. Successful completion of the module "Technologien der Implantfertigung / Implant manufacturing technologies".

↑

Name of module	Number of module
Introduction to physiological control systems	11LE50MO-5258 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Introduction to physiological control systems	lecture course	Core elective	3.0	1.0	90 hours
Introduction to physiological control systems	excercise course	Core elective		1.0	

Qualification
This course will introduce students in engineering and non-engineering fields to the modeling and control of physiological processes. A brief introduction to signals, systems and control theory is provided at the beginning. Several physiological process are then addressed from a control system perspective, discussing state-of-the-art literature. The main goal of this course is to provide a general overview of how control system theory can be applied to understand, modeling and control physiological processes.
Examination achievement
Written examination (90 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Introduction to physiological control systems	11LE50MO-5258 ESE PO 2021
course	
Introduction to physiological control systems	
Event type	Number
lecture course	11LE50V-5258
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	

ECTS-Points	3.0
Workload	90 hours
Attendance	26 hours
Independent study	64 hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
1. Introduction and course overview. 2. Review of signals, systems, and control theory. 3. Positive and negative feedback in physiology. 4. Blood pressure control. 5. Balance control during quiet standing. 6. Complex dynamics of heart rate variability. 7. Feedback and feedforward limb control during reach-to-pinch task. 8. Summary.
Examination achievement
see module details
Course achievement
None
Literature
1. M. Khoo. Physiological control systems: analysis, simulation, and estimation. IEEE Series in Biomedical Engineering, 1999, NY. 2. A. Guyton and J. Hall, Textbook of Medical Physiology, Elsevier, 2006. 3. Current scientific literature.
Compulsory requirement
None

Recommended requirement
None

↑

Name of module	Number of module
Introduction to physiological control systems	11LE50MO-5258 ESE PO 2021
course	
Introduction to physiological control systems	
Event type	Number
excercise course	11LE50Ü-5258
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
See module details
Course achievement
None
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Measurement and analysis of electrophysiological signals	11LE50MO-5325 ESE PO 2021
Responsible	
PD Dr. Matthias Dümpelmann	
Organizer	
Department of Microsystems Engineering-VB	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
None
Recommended requirement
Knowledge in digital signal processing Programming skills in languages like Python

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Measurement and analysis of electrophysiological signals	practical course	Core elective	3.0	2.0	

Qualification
1. Components of equipment for electrophysiological measurements 2. Experience in performing measurements of electrophysiological signals 3. Knowledge about potential noise sources and strategies for their mitigation 4. Experience in cognitive experiments in parallel to electrophysiological measurements 5. Knowledge in methods for signal analysis in time and frequency domain.

Examination achievement
Protokoll / report Benotete Protokolle: Neben der Durchführung von Versuchen werden aufgenommene Signale und Signale aus Datenbanken von den Studierenden analysiert (z.B. mit Hilfe von Python / Erstellung von Software). Graded protocols: In addition to conducting experiments, recorded signals and signals from databases are analyzed by the students (e.g. using Python / creating software).
Course achievement
Durchführurng von Versuchen / Carrying out of experiments
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Measurement and analysis of electrophysiological signals	11LE50MO-5325 ESE PO 2021
course	
Measurement and analysis of electrophysiological signals	
Event type	Number
practical course	11LE50P-5325 PO 2021
Organizer	
Department of Microsystems Engineering-VB	

ECTS-Points	3.0
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
1. Components of equipment for electrophysiological measurements 2. Measurement of the electrocardiogram (ECG) 3. Measurement of the photoplethysmogram as a proxy of the ECG 4. Measurement of the electroencephalogram (EEG) 5. Signal analysis of the ECG and EEG in time and frequency domain 6. Components of systems for cognitive experiments 7. Realization of a cognitive experiments while measuring the electroencephalogram 8. EEG signal analysis of cognitive experiments
Examination achievement
see module details
Course achievement
see module details
Literature
In Englisch: Cohen: Analyzing Neural Time Series Data: Theory and Practice Smith: The scientist and engineer's guide to digital signal processing Niedermeyer, Lopes da Silva: Electroencephalography: basic principles, clinical applictions, and related fields In Deutsch: Openheim, Schafer: Zeitdiskrete Signalverarbeitung

BErnhard, Brensing, Witte: Biosignalverarbeitung: Grundlagen und Anwendungen mit MATLAB
Compulsory requirement
None
Recommended requirement
Knowledge in digital signal processing Programming skills in languages like Python

↑

Name of module	**Number of module**
Micro-fluidics	11LE50MO-7152 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Roland Zengerle	
Organizer	
Department of Microsystems Engineering, MEMS Applications	
Faculty	
Faculty of Engineering Department of Microsystems Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge in physics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Micro-fluidics	lecture course	Core elective	6.0	2.0	180 hours
Micro-fluidics - Exercises	excercise course	Core elective		2.0	

Qualification

Technically correct handling of very small amounts of liquid and gas is of central importance in all key areas of microsystems engineering such as Lab-on-a-Chip applications, InkJet technology, fuel cells, medical drug delivery systems and many more. This lecture gives an overview on physical phenomena and presents some of the most important application examples of microfluidic systems.

The educational objective of the Microfluidics I lecture is to gain a general understanding regarding all basic microfluidic effects including fluid mechanics, fluid properties and both physical as well as chemical interactions at boundary layers.

Participating students will learn to apply micro- and macrofluidic effects and phenomena to design new systems. This is achieved by introducing basic microfluidic elements that can be utilized as elementary units to create complex microfluidic devices.

Examination achievement
Written exam and participation in the exercises (Participation at 50% of the exercises is required to qualify for the exam). The final grade will be determined based on the points earned in the written exam.
Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), in Advanced Microsystems ■ M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Micro-fluidics	11LE50MO-7152 ESE PO 2021
course	
Micro-fluidics	
Event type	Number
lecture course	11LE50V-7152
Organizer	
Department of Microsystems Engineering, MEMS Applications	

ECTS-Points	6.0
Workload	180 hours
Attendance	52
Independent study	128
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

The topics of this course are:

- Basic fluid properties
- Fluid dynamics including the Navier-Stokes-Equation
- Diffusion
- Surface tension
- Electrokinetics
- The design of microfluidic chips
- Basic fluidic elements

Examination achievement

see module details

Course achievement

none

Literature

Literatur:

- Nguyen, Wereley; Microfluidics, Artech House
- Geschke, Klank, Telleman; Microsystem Eng. of Lab-on-a-Chip Devices, Wiley-VCh, 2nd edition
- Bruus; Theoretical Microfluidics, Oxford Univ. Press

Compulsory requirement

none

Recommended requirement
Basic knowledge in physics

↑

Name of module	**Number of module**
Micro-fluidics	11LE50MO-7152 ESE PO 2021
course	
Micro-fluidics - Exercises	
Event type	Number
excercise course	11LE50Ü-7152
Organizer	
Department of Microsystems Engineering, MEMS Applications	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
see module details
Course achievement
none
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
Microfluidics II: Miniaturize, automate and parallelize biochemical analysis: From idea to product launch	11LE50MO-5263 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Roland Zengerle	
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Basics in microfluidics, e.g. "Micro-fluidics"

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Microfluidics II: Miniaturize, automate and parallelize biochemical analysis: From idea to product launch	lecture course	Core elective	6.0	2.0	180 hours
Microfluidics II: Miniaturize, automate and parallelize biochemical analysis: From idea to product launch.	excercise course	Core elective		2.0	

Qualification
Qualified microfluidic engineer with sound knowledge on microfluidic Design, manufacturing of microfluidic cartridges, and the use of microfluidic technologies in clinical settings.
Examination achievement
Ususally a written exam (duration of 90 to 180 minutes) If the number of participants is small, an oral examination (with a duration of 35 minutes) may be held instead. The students will be informed in good time.

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Microfluidics II: Miniaturize, automate and parallelize biochemical analysis: From idea to product launch	11LE50MO-5263 ESE PO 2021
course	
Microfluidics II: Miniaturize, automate and parallelize biochemical analysis: From idea to product launch	
Event type	Number
lecture course	11LE50V-5263
Organizer	
Department of Microsystems Engineering, MEMS Applications	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Content: This lecture teaches the use of microfluidic technologies for automation of biochemical analyses. Fields of application are the detection of pathogens, the diagnosis and therapy accompanied monitoring of tumor diseases as well as water analysis. In a first section, the complete design process from initial requirements and project specifications to simulation-based design, manufacturing of functional models and testing will be addressed. The creation of flow drafts, the simulation of microfluidic networks and CAD design will be taught in an accompanying tutorial. In following lectures, product development will be examined. This includes the scalable manufacturing of disposable test cartridges, the determination of usability as well as questions of licensing. In summary, the lecture covers the development process from initial idea to product. In the second part of the tutorial, the students will work on an exemplary project.
Examination achievement
see module details
Course achievement
none
Compulsory requirement
none
Recommended requirement
Basics of microfluidics, e.g. Microfluidics I lecture

↑

Name of module	**Number of module**
Microfluidics II: Miniaturize, automate and parallelize biochemical analysis: From idea to product launch	11LE50MO-5263 ESE PO 2021
course	
Microfluidics II: Miniaturize, automate and parallelize biochemical analysis: From idea to product launch.	
Event type	Number
excercise course	11LE50Ü-5263
Organizer	
Faculty of Engineering Department of Microsystems Engineering, MEMS Applications	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
see module details
Course achievement
none
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	Number of module
Nanobiotechnologie	11LE50MO-5308 ESE PO 2021
Responsible	
Prof. Dr. Oliver Ambacher	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Nanobiotechnologie / Nanobiotechnology - Lecture	lecture course	Core elective	3.0	2.0	90 Stunden

Qualification
Die Studierenden werden in die Lage versetzt, die Funktionsweise von organischen Mikro- und Nanosystemen zu verstehen. Hierzu gehören z.B. Haarzellen, Motorproteine, organische Nanomotoren und Ionenkanäle. Die Studierenden besitzen Fachkompetenz in der Beschreibung und Analyse von organischen Nanostrukturen, die für die Funktion kleinster biologischer Organismen von entscheidender Bedeutung sind. Ihre Fachkompetenz erstreckt sich bis zur Kombination von organischen und anorganischen Mikro- und Nanosystemen z.B. zur Realisierung kleinster Antriebssysteme. | Students will be able to understand the functioning of organic micro- and nanosystems. These include, for example, hair cells, motor proteins, organic nanomotors and ion channels. Students will have expertise in the description and analysis of organic nanostructures that are critical to the function of minute biological organisms. Their expertise extends to the combination of organic and inorganic micro- and nanosystems, e.g., for the realization of very small drive systems.
Examination achievement
oral exam (duration of 30 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Nanobiotechnologie	11LE50MO-5308 ESE PO 2021
course	
Nanobiotechnologie / Nanobiotechnology - Lecture	
Event type	Number
lecture course	11LE50V-5308
Organizer	
Department of Sustainable Systems Engineering, Professorship in Power Electronics	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26 Stunden
Independent study	64 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	german

Contents
Zu den Themen der Nanobiotechnologie gehört die Diskussion von organischen Nanosystemen in der menschlichen Wahrnehmung, die Erklärung des Handlings und Charakterisierens von Proteinen und Viren, die Untersuchung elektronischer und optischer Eigenschaften von einzelnen Molekülen genauso wie die Technologie zur Herstellung von Sensoren für kleinste Flüssigkeitsmengen. An der Schnittstelle zwischen der Mikro- und Nanowelt, der Schnittstelle auch zwischen belebter und unbelebter Materie, werden moderne Charakterisierungsverfahren (z.B. Elektronenmikroskopie, Kraftmikroskopie) nötig, um von physikalischen oder chemischen Eigenschaften der organischen Moleküle eine Brücke zum Verständnis der Funktion von Aminosäuren, Proteinen und Zellen zu schlagen. Diese Methoden und ihre Anwendung auf biologisch relevante Systeme werden ebenso erklärt wie die Technologie zur Herstellung von künstlichen Mikro- und Nanostrukturen zur sensorischen Kopplung an biologische Organismen.
Examination achievement
siehe Modulebene
Course achievement
keine
Literature
■ Biochemie, J.M. Berg, J.L. Tymoczko, L. Stryer, Spektrum Akademischer Verlag, Heidelberg 2003 ■ Physiologie des Menschen, R.F. Schmidt, F. Lang, G. Thews, Springer Medizin Verlag Heidelberg 2005
Compulsory requirement
keine

Recommended requirement
keine

↑

Name of module	**Number of module**
Neurophysiology - Laboratory	11LE50MO-5316 ESE PO 2021
Responsible	
Prof. Dr. Ulrich Hofmann	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Prerequisite to become eligible for this course is the participation in the exercises in "Implant manufacturing technologies“ or participation in the seminar „Neuroprosthetics“ in the previous winter semester.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Neurophysiologie - Praktikum / Neurophysiology - Laboratory	practical course	Core elective	3.0	4.0	90 hours

Qualification
Participants will gain first hand experiences into neuroscientific and electrophysiologically verifiable paradigms to natural signal processing in the rat brain *in vivo*. Participants will get in depth insight into the current knowledge of the somatosensory system, the visual system and the motor system. In addition, the rat's learning and orientation system will be introduced in depth as well. Signal processing methods will be presented and for later use in exercises substantiated. Participants will learn a respectful and honorable handling of living beings, even if they are „only“ lab rats. Students will gain first hand experience with multisite electrophysiological recordings from anesthetized and freely moving animals. Signals acquired during these day long experiments will be analyzed according to state of the art and results will be presented as reports and talks.
Examination achievement
Students have to submit 4 reports. The module grade is calculated taking the average of the grades obtained for each report. If a student misses one session due to illness, an amended date for the missed lab session will be offered.

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Neurophysiology - Laboratory	11LE50MO-5316 ESE PO 2021
course	
Neurophysiologie - Praktikum / Neurophysiology - Laboratory	
Event type	Number
practical course	11LE50P-5316

ECTS-Points	3.0
Workload	90 hours
Hours of week	4.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective

Contents

Students will in three neurophysiological paradigms (two acute, one freely behaving) under experienced supervision participate.
Students will get in depth and first hand insight into the current knowledge of the somatosensory system, the visual system and the motor system. In addition, the rat's learning and orientation system will be introduced as well.
Signal processing methods will be presented and for later use in exercises substantiated.
They will gain hands on experience with in vivo animal electrophysiology with micro devices and collect data for subsequent home based analysis.
Their analysis results will be presented as final teaching experience.

Examination achievement

see module details

Course achievement

None

Literature

- Windhorst, U. and H. Johansson (1999). Modern Techniques in Neuroscience Research. Berlin, Springer.
- Kandel, E. R., J. H. Schwartz and T. M. Jessel (1991). Principles of neural science. London, Prentice-Hall.
- D Nicolelis, M. A. L., Ed. (1999). Methods for Neural Ensemble Recordings. CRC Methods in Neuroscience. Boca Raton, FL, CRC Press.
- diverse journal papers like:
  - Wilson, M. A. and B. L. McNaughton (1994). "Reactivation of Hippocampal ensemble memories during sleep." Science 265: 676-682.
  - Wilson, M. A. and B. L. McNaughton (1993). "Dynamics of the hippocampal ensemble code for space." Science 261: 1055-1058.

Compulsory requirement

None

Recommended requirement

Prerequisite to become eligible for this course is the participation in the exercises in "Implant manufacturing

technologies“ or participation in the seminar „Neuroprosthetics“ in the last winter semester.
Recommendation
The experiments fall under the Animal Welfare Act - so all participants must be known by name before the first day of the experiment.

↑

Name of module	**Number of module**
Neuroprosthetics	11LE50MO-5318 ESE PO 2021
Responsible	
Prof. Dr. Ulrich Hofmann	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	3.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
High school level knowledge in mathematics and natural sciences

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Neuroprothetik / Neuroprosthetics - Seminar	seminar	Core elective	3.0	3.0	90 hours

Qualification
In times of an explosion of so called bioelectronic medicine remedies, aka electroceuticals, engineering students will gain an introductory knowledge of neuroscientific basics, a profound knowledge of technical interfaces to the brain and a wide view on diseases presumbaly treated by these devices. In particular, they will investigate the pathes from bench to bedside bringing medical devices into clinical use. In the end, they will be able to critically assess business models of startups in the field of bioelectronic medicine.
Examination achievement
Written documentation and oral presentation. The module grade is based on the written documentation (50%) and the oral presentation (50%).
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Neuroprosthetics	11LE50MO-5318 ESE PO 2021
course	
Neuroprothetik / Neuroprosthetics - Seminar	
Event type	Number
seminar	04LE50V-5318

ECTS-Points	3.0
Workload	90 hours
Attendance	39 hours
Independent study	51 hours
Hours of week	3.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Introductory lessons contain:
- Basic concepts of neuroscience
- Interfacing the nervous system
- Modelling approaches for CNS applications
- Neuroethical aspects

Student covered topics will contain:
- Cochlea Implant - Deafness
- Retina Implant - Blindness
- Deep Brain Stimulation - Parkinson‘s Disease
- Spinal Cord Stimulation - Chronic Pain Syndrome
- Vagal Nerve Stimulation - Epilepsy
- Functional Electrical Stimulation - Drop Foot Syndrome
- Human Machine Interfacing - BCI and BMI
- Foreign Body Reaction

Examination achievement

see module details

Course achievement

None

Literature

- Farina, D., Jensen, W., Akay, M., Eds. (2013). INTRODUCTION TO NEURAL ENGINEERING FOR MOTOR REHABILITATION, IEEE
- Dagnelie, G., Ed. (2011). Visual Prosthetics: Physiology, Bioengineering, Rehabilitation: Physiology, Bioengineering and Rehabilitation, Springer
- DiLorenzo, D. J. and J. D. Bronzino, Eds. (2008). Neuroengineering Boca Raton, CRC Press
- Akay, M. (2007). Handbook of Neural Engineering, IEEE Press, Wiley

■ Dornhege, G., et al., Eds. (2007). Toward Brain-Computer Interfacing. Neural Information Processing Series. Cambridge, MA, MIT Press ■ Horch, K. W. and G. S. Dhillon (2004). Neuroprosthetics - Theory and Practice. Singapore-London, World Scientific Publishing
Compulsory requirement
None
Recommended requirement
High level knowledge in mathematics and natural sciences

↑

Name of module	**Number of module**
Neuroscience for Engineers	11LE50MO-5319 ESE PO 2021
Responsible	
Prof. Dr. Ulrich Egert	
Organizer	
Department of Microsystems Engineering, Biomicrotechnology	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	3.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Neurowissenschaften für Ingenieure / Neuroscience for Engineers - Lecture	lecture course	Core elective	3.0	2.0	90 hours
Neurowissenschaften für Ingenieure / Neuroscience for Engineers - Exercises	excercise course	Core elective		1.0	

Qualification
After completing this module, students will understand the fundamental neuroscientific concepts, methods, processes and structures that define or influence the function of technical components in biomedical applications.
Examination achievement
Written exam (90 min.)
Course achievement
none

Usability
Wahlpflichtmodul für Studierende des Studiengangs ■ Bachelor of Science in Mikrosystemtechnik (PO 2018), Wahlpflichtbereich, Bereich Mikrosystemtechik Compulsory elective module for students of the study proram ■ Master of Science in Microsystems Engineering (PO 2021), concentration area Biomedical Engineering ■ Master of Science in Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ Master of Science in Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Neuroscience for Engineers	11LE50MO-5319 ESE PO 2021
course	
Neurowissenschaften für Ingenieure / Neuroscience for Engineers - Lecture	
Event type	Number
lecture course	11LE50V-5319
Organizer	
Department of Microsystems Engineering, Biomicrotechnology	

ECTS-Points	3.0
Workload	90 hours
Attendance	39 hours
Independent study	51 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

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

Examination achievement

see module details

Course achievement

none

Literature
Literature will be presented during the lecture
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	Number of module
Neuroscience for Engineers	11LE50MO-5319 ESE PO 2021
course	
Neurowissenschaften für Ingenieure / Neuroscience for Engineers - Exercises	
Event type	Number
excercise course	11LE50Ü-5319
Organizer	
Department of Microsystems Engineering, Biomicrotechnology	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
see lecture
Course achievement
None
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Selected Problems in Biosignal Processing	11LE50MO-5303 ESE PO 2021
Responsible	
Prof. Dr. Ulrich Hofmann	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	3.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Prerequisite to be able to follow this module is a thorough understanding of classical signal processing. Strongly recommended is the knowledge of one „programming“ language like Python (preferably), Matlab (or Octave) or even IDL (not supported). It is strongly recommended to complete the module "Neuroprostetics" prior to taking this course.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Ausgewählte Problemstellungen in Biosignalverarbeitung / Selected Problems in Biosignal Processing - Lecture	lecture course	Core elective	3.0	2.0	90 hours
Ausgewählte Problemstellungen in Biosignalverarbeitung / Selected Problems in Biosignal Processing - Exercises	excercise course	Compulsory		1.0	

Qualification
Participants will learn to interpret and analyze biological signals of high bandwidth. They will ▪ gain a deep knowledge of feature extraction methods, ▪ utilize selected classification methods and ▪ decision making methods
Examination achievement
Written documentation and oral presentation about the software developped. The module grade is based on the written documentation (50%) and the oral presentation (50%).

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Selected Problems in Biosignal Processing	11LE50MO-5303 ESE PO 2021
course	
Ausgewählte Problemstellungen in Biosignalverarbeitung / Selected Problems in Biosignal Processing - Lecture	
Event type	Number
lecture course	11LE50V-5303

ECTS-Points	3.0
Workload	90 hours
Attendance	45 hours
Independent study	45 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Selected sources of biosignals:
- ECG
- EMG
- EOG
- EEG
- LFP
- Multi- and Single Unit Neuronal Records

Selected feature extraction methods:
- Nyquist Sampling and standard conditioning
- (adaptive) Filtering
- Fouriertransform and related methods:
  - Fourier Coefficients,
  - Short Term Fourier Transform
  - Gabor Functions
  - Discrete Cosinus Transform
  - Short Term Fourier Transform
- Coarse Graining Signal Analysis
- Bispectrum and Bi-Coherence
- Empirical Mode Decomposition (Hilbert-Huang Transformation)
- Undecimated Wavelet Transform and Polyphase Matrices
- The Teager Operator
- Compressed Sensing
- Kernel Methods and Spike Detections

Selected Classification and Decision Methods
- Principal Components
- Independent Component Analysis

- LDA, QDA, RFD
- Gaussian Mixture Models
- SVM, soft margin SVM
- Hidden Markov Modells
- Maximum Relevance Minimum Redundancy
- Ensemble Methods
- Bagging

Examination achievement
see module details
Course achievement
None
Compulsory requirement
None
Recommended requirement
Prerequisite to be able to follow this module is a thorough understanding of classical signal processing. Strongly recommended is the knowledge of one „programming“ language like Python (preferably), Matlab (or Octave) or even IDL (not supported). It is strongly recommended to complete the module "Neuroprosthetics" prior to taking this course.

↑

Name of module	**Number of module**
Selected Problems in Biosignal Processing	11LE50MO-5303 ESE PO 2021
course	
Ausgewählte Problemstellungen in Biosignalverarbeitung / Selected Problems in Biosignal Processing - Exercises	
Event type	Number
excercise course	11LE50Ü-5303

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents
Examination achievement
See lecture
Course achievement
None
Literature
tba
Compulsory requirement

↑

Name of module	Number of module
Signal processing and analysis in brain signals	11LE50MO-5312 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Signalverarbeitung und Analyse von Gehirnsignalen / Signal processing and analysis in brain signals - Lecture	lecture course	Compulsory	3.0	2.0	90 hours

Qualification
The objective of the module is to show, how signal processing and analysis methods can add additional information to the classical ways of interpreting brain signals measured by electroencephalography (EEG) or magnetoencephalography (MEG). This goes beyond the basic signal processing methods to separate the signal from background noise. General techniques for pattern recognition will be presented and how they are tailored for the daily use in clinical practice or neuroscience research. As a result students will have knowledge of general tools in pattern recognition in recordings of brain signals and how to adapt them to the requirements of the specifics needs in clinical use or for research projects. The second part of the module will add modelling to the signal analysis to perform the localization of generators of brain activity. Different approaches of modelling of the head and the generators of the brain activity will be introduced. The objective is to provide the students with knowledge about different modelling levels and strategies about the selection of generator models, which are appropriate for a given source localization task.

Examination achievement
Oral exam (30 minutes)
Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Signal processing and analysis in brain signals	11LE50MO-5312 ESE PO 2021
course	
Signalverarbeitung und Analyse von Gehirnsignalen / Signal processing and analysis in brain signals - Lecture	
Event type	Number
lecture course	11LE50V-5312
Organizer	
Department of Microsystems Engineering, Biomedical Microtechnology	

ECTS-Points	3.0
Workload	90 hours
Attendance	26 hours
Independent study	64 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents
The course starts with an introduction to the basic principles of the measurement of neurophysiological signals mainly EEG and MEG. Despite a basic technical introduction of the measurement systems an overview about physiological and pathological patterns and rhythms in brain signal is given. Pattern recognition in the diagnostics of patients suffering from epilepsy is one core topic of the module. Long term recordings of EEG in epilepsy diagnostic create a high demand for automatic EEG analysis procedures. Three different types of events are at the moment in the focus for automatic detection strategies. a) Epileptic seizures, which are the core syndrome of the disease. Automatic detection may facilitate the review of long term recordings tremendously. b) Short high amplitude peaks in EEG and MEG called spikes contribute to the diagnoses of epilepsy and give information related to the localization of the seizure onset region in focal epilepsy. c) Oscillatory activity in the frequency range between 80 Hz and 600 Hz gives according to recent result probably more specific information about the seizure origin area than spikes. Signal processing and pattern recognition strategies are presented and how they can be applied to the patterns of interest in epilepsy diagnostic. In detail following strategies will be presented: a) Heuristics b) Template matching c) Wavelet transformation d) Hilbert transformation e) Background and target modelling f) Artificial neural networks A second focus of the module is related to the localization of generators of neuronal activity based on EEG and MEG measurements.

The introduction starts with the presentation of the Maxwell equations and the common simplifications as they are applied in EEG and MEG source localization. Localization includes two basic components, the forward simulation and an inverse parameter estimation procedure. Concepts of the following forward models representing the physical properties of the head are presented: a) Spherical model b) Boundary element model c) Finite element model Main types of focal and distributed inverse models will form the contents of the inverse part of the source localization procedure. Exemplary application examples will show the complete processing chain from measurements and image acquisition to localization results.
Examination achievement
see module details
Course achievement
None
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Silicon-based Neural Technology	11LE50MO-5116 ESE PO 2021
Responsible	
Prof. Dr. Oliver Paul	
Organizer	
Department of Microsystems Engineering, Microsystem Materials	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Advanced Silicon Technologies for MEMS and IC

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Neurale Technologie auf Silikonbasis / Silicon-based Neural Technology - Lecture	lecture course	Core elective	3.0	2.0	90 hours

Qualification
Students will gain a detailed overview of silicon-based probes used in basic neuroscience research and their combination with alternative materials to provide the desired functionalities. Students will learn the basic requirements regarding system design and function, as well as the system-specific manufacturing technologies.
Examination achievement
Oral examination if there are 20 or fewer than 20 registered participants; written examination if there are more than 20 registered participants (minimum 60 and maximum 240 minutes). Details will be announced by the examiner in due time.
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Silicon-based Neural Technology	11LE50MO-5116 ESE PO 2021
course	
Neurale Technologie auf Silikonbasis / Silicon-based Neural Technology - Lecture	
Event type	Number
lecture course	11LE50V-5116
Organizer	
Department of Microsystems Engineering, Microsystem Materials	

ECTS-Points	3.0
Workload	90 hours
Attendance	30
Independent study	60
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

- Introduction - Basic requirements in neuroscience
- Electrical probes
- Fluidic probes
- Optical probes
- Chemotrodes
- IC Technologies for Signal Amplification and Processing
- Packaging and interconnection technologies

Examination achievement

see module details

Course achievement

see module details

Literature

current conference and journal articles

Compulsory requirement

none

Recommended requirement

Advanced Silicon Technologies for MEMS and IC

↑

Name of module	**Number of module**
Wearable and Implantable Computing (WIC)	11E13MO-1402_PO 2020
Responsible	
Prof. Dr. Oliver Amft	
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Attendance	32 Stunden / Hours
Independent study	116 Stunden / Hours
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Basic timeseries analysis methods, basic programming skills, coding in Python

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Wearable and Implantable Computing (WIC)	lecture course	Core elective	6.0	2.0	180 Stunden / Hours
Wearable and Implantable Computing (WIC)	excercise course	Core elective		2.0	

Qualification
Students are able to ■ Understand design concepts and apply/analyse wearable and implantable system design methods. ■ Analyse physical principles, select and optimise on-body energy harvesting and power management techniques. ■ Create context recognition and energy-efficient pattern analysis pipelines using sparse sampling and pattern processing methods. ■ Build wearable system prototypes and apply system evaluation methods, including design for biocompatibility.

Examination achievement
mündliche Prüfung (i.d.R. 30 oder 45 Minuten) | Oral exam (usually 30 or 45 minutes) If there are too many students for a reasonably organized oral exam, it will be held as a written exam instead, announced well in advance.
Course achievement
Durchführung von Versuchen und Ergebnisprotokoll | Execution of experiments and written report of results
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung **|** Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science **OR** in Microsystems Engineering Concentrations Area Circuits and Systems/Biomedical Engineering ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems/Biomedical Engineering ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme/Biomedizinische Technik Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. M.Sc. Embedded Systems Engineering **and** Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. M.Sc. Embedded Systems Engineering

↑

Name of module	**Number of module**
Wearable and Implantable Computing (WIC)	11E13MO-1402_PO 2020
course	
Wearable and Implantable Computing (WIC)	
Event type	Number
lecture course	11E13V-1402_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Attendance	32 Stunden / Hours
Independent study	116 Stunden / Hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The course provides students with a comprehensive overview and in-depth skills on system design of sensor-based wearable and implantable computing systems. Course covers frequent sensors and actuators and their system integration, context recognition methods and selected algorithms, powering and energy management concepts (task scheduling, sparse sampling, and on-demand signal processing), energy harvesting methods, and system design topics (flexible electronics, electronics textile integration, multiprocess additive manufacturing), as well as principles of system validation.
Examination achievement
see module details
Course achievement
see module details
Literature
Up-to-date literature recommendations are provided during the lectures.
Compulsory requirement
None
Recommended requirement
Basic timeseries analysis methods, basic programming skills, coding in Python

↑

Name of module	**Number of module**
Wearable and Implantable Computing (WIC)	11E13MO-1402_PO 2020
course	
Wearable and Implantable Computing (WIC)	
Event type	Number
excercise course	11E13Ü-1402_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	
Attendance	32 Stunden / Hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Student groups will investigate concrete cases including context recognition, energy-efficient signal processing, and digital design of wearable systems. A wearable device prototype will be realised per student group.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
MSE Study Project in Concentration Biomedical Engineering	11LE50MO-5997 ESE SP-BE
Responsible	
Prof. Dr.-Ing. Bastian Rapp	
Faculty	
Faculty of Engineering	

ECTS-Points	9.0
Workload	270 Stunden / hours
Hours of week	
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
none
Recommended requirement
allgemeine mathematische Grundlagen, praktische und theoretische Grundlagen der Ingenieurswissenschaften, Programmierkenntnisse, themenspezifische Vorkenntnisse für den gewählten Themenbereich | general fundamental mathematical knowledge, practical and theoretical foundations in Engineering Sciences, programming skills, subject-specific knowledge for the chosen topics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload

Qualification
In this module students get involved in the actual research process of the chosen work group/chair in the area of Biomedical Engineering. Depending on their personal field of interest and their expertise in various research and teaching areas offered at the Department of Microsystems Engineering, they decide on a specific topic and deepen their knowledge and skills in this area as well as their overall proficiency in academic work and research. They learn to work on the different tasks required for the specific project under given technical specifications, to develop appropriate systems and to work experimentally and constructively in projects. Students acquire the ability to familiarize themselves with new engineering problems and do independent background research. They will work with modern development environments and adhere to the generally accepted quality standards. During the project, working in a team as well as observing the rules of good scientific work will be trained.
Examination achievement
The graded assessment is (depending on the topic) either a written research paper (if it is rather a theoretical or fundamentally based topic; length usually maximum 40 pages) or the creation of a software or a demonstrator including a sufficient documentation (according to the scientific standards) and subsequent discussion. Details are agreed upon with the supervisor (usually a person authorized to conduct examinations at the Department of Microsystems Engineering) when the topic is assigned.

Course achievement
As a rule, the course work consists of the following components: - regular attendance of (team) meetings or discussions with the supervisor - oral presentation (usually 20 - 30 minutes) with subsequent discussion
Recommendation
Language is usually English, but might be negotiable (changed to German). Please learn about the procedure of finding a topic and registering for the project in good time. (For instance, see "A to Z - Study FAQ" under "Studies and Teaching" on our faculty website.) Students are expected to self-organize the given tasks and do background research.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Biomedical Engineering

↑

Name of node	Number of node
Photonics	11LE50KT-MSc-787-2021-MSE-P
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Compulsory

↑

Name of module	**Number of module**
Advanced Optics Laboratory	11LE50MO-5280 ESE PO 2021
Responsible	
Prof. Dr. Hans Zappe	
Organizer	
Department of Microsystems Engineering, Professorship in Micro-optics	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
Successful participation in the 'Basic Optics Laboratory' is a prerequisite
Recommended requirement
BSc. level in physics and mathematics; MSc. course Micro-optics and knowledge from the Basic optics Lab

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Optik-Praktikum Fortgeschritten / Advanced Optics Laboratory	practical course	Core elective	3.0	2.0	90 hours

Qualification

The students will develop advanced expertise in the design, assembly and characterization of optical systems and become experienced in understanding physics in optical systems.

At the completion of the course, the students will possess:

- the ability to design optical systems
- the ability to assemble and align complex optical systems
- the ability to analyze the properties of optical systems
- an insight into modern optical experiments
- advanced knowledge in analyzing experimental results
- an understanding of physics in optical setups

Examination achievement

A laboratory report is required for each of the 6 experiments. The overall grade will be the average of the grades of the individual laboratory reports. All experiments must be performed and a lab report written. In case of illness an amended date for the missed experiment will be offered.

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	**Number of module**
Advanced Optics Laboratory	11LE50MO-5280 ESE PO 2021
course	
Optik-Praktikum Fortgeschritten / Advanced Optics Laboratory	
Event type	Number
practical course	11LE50P-5217-2
Organizer	
Department of Microsystems Engineering, Professorship in Micro-optics	

ECTS-Points	3.0
Workload	90 hours
Attendance	30 hours
Independent study	60 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

This advanced Optics Lab Course provides an opportunity for hands-on experimentation on topics introduced in the different optics courses at IMTEK. The course is based on the knowledge acquired in the 'Basic Optics Laboratory' which is a prerequisite.

Table of contents:
- Anamorphic imaging
- Dynamically addressable gratings
- Whispering gallery resonators
- Michelson interferometer and coherence
- Three dimensional light distribution in a 6f system
- Diode pumped solid state laser

Examination achievement

see module details

Course achievement

None

Literature

In German:
- Naumann/Schröder: Bauelemente der Optik
- E. Hecht: Optik
- Walcher: Praktikum der Physik
- Westphal: Physikalisches Praktikum
- Geschke: Physikalisches Praktikum

In English:

- H. Zappe: Fundamentals of Micro-optics
- Goodman: Introduction to Fourier Optics
- E. Hecht: Optics
- B. Saleh & M. Teich: Fundamentals of Photonics
- W. Smith: Modern Optical Engineering
- P. Hariharan: Basics of interferometry
- R.R. Shannon: The art and science of optical design
- W.J. Smith: Practical optical system layout

Compulsory requirement
Successful participation in the 'Basic Optics Laboratory' is a prerequisite
Recommended requirement
None
Recommendation
Participants in this laboratory course will work in groups on the ten experimental modules. Individual guidance will be in English and German according to preference. Instruction manuals in English and German will be made available.

↑

Name of module	**Number of module**
Basic Optics Laboratory	11LE50MO-5213 ESE PO 2021
Responsible	
Prof. Dr. Hans Zappe	
Organizer	
Department of Microsystems Engineering, Professorship in Micro-optics	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
BSc. level in physics and mathematics; MSc. course Micro-optics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Optik-Praktikum Grundlagen / Basic Optics Laboratory	practical course	Core elective	3.0	2.0	90 hours

Qualification

The Basic Optics Laboratory provides an opportunity for hands-on experimentation on the topics introduced in the Micro-optics course. As a result, the students will develop expertise in the design, assembly and characterization of optical systems and become experienced in making optical measurements.
At the completion of the course, the successful student should possess:

- the ability to analyze measurement data and estimate errors;
- the ability to apply error propagation methods;
- the ability to assemble and align optical systems;
- a basic understanding of optical design methods;
- the ability to apply optical measurement techniques;
- the ability to apply analytical and graphical techniques for analyzing optical images.

Examination achievement

A laboratory report is required for each of the 8 experiments. The overall grade will be the average of the grades of the individual laboratory reports. All experiments must be performed and a lab report written. In case of illness an amended date for the missed experiment will be offered.

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	Number of module
Basic Optics Laboratory	11LE50MO-5213 ESE PO 2021
course	
Optik-Praktikum Grundlagen / Basic Optics Laboratory	
Event type	Number
practical course	11LE50P-5213-2
Organizer	
Department of Microsystems Engineering, Professorship in Micro-optics	

ECTS-Points	3.0
Workload	90 hours
Attendance	26 hours
Independent study	64 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

One laboratory experiment has been conceived for each of the important topics addressed in the Micro-optics course; a different experiment is performed each week of the laboratory course. The topics addressed include geometric, reflective, diffractive and fiber optics as well as Fourier optics, interference, diffraction and polarization. To allow adequate representation and analysis of the measured experimental data, the course begins with a compact mini-lecture on data analysis.

Table of contents:

1. Statistics and data analysis
2. Error propagation
3. Focal length of lenses
4. Focal length of lens systems
5. Construction of a microscope
6. Diffraction from gratings
7. Newton’s rings
8. Fiber optics
9. Construction of an interferometer
10. Polarization

Examination achievement

see module details

Course achievement

None

Literature

In German:

- E. Hecht: Optik

- Walcher: Praktikum der Physik
- Westphal: Physikalisches Praktikum
- Geschke: Physikalisches Praktikum

In English:
- H. Zappe: Fundamentals of Micro-optics
- E. Hecht: Optics
- B. Saleh & M. Teich: Fundamentals of Photonics
- S. Sinziger & J. Jahns: Microoptics
- W. Smith: Modern Optical Engineering
- P. Hariharan: Basics of interferometry
- R.R. Shannon: The art and science of optical design
- D. Malacara: Optical shop testing
- W.J. Smith: Practical optical system layout

Compulsory requirement
None
Recommended requirement
BSc. level in physics and mathematics; MSc. course Micro-optics.
Recommendation
Participants in this laboratory course will work in groups on the ten experimental modules. Individual guidance will be in English and German according to preference. Instruction manuals in English and German will be made available.

↑

Name of module	**Number of module**
Gas sensors	11LE50MO-5704 ESE PO 2021
Responsible	
Prof. Dr. Jürgen Wöllenstein	
Organizer	
Department of Microsystems Engineering, Thin-film Gas Sensors	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Gassensorik / Gas sensors - Lecture	lecture course	Core elective	3.0	2.0	90 Stunden

Qualification
Das Ziel dieses Moduls ist die Vermittlung der physikalischen, chemischen, elektrischen Funktionsweise von Gassensoren. Dabei werden aufbauend auf den vermittelten Grundlagen typische Sensoranordnungen, Herstellungs-verfahren mit Fokus auf die Mikrosystemtechnik sowie Anwendungen der Sensoren in der Praxis vorgestellt. Die Studierenden sollen den Zusammen-hang zwischen den Messprinzip, Design, Fertigungsprozessen und dem Einsatz der Sensoren erlernen. | The aim of this module is to teach the physical, chemical and electrical functions of gas sensors. Building on the fundamentals taught, typical sensor arrangements, manufacturing processes with a focus on microsystems technology and applications of the sensors in practice are presented. The students should learn the connection between the measuring principle, design, manufacturing processes and the application of the sensors.
Examination achievement
oral examination (30 minutes)

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	**Number of module**
Gas sensors	11LE50MO-5704 ESE PO 2021
course	
Gassensorik / Gas sensors - Lecture	
Event type	Number
lecture course	11LE50V-5704
Organizer	
Department of Microsystems Engineering, Thin-film Gas Sensors	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	30 Stunden
Independent study	60 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	german

Contents

In der Vorlesung werden Gassensoren, die auf unterschiedlichsten, chemischen und physikalischen Prinzipien basieren, vorgestellt und deren Funktionsweise, Herstellung und Anwendung vermittelt. Gassensoren decken Massenmärkte mit sehr großen Stückzahlen ebenso ab, wie applikationsspezifische Sonderlösungen. Folgende wichtige Grundlagen für die Gassensorik werden diskutiert:

- Wechselwirkung Gas-Halbleiter, Adsorption, Elektrische Auswirkungen von adsorbierten Gasen
- Wärmeleitung u. –kapazität, Paramagnetismus von Gasen
- Schwingungs- und Rotationsspektren im IR, Druck- und Dopplerverbreiterung, Linienformen
- Interferometer, Schwarzkörperstrahlung, Elektrochemie

Folgende Bauelemente und Messsysteme werden vorgestellt:

- Metalloxidgassensoren, Lambdasonde, Gassensitive Feldeffekttransistoren
- Wärmeleitfähigkeitssensoren, Pelistoren
- Paramagnetischer Sauerstoffsensor
- Optische Systeme (Laserspektrometer, Filterphotometer, Photoakustik, Wellenleiter), Fourier Transformations Infrarot Spektrometer
- Elektrochemische Sensoren, Elektronische Nasen

Examination achievement

siehe Modulebene

Course achievement

keine

Literature

Begleitend zur Vorlesung wird ein Folien-Skriptum zur Verfügung gestellt.

Compulsory requirement
Keine
Recommended requirement
Keine

↑

Name of module	**Number of module**
Lasers	11LE50MO-5283 PO 2021
Responsible	
PD Dr. Ingo Breunig	
Organizer	
Department of Microsystems Engineering, Optical Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Compulsory
Frequency	takes place each summer term

Compulsory requirement
keine

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Lasers	lecture course	Core elective	6.0	2.0	180 Stunden / 180 hours
Laser	excercise course	Compulsory		2.0	

Qualification
Lasers are versatile tools with a high relevance for microsystems engineering. In this course, the students gain knowledge about different types of lasers and their respective applications. They achieve a deeper understanding on the fundamentals of laser operation. Consequently, the participants will be able to - Select an apprpriate laser for a given task - Better design microsystems including lasers - Easier understand already existing systems
Examination achievement
Klausur / written exam (Dauer/duration 120 Mins.)
Course achievement
keine | none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	**Number of module**
Lasers	11LE50MO-5283 PO 2021
course	
Lasers	
Event type	Number
lecture course	11LE50V-5283 PO 2021
Organizer	
Department of Microsystems Engineering, Optical Systems	

ECTS-Points	6.0
Workload	180 Stunden / 180 hours
Attendance	52 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
Fundamentals of laser operation and basic setup - Resonator concepts and miniaturization concepts - Properties of different laser types (gas lasers, solid state lasers, semiconductor lasers) - Important operation modes (single frequency, short laser pulses) - Changing the color of laser light - Applications (analytics, 3d shape determination,...)
Examination achievement
siehe Modulebene
Course achievement
siehe Modulebene
Literature
A. E. Siegman, "Lasers" D. Meschede, "Optics, Light and Lasers" A. Yariv, "Photonics: Optical Electronics in Modern Communications"
Compulsory requirement
None
Recommended requirement
It is recommended to have attended the "Micro-optics" lecture before atteding this course.

↑

Name of module	**Number of module**
Lasers	11LE50MO-5283 PO 2021
course	
Laser	
Event type	Number
excercise course	11LE50Ü-5283 PO 2021
Organizer	
Department of Microsystems Engineering, Optical Systems	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Compulsory
Languages	german, english

Contents
In the tutorials, the content of the lectures will be applied using practical examples. Here, we emphasize the importance of knowing which approximations/assumptions are made when describing the underlying effects.Furthermore, we cover relevant engineering-based questions like: Why do semiconductor-laser materials have a refractive index of 3 and beyond? or Why do we need tens of amplifiers for transatlantic laser-based telecommunication?
Examination achievement
siehe Modulebene
Course achievement
siehe Modulebene
Compulsory requirement

↑

Name of module	**Number of module**
Physics of Microscopy and Optical Image Formation	11LE50MO-5902 ESE PO 2021
Responsible	
Prof. Dr. Alexander Rohrbach	
Organizer	
Department of Microsystems Engineering, Bio- and Nano-Photonics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	5.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Photonische Mikroskopie / Photonic Microscopy - Lecture	lecture course	Core elective	6.0	3.0	180 hours
Physics of Microscopy and Optical Image Formation	excercise course	Core elective		2.0	

Qualification
The students shall understand how light can be guided through optical systems, how optical information can be described effectively by three-dimensional transfer functions in Fourier space, how the phase information of a wave can be transferred into amplitude information to produce image contrast. Furthermore, the students will learn to distinguish coherent and incoherent imaging techniques and learn about state-of-the-art techniques with self-reconstructing beams, two photon excitation, fluorophore depletion by stimulated emission (STED) or multi-wavelength mixing as in coherent anti-Stokes Raman scattering (CARS). This module is a application-oriented mixture of fundamental physics, conceivable mathematical theories and numerous examples and images and tries to convey the latest state of this particular scientific discipline, which will massively influence the areas of nanotechnology, biology and medicine in the next years.

Examination achievement
Up to 6 students: oral exam (40 minutes) 7 or more students: written exam (120 minutes)
Course achievement
In order to meet the requirements of the "Studienleistung", the students have to treat a minimum of 60% of the tutorial exercises, and additionally present minimum two exercises in the tutorials.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	**Number of module**
Physics of Microscopy and Optical Image Formation	11LE50MO-5902 ESE PO 2021
course	
Photonische Mikroskopie / Photonic Microscopy - Lecture	
Event type	Number
lecture course	11LE50V-5902
Organizer	
Department of Microsystems Engineering, Bio- and Nano-Photonics	

ECTS-Points	6.0
Workload	180 hours
Attendance	75 hours
Independent study	105 hours
Hours of week	3.0
Recommended semester	3
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

1. Microscopy: History, Presence and Future
1.1 History
1.2 Present and Future Tasks
1.3 Literature

2. Wave- and Fourier-Optics
2.1 What is Light?
2.2 The change of Light in Matter
2.3 Helmholtz equation and plane waves
2.4 Wave functions in space and frequency domain
2.5 Superposition of waves: Interference and Coherence
2.6 Fourier-Optics
2.7 Wave propagation and diffraction

3. Three-dimensional optical imaging and information transfer
3.1 Imaging through lenses
3.2 Optical image formation – a spatial low-pass filtering
3.3 Optical resolution and optical transfer function
3.4 Coherent and incoherent imaging
3.5 Vectorial light focusing
3.6 Aberrations of the Point-Spread Function

4. Contrast enhancement by Fourier-filtering
4.1 Image formation with phase objects
4.2 Phase contrast according to Zernike
4.3 Dark field microscopy and amplitude spatial filters

4.4 Generating contrast by polarization 4.5 Holographic microscopy 5. Fluorescence – Basics and Techniques 5.1 Definitions and principles of light scattering 5.2 Fluorescence excitation und emission 5.3 Decay rates and fluorescence lifetime 5.4 Fluorescence Polarisation and Anisotropy 6. Point scanning and confocal microscopy 6.1 Image formation with point- and area-detectors 6.2 Confocal microscopy 6.3 4pi Microscopy 7. Microscopy in thick media 7.1 Photon diffusion in strongly scattering media 7.2 Light Sheet Microscopy 7.3 Microscopy with holographic scan beams 7.4 Lattice light-sheet microscopy 8. Nearfield and Evanescent Field Microscopy 8.1 The spectrum of near fields and far fields 8.2 Nearfield Scanning Optical Microscopy (NSOM) 8.3 Evanescent illumination and TIR- Microscopy 9. Super-resolution by structured illumination 9.1 Modulated illumination to increase resolution 9.2 Structured illumination for axial sectioning 10. Multi-Photon-Microscopy 10.1 Basics of nonlinear optics 10.2 Two-photon fluorescence microscopy 10.3 Second Harmonic Generation-Microscopy 10.4 CARS microscopy 11. Super-resolution imaging by switching single molecules 11.1 Position tracking 11.2 STED-Microscopy 11.3 PALM and STORM 11.4 Super-resolution optical fluctuation imaging (SOFI) 12. Appendix 12.1 Signal and Noise 12.2 Survey about super resolution microscopy
Examination achievement
Up to 6 students: oral exam (40 minutes) 7 or more students: written exam (120 minutes)
Course achievement
see Tutorials
Literature
An additional scriptum with defined blank areas (white boxes), accompanying the lecture contents, will be provided.
Compulsory requirement
none

Recommended requirement
none

↑

Name of module	**Number of module**
Physics of Microscopy and Optical Image Formation	11LE50MO-5902 ESE PO 2021
course	
Physics of Microscopy and Optical Image Formation	
Event type	Number
excercise course	11LE50Ü-5902
Organizer	
Department of Microsystems Engineering, Bio- and Nano-Photonics	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective

Contents
The tutorials help the student to get a more in depth and thorough understanding of the lecture. Here, a special focus is put on the transfer of knowledge obtained in the lecture. To achieve this the students should prepare weekly exercises and present them during the tutorial. Only difficult exercises may be presented by the tutors.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	Number of module
Nano-Photonics - Optical manipulation and particle dynamics	11LE50MO-5281 ESE PO 2021
Responsible	
Prof. Dr. Alexander Rohrbach	
Organizer	
Department of Microsystems Engineering, Bio- and Nano-Photonics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	5.0
Recommended semester	4
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Basic courses in mathematics and physics, foundations of optics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Nano-Photonics - Optical manipulation and particle dynamics	lecture course	Core elective	6.0	3.0	180 h
Nano-Photonics - Optical manipulation and particle dynamics	excercise course	Core elective		2.0	

Qualification
You think basic research and applied research cannot be well combined? You think that directing a laser pointer beam into a droplet of coffee results in infinitely complex physics, but explaining the physics therein is not good for anything? You want to learn complex physics of technologies that is of social benefit? If yes, this lecture can be interesting to you! In this lecture you will learn - the direct relation from the Maxwell equations and the electromagnetic force density to optical forces and optical tweezers, which allowed to control molecular processes mainly in cellular biology and medicine - how photons transfer momentum to microscopic objects and how scattered photons transfer information about the state of the objects. In particular coherent light can encode extremely much information about the state of small objects, which, driven by thermal forces, continuously change their position and orientation relative to their environment. All this can be directly measured through µs-nm particle tracking.

- how smallest probes can interact on a molecular scale with their environment, which can be analyzed by correlations of changes in the probe's states. In this way, the interaction of probes with living cells gives new insights into cellular diseases. This includes not only bacterial and viral infections, but also exposure of particulate matter to lung cells.
Examination achievement
Written exam (120 minutes)
Course achievement
There are exercises at regular intervals that have to be worked on and handed in.These are corrected and assessed with points. The course work is considered succesfully passed when the student has submitted 60% of the exercises and demonstrated the solution of two assignments during the exercise sessions.
Usability
Wahlpflichtmodul für Studierende des Studiengangs ■ Bachelor of Science in Mikrosystemtechnik (PO 2018) im Wahlpflichtbereich, Bereich Mikrosystemtechnik Compulsory elective module for students of the study program ■ Master of Science in Microsystems Engineering (PO 2021), concentration area Photonics ■ Master of Science in Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ Master of Science in Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	Number of module
Nano-Photonics - Optical manipulation and particle dynamics	11LE50MO-5281 ESE PO 2021
course	
Nano-Photonics - Optical manipulation and particle dynamics	
Event type	Number
lecture course	11LE50V-5281
Organizer	
Department of Microsystems Engineering, Bio- and Nano-Photonics	

ECTS-Points	6.0
Workload	180 h
Attendance	65 h
Independent study	115 h
Hours of week	3.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Motivation:

You think basic physics research and applied research leading to a social benefit cannot be well combined? When particles or macro-molecules undergo thermal collisions with smaller molecules in (complex) fluids or in air, thermal (Brownian) motion with stochastic changes in positions and velocities take place - beyond our imagination. Such particles can be viruses or particulates from combustion engines in the air that get into contact with e.g. lung cells. How can a limited number of photons be generated in such a way that they scatter efficiently at the small, fast particles and carry the maximum information with them. How can the particle information encoded by the scattered photons be amplified by intelligent detection mechanisms? How can rare but important interaction events be manipulated by photon momentum transfer and optical forces?

In this lecture you will learn
- the transfer from the Maxwell equations and the electromagnetic force density to optical forces and optical tweezers, which allow to control molecular processes relevant to cellular biology and medicine
- the basics of light scattering, how photons transfer momentum to microscopic objects and how scattered photons transfer information about the state of the objects. In contrast to incoherent photons, coherent light encodes significantly more information about small objects, which, driven by thermal forces, continuously change their position and orientation relative to their environment. All this can be directly measured through µs-nm particle tracking.
- how smallest probes can interact on a molecular scale with their environment, which can be analyzed by correlations of changes in the probe's states. In this way, the interactions of probes with living cells give new insights into cellular diseases, such as bacterial and viral infections, but also exposure of particulate matter to lung cells.
The summer term lecture “Wave Optics” is quite helpful to hear, but not mandatory.

Contents ■ Introduction ■ Light – Carrier of Information and Actor ■ Microscopy und Light Focussing ■ Light Scattering ■ Manipulation by Optical Forces ■ Particle Tracking beyond the Uncertainty Regime ■ Thermal Motion and Calibration ■ Photonic Force Microscopy ■ Applications in Biophysics and Medicine ■ Time-Multiplexing and holographic optical traps ■ Applications in Micro- and Nano-Technology ■ Appendix
Examination achievement
see module details
Course achievement
see module details
Literature
Accompanying to the lecture printed lecture notes with defined gaps (white boxes) are distributed.
Compulsory requirement
None
Recommended requirement
Basic courses in mathematics and physics, foundations of optics

↑

Name of module	**Number of module**
Nano-Photonics - Optical manipulation and particle dynamics	11LE50MO-5281 ESE PO 2021
course	
Nano-Photonics - Optical manipulation and particle dynamics	
Event type	Number
excercise course	11LE50Ü-5281
Organizer	
Department of Microsystems Engineering, Bio- and Nano-Photonics	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The tutorials help the students to get a more in depth and thorough understanding of the lecture. Here, a special focus is put on the transfer of knowledge obtained in the lecture. To achieve this the students should prepare weekly exercise and present them during the tutorial. Only difficult exercises are presented by the tutors.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
Basic courses in mathematics and physics, foundations of optics

↑

Name of module	**Number of module**
Optical Methods for Quality Assurance in Sustainable Production	11LE50MO-4305 ESE PO 2021
Responsible	
Prof. Dr. Daniel Carl	
Organizer	
Department of Sustainable Systems Engineering-VB	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 h
Hours of week	2.0
Recommended semester	3
Duration	1 semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
None
Recommended requirement
Fundamental knowledge about photonics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Optical Methods for Quality Assurance in Sustainable Production - Vorlesung	lecture course	Core elective	3.0	2.0	90 h

Qualification

Metrology plays for the majority of manufacturers one of the most important roles in quality control, being essential to avoid production of “non-good” parts and hence to stop wasting of energy, materials, and productivity. Here optics helps to make efficient use of resources and to produce high-quality parts and goods that finally really work for a long period of use. This are immediate benefits for a more sustainable world. Since here economic and environmental aspects are in line, penetration of this technology is happening. The key is to identify the chances and to develop the tailored, reliable optical metrology to do this job. Within this context, the lecture gives insights into the fundamental principles and methods of optical metrology for production control.

In detail, the students will learn
- basic principles of geometrical optical measurements,
- fundamentals of wave optics,
- operation of optical sensors,
- principles of digital data/image processing,
- different optical measurement methods and their applications.

■ schematics to identify opportunities to improve the efficiency of production processes by optical metrology
Examination achievement
Final written supervised exam, 90 min. 5 topics with 3-5 questions on each topic.
Course achievement
None
Usability
Elective module for students of the study program ■ M.Sc. in Sustainable Systems Engineering (PO 2021) in the technical concentration area *Sustainable Materials Engineering*

↑

Name of module	Number of module
Optical Methods for Quality Assurance in Sustainable Production	11LE50MO-4305 ESE PO 2021
course	
Optical Methods for Quality Assurance in Sustainable Production - Vorlesung	
Event type	Number
lecture course	11LE68V-4305 PO 2021

ECTS-Points	3.0
Workload	90 h
Attendance	30 h
Independent study	60 h
Hours of week	2.0
Recommended semester	3
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

- Basic principles of geometrical optical measurements
- Fundamentals of wave optics
- Optical Sensors
- Overview of optical measurement principles and their applications
- Incoherent methods (Triangulation, Fringe projection, …)
- Coherent methods (Interferometry, Speckle, Holography, …)
- Confocal methods
- Examples for successful implementation of optical metrology in industry, with economical and sustainability win-win situations

The lecture includes an excursion to production control laboratories at Fraunhofer IPM.

Examination achievement

See module

Course achievement

See module

Literature

- LEACH, Richard (Hg.). Optical measurement of surface topography. Berlin: Springer, 2011.
- Saleh, Bahaa EA, and Malvin Carl Teich. Fundamentals of photonics. John Wiley & Sons, 2019.

Compulsory requirement

None

Recommended requirement

Fundamental knowledge about photonics

Teaching method
Lecture

↑

Name of module	**Number of module**
Optical Materials	11LE50MO-5113-2 ESE PO 2021
Responsible	
Prof. Dr. Karsten Buse	
Organizer	
Department of Microsystems Engineering, Optical Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
It is strongly recommended to attend the Micro-optics lecture before attending this course.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Optische Materialien / Optical Materials - Lecture	lecture course	Core elective		2.0	180 hours
Optische Materialien / Optical Materials - Exercises	excercise course	Core elective		2.0	

Qualification
Optical devices rely on optical materials that control the propagation (lenses, fibers), the polarization (half-wave plates, Faraday rotators), or the frequency (nonlinear-optical materials) of light. In this course, we will classify optical materials and cover the fundamentals of light-matter interaction as well as effects that are widely used in many applications. Our goal is to enable the participants to understand important optical devices from the material point-of-view and to qualify the attendees to select the right material for a particular application.
Examination achievement
Written exam (150 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	**Number of module**
Optical Materials	11LE50MO-5113-2 ESE PO 2021
course	
Optische Materialien / Optical Materials - Lecture	
Event type	Number
lecture course	11LE50V-5113
Organizer	
Department of Microsystems Engineering, Optical Systems	

ECTS-Points	
Workload	180 hours
Attendance	60 hours
Independent study	120 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

1. Classification of optical materials
2. Fabrication
3. Interaction of light and matter
4. Pulse propagation in dispersive materials
5. Birefringence
6. Faraday effect
7. Nonlinear-optical effects
8. Pockels effect
9. Kerr effect
10. Photorefractivity
11. Frequency conversion
12. Optical parametric oscillators
13. Optical whispering galleries

Examination achievement

see module details

Course achievement

None

Literature

- B. E. A. Saleh, M. C. Teich, „Grundlagen der Photonik“
- A. Yariv, "Photonics: Optical Electronics in Modern Communications"

Compulsory requirement

None

Recommended requirement
It is strongly recommended to attend the Micro-optics lecture before attending this course.

↑

Name of module	**Number of module**
Optical Materials	11LE50MO-5113-2 ESE PO 2021
course	
Optische Materialien / Optical Materials - Exercises	
Event type	Number
excercise course	11LE50Ü-5113
Organizer	
Department of Microsystems Engineering, Optical Systems	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
See module details
Course achievement
None
Compulsory requirement

↑

Name of module	**Number of module**
Optical MEMS	11LE50MO-5240 ESE PO 2021
Responsible	
Prof. Dr. Hans Zappe	
Organizer	
Department of Microsystems Engineering, Professorship in Micro-optics	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	4
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
It is strongly recommended to successfully complete the Micro-optics module before taking this course.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Optische MEMS / Optical MEMS - Lecture	lecture course	Core elective	3.0	2.0	90 hours

Qualification

- Theoretical understanding of fundamental optical phenomena exploited by the MOEMS technology
- Acquisition of the essential skills necessary for the design, microfabrication, modeling, and characterization of MEMS/MOEMS components
- A comprehensive knowledge of MOEMS based commercial systems and a basic understanding of the particular applications enabled by MOEMS

Examination achievement

Written exam (100 minutes)

Course achievement

none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	**Number of module**
Optical MEMS	11LE50MO-5240 ESE PO 2021
course	
Optische MEMS / Optical MEMS - Lecture	
Event type	Number
lecture course	11LE50V-5240

ECTS-Points	3.0
Workload	90 hours
Attendance	26 hours
Independent study	64 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Module1: MOEMS Fundamentals
• Optics Review
• MEMS Manufacturing Techniques
• Actuators and Position Sensing
• Design and Modeling
• Test and Characterization

Module 2: MOEMS Devices
• Micromirrors
• Tunable Gratings
• Active Microlenses
• Tunable Optical Resonators

Module 3: MOEMS Systems
• Display and Imaging Systems
• MOEMS in Telecommunication Networks
• Scientific Instrumentation

Examination achievement

see module details

Course achievement

none

Literature

MEMS and MOEMS Related Books
- An Introduction to Microelectromechanical Systems Engineering by N. Maluf
- Microsystem Design by Stephen Senturia
- Micromachined Transducers Sourcebook by G. Kovacs

- Fundamentals of Microfabrication by Marc Madou
- Micro Electro Mechanical System Design by J. Allen
- Analysis and Design Principles of MEMS Devices by Minhang Bao
- The MEMS Handbook by Mohamed Gad-el-Hak
- MOEMS: Micro-Opto-Electro-Mechanical Systems by Manouchehr E. Motamedi
- Foundations of MEMS by Chang Liu
- MEMS & Microsystems by Tai-Ran Hsu

Scientific Journals

- Journal of Microelectromechanical Systems / IEEE
- Journal of Micromechanics and Microengineering / IOP
- Journal of Micro/Nanolithography, MEMS, and MOEMS / SPIE
- Microsystem Technologies / SPRINGER
- Sensors and Actuators A-Physical / ELSEVIER
- Applied Optics / OSA
- Optics Letters / OSA
- Optics Express / OSA
- Applied Physics Letters / AIP
- Journal of Biomedical Optics / SPIE

Compulsory requirement
None

Recommended requirement
It is strongly recommended to successfully complete the Micro-optics module before taking this course.

↑

Name of module	**Number of module**
Optical measurement techniques	11LE50MO-5710 ESE PO 2021
Responsible	
Prof. Dr. Karsten Buse	
Organizer	
Department of Microsystems Engineering, Optical Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Optische Messverfahren: Grundlagen und Anwendungen in der Praxis / Optical measurement techniques - Seminar	seminar	Core elective	3.0	2.0	90 hours

Qualification
The students gain knowledge about different optical measurement techniques for shape determination of objects or for material characterization. They achieve a deeper understanding of the physical background. Consequently, the participants are able to estimate the fundamental and technological limitations of the methods presented. This enables the students to select an appropriate optical measurement technique for a given task. Furthermore, the participants get trained in preparing and presenting excellent talks.
Examination achievement
Short written summary of topic and oral presentation (duration 30 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	Number of module
Optical measurement techniques	11LE50MO-5710 ESE PO 2021
course	
Optische Messverfahren: Grundlagen und Anwendungen in der Praxis / Optical measurement techniques - Seminar	
Event type	Number
seminar	11LE50V-5710
Organizer	
Department of Microsystems Engineering, Optical Systems	

ECTS-Points	3.0
Workload	90 hours
Attendance	26 hours
Independent study	64 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
During the first meeting the organizers will present a list of topics from which each active participant of the seminar can select one. For each topic literature will be provided. Starting with this material the active participants of the seminar will familiarize themselves with the content. This will be done by discussions as well as by further literature search. Based on the accumulated knowledge, an outline for talks will be made and finally the viewgraphs will be prepared. Then the talk will be presented in the seminar. Typical duration of the talk is 30 minutes. After the talk there will be a discussion about the content. And as a second part of the discussion technical issues of the talk will be analyzed. Finally, a short written summary of the talk will be prepared. Talks can be given in German or English. This semester, the following topics are available: ■ 3d-shape determination ■ Optical microresonators for sensing ■ Terahertz waves for material characterization ■ Photoacoustic spectroscopy ■ Laser spectroscopy ■ Fluorescence spectroscopy ■ and more
Examination achievement
see module details
Course achievement
None

Literature
The advisor will provide literature as a starting package.
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Optoelectronics	11LE50MO-5229 ESE PO 2021
Responsible	
Prof. Dr. Hans Zappe	
Organizer	
Department of Microsystems Engineering, Professorship in Micro-optics	
Faculty	
Faculty of Engineering	

ECTS-Points	4.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	4
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
Students have to have passed the final exam in Micro-optics.
Recommended requirement
BSc. level physics and mathematics; MSc course Micro-optics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Optoelektronik / Optoelectronic- Lecture	lecture course	Core elective	3.0	2.0	90 hours

Qualification

Optoelectronics is situated at the overlap between optics and electronics and forms the core of the field of photonics. Lasers and LEDs are essential optical semiconductor devices which form the basis for technologies ranging from world-wide high-speed optical data networks to advanced medical instrumentation to high-efficiency indoor lighting.

This course covers the optoelectronics field and introduces the student to the physical principles underlying lasers and quantum light emission; the III-V materials on which almost all optoelectronic components are based; the structure and functionality of laser diodes, LEDs, photodetectors and modulators; and a wide variety of applications for optoelectronic components.

At the completion of the course, the successful student should possess:
- the ability to understand and analyze the essential properties of lasers;
- the ability to understand and analyze the essential properties of photodetectors and modulators;
- an understanding of the basics of III-V materials and their fabrication;

- an awareness of the important physical phenomena on which optoelectronics relies;
- a basic understanding of the physical processes underlying quantum electronics;
- the ability to understand and apply optoelectronic components to microsystems applications;
- the ability to research, plan, and write a technical paper of a standard required for a scientific publication.

Examination achievement
To receive credit for the course, the student will be required to research, write and submit a four-page written paper, using the style of international scientific journals, on a topic related to optoelectronics.
Course achievement
The course work is passed if students have earned at least 25 points on the lecture quizzes (10 quizzes, maximum 3 points each)
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	Number of module
Optoelectronics	11LE50MO-5229 ESE PO 2021
course	
Optoelektronik / Optoelectronic- Lecture	
Event type	Number
lecture course	11LE50V-5229
Organizer	
Department of Microsystems Engineering, Professorship in Micro-optics	

ECTS-Points	3.0
Workload	90 hours
Attendance	26 hours
Independent study	64 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The course considers optoelectronics from the basic photonic and electronic processes, through the materials required, to the individual structures and functionality of the most essential optoelectronic components. 1. Quantum light 2. Materials 3. Light-emitting diodes 4. Lasers 5. Macroscopic lasers 6. Laser diodes 7. Characterization 8. Photodetectors 9. Modulators 10. Applications: communications & medicine
Examination achievement
see module details
Course achievement
see module details
Literature
■ A. Yariv: Optical Electronics ■ A. Siegmann: Lasers ■ H. Zappe: Laser Diode Microsystems ■ M. Fukuda: Optical Semiconductor Devices W.T. Silfvast: Laser Fundamentals

Compulsory requirement
None
Recommended requirement
BSc. level physics and mathematics; MSc course Micro-optics

↑

Name of module	**Number of module**
Spektroskopische Methoden	11LE50MO-5717 ESE PO 2021
Responsible	
Prof. Dr. Jürgen Wöllenstein	
Organizer	
Department of Microsystems Engineering, Thin-film Gas Sensors	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Spektroskopische Methoden	lecture course	Core elective	3.0	2.0	90 Stunden

Qualification
Das Ziel des Moduls ist die Vermittlung der physikalischen Grundlagen und Bauteile moderner spektroskopischer Systeme. Dabei werden aufbauend auf den vermittelten Grundlagen typische Systeme, Modultechnologien und Anwendungen vorgestellt. Die Studierenden sollen die Funktionsweise und den Aufbau spektroskopischer Geräte verstehen und deren Anwendungsgebiete und Anforderungen erlernen. | The aim of the module is to teach the physical fundamentals and components of modern spectroscopic systems. Building on the fundamentals taught, typical systems, module technologies and applications are presented. Students will understand the operation and design of spectroscopic devices and learn their application areas and requirements.
Examination achievement
Oral exam (30 minutes) If the number of participants is rather high, a written exam may be held instead. The students will be informed in good time.

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	Number of module
Spektroskopische Methoden	11LE50MO-5717 ESE PO 2021
course	
Spektroskopische Methoden	
Event type	Number
lecture course	11LE50V-5717
Organizer	
Department of Microsystems Engineering, Thin-film Gas Sensors	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26 Stunden
Independent study	64 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	german

Contents
Spektroskopische Anwendungen finden sich einer Vielzahl von Industrien, der Anwendungsorientierten- und Grundlagenforschung. In der Vorlesung wird ein Verständnis der physikalischen Grundlagen der verschiedenen Spektroskopietechniken und häufig verwendeten Komponenten vermittelt. Der Stand der Technik der verschiedenen Systeme wird vorgestellt.
Examination achievement
siehe Modulebene
Course achievement
keine
Literature
Begleitend zur Vorlesung werden die verwendeten Folien zur Verfügung gestellt.
Compulsory requirement
keine
Recommended requirement
keine

↑

Name of module	**Number of module**
Wave Optics	11LE50MO-5221 ESE PO 2021
Responsible	
Prof. Dr. Alexander Rohrbach	
Organizer	
Department of Microsystems Engineering, Bio- and Nano-Photonics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	5.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Wave Optics	lecture course	Core elective	6.0	3.0	180 hours
Wave Optics	excercise course	Core elective		2.0	

Qualification
The students understand how light interacts with small structures and how optical systems guide light. They know Maxwell's equations and the description of light as photon or wave, depending on the given problem. Furthermore, they understand the close connection between spatial and temporal coherence, interference and holography. The students also know the concepts of linear and non-linear light scattering, as well as the most important plasmonic effects. In total, the students know how to shape light in three dimensions and how optical problems that arise in research and development are solved.
Examination achievement
For 6 or less students oral exam (40 min.), for 7 or more students written exam (120 min.)

Course achievement
The course work is considered succesfully passed when the student has submitted 60% of the exercises and demonstrated the solution of two assignments during the exercise sessions.
Usability
Wahlpflichtmodul für Studierende des Studiengangs ■ Bachelor of Science in Mikrosystemtechnik (PO 2018), im Wahlpflichtbereich, Bereich Mikrosystemtechnik Compulsory elective module for students of the study pogram ■ M.Sc. Microsystems Engineering (PO 2021), concentration area Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	**Number of module**
Wave Optics	11LE50MO-5221 ESE PO 2021
course	
Wave Optics	
Event type	Number
lecture course	11LE50V-5221
Organizer	
Department of Microsystems Engineering, Bio- and Nano-Photonics	

ECTS-Points	6.0
Workload	180 hours
Attendance	65 hours
Independent study	115 hours
Hours of week	3.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

--- in English ---

We do not really know what light is, although the concepts to describe light as waves or as particles usually work well. It is a nontrivial task to explain the colorful intensity distributions we see every day, i.e. the interactions of light with matter. Controlling light on the macroscale and the nanoscale is the key for generating impact in research, development and industry. However, this requires a thorough understanding of wave optics and its powerful theoretical instrument, the description by Fourier transforms.
This english lecture is accompanied by many live experiments and by weekly tutorials, where exercises are discussed that students have to calculate from one week to the next.
The new lecture is a fusion of the two former lectures “Moderne Optik I & II“ and is now organized in 6 chapters.

1. Introduction
Some motivation, literature and a bit of history

2. From Electromagnetic Theory to Optics
What is light ? Which illustrative pictures do the Maxwell equations provide? If matter, dielectric and metallic, consists of coupled, damped springs (harmonic oscillators), how does matter depend on the frequency of light ? What do the wave equation and the Helmholtz equation express and how can one handle waves in position space and frequency space.

3. Fourier-Optics
How does a wave transforms position information into directional information ? Why can this be well described by Fourier transformations in 1D, 2D and 3D ? What has this to do with linear optical system theory including spatial frequency filters and the sampling theorem?

4. Wave-optical Light Propagation and Diffraction
Different methods are introduced of how to describe the propagation of ways in position space and frequency space. We do the direct transfer from propagation to diffraction of light and momentum space. We treat evanescent waves, thin diffracted objects, the propagation of light in inhomogeneous media and the diffraction at gratings. This allows to discuss important active elements such as acousto-optic and spatial light modulators. We end with adaptive optics and phase conjugation.

5. Interference, Coherence and Holography
We learn how a composition of k-vectors define the phases of interfering waves and the resulting stripe patterns. The relative phases of each partial wave in space and time change the interference significantly and define the coherence of light - these concepts will be discussed in detail. We learn how to write and read phase information in holography.

6. Light Scattering and Plasmonics
The interaction of light with matter is based on particle scattering: we discuss the theoretical concepts of light scattering on the background of Fourier theory. We expend these approaches to photon diffusion, nonlinear optics, fluorescence and Raman scattering or scattering at semiconductor quantum dots - which are all hot topics in modern Photonics. A big emphasis is put on the description of surface plasmons and particle plasmons, where light can be extremely confined.

--- in Deutsch ---
Wir wissen nicht wirklich was Licht ist, obwohl die physkalischen Konzepte um Licht als Welle oder als Partikel zu beschreiben, sehr effizient funktionieren. Oft sind jedoch die quantitativen Beschreibungen von farbenvollen Intensitätsverteilungen, die wir alltäglich sehen können, recht kompliziert zu erfassen. Hierbei ist die Kontrolle von Licht, auf makroskopischer und nanoskaliger Ebene der Schlüssel zu eindrucksvollen Ergebnissen und Entdeckungen, die sowohl in der Wissenschaft als auch in der Industrie erzielt werden. In der Vorlesung „Wellenoptik“ werden wir theoretische Werkzeuge, wie beispielsweise die Fourier-Transformation, detailliert besprechen und auf diese Weise Schritt für Schritt ein tiefgründiges Verständnis der Wellenoptik erarbeiten. Die Vorlesung wird begleitet von vielen Experimenten und Übungen welche den Vorlesungsstoff vertiefen und in wöchentlichen Tutoraten besprochen werden.

1. Einleitung
Motivation, weiterführende Literatur und eine kleine Historie.

2. Von der elektromagnetischen Theorie zur Optik
Was ist Licht? Welches illustrative Bild zeichnen die Maxwell Gleichungen? Wenn dielektrische und metallische Materie als gedämpfte Federn beschrieben werden kann, wie ist der Zusammenhang zwischen Material und der Wellenlänge des einfallenden Lichts? Was sagen die Wellengleichung und die Helmholtz Gleichung aus? Wie können Wellen im Orts- und im Frequenzraum beschrieben werden?

3. Fourier-Optik
Wie verändert eine Welle eine Positionsinformation in eine Richtungsinformation? Was ist die Beziehung zur Fourier-Transformationen in 1D, 2D und 3D? Wie steht dies im Zusammenhang mit linearer optischer Systemtheorie, Raumfiltern und dem Abtasttheorem?

4. Wellenoptik, Lichtausbreitung und Beugung
Verschiedene Methoden werden vorgestellt wie die Lichtausbreitung im Orts- und im Frequenzraum beschrieben werden können. Wir stellen den direkten Transfer zwischen Lichtausbreitung und Beugung von Licht her. Wir behandeln evaneszente Wellen, dünne beugende Objekte, die Lichtausbreitung in inhomogenen Medien als auch die Impulserhaltung an optischen Gittern. Dies ermöglicht uns wichtige aktive optische Elemente wie zum Beispiel akusto-optische Modulatoren und SLMs zu diskutieren. Dieses Kapitel endet mit den Themen, adaptive Optik und Phasenkonjugation.

5. Interferenz, Kohärent und Holographie
Wir lernen wie die Komposition von k-Vektoren die Phase interferierender Wellen und die daraus resultierenden Streifenmuster definieren. Die relative Phase einer jeden Teilwelle in Raum und Zeit verändern hier-

bei die Interferenz signifikant und definieren die Kohärenz des Lichts; Diese Konzepte werden detailliert diskutiert. Wir lernen wie Phaseninformation mittels Holographie gelesen und geschrieben werden kann.

6. Lichtstreuung und Plasmonik
Die Interaktion von Licht mit Materie basiert auf der Partikel-Streuung: Wie diskutieren die theoretischen Konzepte der Lichtstreuung im Bezug auf die Fourier-Theorie. Wir erweitern diese Herangehensweise zur Photonendiffusion, nichtlinearer Optik, Fluoreszenz und Raman Streuung als auch Streuung an Halbleitern – alles brandaktuelle Themen in der modernen Photonik. Ein großer Schwerpunkt wird hierbei auf die Beschreibung von Oberflächenplasmonen und Partikelplasmonen gelegt. Hier kann Licht räumlich, extrem beschränkt werden.

1. Einleitung
1.1. Motivation
1.2. Literatur
1.3. Etwas Historie
2. Von der elektromagnetischen Theorie zur Optik
2.1. Was ist Licht?
2.2. Die Maxwell-Gleichungen
2.3. Die Veränderung von Licht in Materie
2.4. Wellengleichung & Helmholtzgleichung
2.5. Wellen im Orts- und Frequenzraum
3. Fourier-Optik
3.1. Einleitung
3.2. Die Fourier-Transformation
3.3. Linear-optische Systeme
3.4. Raumfilter
3.5. Das Sampling Theorem
4. Wellenoptische Lichtausbreitung und Beugung
4.1. Paraxiale Lichtausbreitung und Gauss-Strahlen
4.2. Wellenausbreitung und Beugung
4.3. Evaneszente Wellen
4.4. Beugung an dünnen Phasen- und Amplitudenobjekten
4.5. Lichtausbreitung in inhomogenen Medien
4.6. Beugung an gittern
4.7. Acousto-Optik
4.8. Spatiale Lichtmodulatoren
4.9. Adaptive Optik und Phasenkonjugation
5. Interferenz, Kohärenz und Holographie
5.1. Grundlagen
5.2. Interferometrie
5.3. Grundlagen der Kohärenz-Theorie
5.4. Prinzipien der Holographie
6. Lichtstreuung und Plasmonik
5.5. Streuung von Licht an Partikeln
5.6. Photonen Diffusion
5.7. Grundlagen nichtlinearer Optik
5.8. Fluoreszenz und Raman-Streuung
5.9. Fluoreszierende Quantum-Dots
5.10. Oberflächenplasmone and Partikelplasmone

Examination achievement
see module details

Course achievement
see module details

Literature
Lecture notes with defined voids (white boxes) will be provided.
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Wave Optics	11LE50MO-5221 ESE PO 2021
course	
Wave Optics	
Event type	Number
excercise course	11LE50Ü-5221
Organizer	
Department of Microsystems Engineering, Bio- and Nano-Photonics	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
During the exercise sessions the content of the lecture will be discussed in-depth and consolidated. In particular, students will be taught to transfer the acquired knowledge. The weekly exercise sheets have to be solved within a week and during the exercise sessions students will take turns in demonstrating their solutions on the blackboard, or - in the case of difficult assignments - the solution will be demonstrated by the tutor.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
MSE Study Project in Concentration Photonics	11LE50MO-5999 ESE SP-Ph
Responsible	
Prof. Dr.-Ing. Bastian Rapp	
Faculty	
Faculty of Engineering	

ECTS-Points	9.0
Workload	270 Studen / hours
Hours of week	
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
none
Recommended requirement
allgemeine mathematische Grundlagen, praktische und theoretische Grundlagen der Ingenieurswissenschaften, Programmierkenntnisse, themenspezifische Vorkenntnisse für den gewählten Themenbereich | general fundamental mathematical knowledge, practical and theoretical foundations in Engineering Sciences, programming skills, subject-specific knowledge for the chosen topics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload

Qualification
In this module students get involved in the actual research process of the chosen work group/chair in the area of Photonics. Depending on their personal field of interest and their expertise in various research and teaching areas offered at the Department of Microsystems Engineering, they decide on a specific topic and deepen their knowledge and skills in this area as well as their overall proficiency in academic work and research. They learn to work on the different tasks required for the specific project under given technical specifications, to develop appropriate systems and to work experimentally and constructively in projects. Students acquire the ability to familiarize themselves with new engineering problems and do independent background research. They will work with modern development environments and adhere to the generally accepted quality standards. During the project, working in a team as well as observing the rules of good scientific work will be trained.
Examination achievement
The graded assessment is (depending on the topic) either a written research paper (if it is rather a theoretical or fundamentally based topic; length usually maximum 40 pages) or the creation of a software or a demonstrator including a sufficient documentation (according to the scientific standards) and subsequent discussion. Details are agreed upon with the supervisor (usually a person authorized to conduct examinations at the Department of Microsystems Engineering) when the topic is assigned.

Course achievement
As a rule, the course work consists of the following components: - regular attendance of (team) meetings or discussions with the supervisor - oral presentation (usually 20 - 30 minutes) with subsequent discussion
Recommendation
Language is usually English, but might be negotiable (changed to German). Please learn about the procedure of finding a topic and registering for the project in good time. (For instance, see "A to Z - Study FAQ" under "Studies and Teaching" on our faculty website.) Students are expected to self-organize the given tasks and do background research.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Photonics

↑

Name of node	**Number of node**
Customized Course Selection	11LE50KT-MSc-787-2021-CCS
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Core elective
ECTS-Points	18.0

Comment
Instead of doing courses surpassing the bare minimum of 18 ECTS credits each in the areas of ■ Elective Courses in Computer Science ■ Elective Courses in Computer Science ■ Advanced Microsystems Engineering ■ Microsystems Engineering Concentration Area students can choose other courses of up to 18 ECTS credits that are offered in the Customized Course Selection. These courses can be chosen from ■ Modules/courses from MSc Computer Science or MSc Microsytsems Engineering that are completed as pass/fail courses (“Studienleistung”) only ■ Courses from other Subjects or Departments/Faculties at the University of Freiburg ■ One language course (offered by SLI) All these modules/courses are pass/fail assessments (Studienleistungen, "SL").

↑

Name of module	**Number of module**
MST Design Lab I for Microsystems Engineering	11LE50MO-7003 ESE PO 2021
Responsible	
Prof. Dr. Peter Woias	
Organizer	
Department of Microsystems Engineering, Design of Microsystems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 term
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
MST Design Lab I for Microsystems Engineering	lecture course	Compulsory	6.0	2.0	180 hours
MST Design Lab I for Microsystems Engineering - Praktische Übung	practical course	Compulsory		2.0	

Qualification
The MST Design Lab I is composed from a lecture and an associated lab course. This module is considered as an introduction into the essentials of product design, with a focus towards microsystems. The students shall learn the following topics: "What is product design, what are the suitable strategies for this endeavour?" and "What methodical or technical tools are available for product design, how are they used in the most efficient way?" Tools and strategies are content of the lecture. In the lab course the students will work in groups as virtual start-up companies, to find a product idea, design the product, make a specification sheet for the same and design a working technical solution. All work is done is done virtually, using methodical tools, mathematical models and calculations.
Examination achievement
none

Course achievement
The following deliveries have to be handed in or done at the end of the semester, and will be the basis for grading: A written report, comprising of tasks 1 to 3: Task 1: Specification sheet and market study for your product idea Task 2: Analysis of the specification sheet, solution concept, functional analysis Task 3: mathematical prove of feasibility, budget calculations An oral presentation of the project results (Task 4), together with a hand-in of the presentation material
Usability
Mandatory module for students of the study program ■ M.Sc.Microsytems Engineering (PO 2021) Compulsory elective module for students of the study program ■ M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Customized Course Selection

↑

Name of module	Number of module
MST Design Lab I for Microsystems Engineering	11LE50MO-7003 ESE PO 2021
course	
MST Design Lab I for Microsystems Engineering	
Event type	Number
lecture course	11LE50V-7003_PO 20091
Organizer	
Department of Microsystems Engineering, Design of Microsystems	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents

In the lecture the 4-phase model of product design is treated. Together with the four phases, appropriate desing tools are presented and trained in conjunction with the associated lab course. Contents of the lecture are as follows:

- Introduction: What is product design?
- Product planning and situation analysis
- Product search strategies
- Specification sheets
- Abstraction of specification sheets and functional principles
- Creativity techniques
- Rapid prototyping
- Intellectual property protection by patents
- Technical knowledge related to the proposed product application area

Examination achievement

Course achievement

see module details

Compulsory requirement

none

Recommended requirement

none

↑

Name of module	**Number of module**
MST Design Lab I for Microsystems Engineering	11LE50MO-7003 ESE PO 2021
course	
MST Design Lab I for Microsystems Engineering - Praktische Übung	
Event type	Number
practical course	11LE50prÜ-7003_PO 20091
Organizer	
Department of Microsystems Engineering, Design of Microsystems	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents
In the lab course product design is exercised by the students themselves, working in groups as virtual start-up companies. Their task is to find an innovative product idea, evaluate the potential market for their product, put together a specification sheet, evaluate the same and find a viable technical solution for their product idea. At the end of the semester all groups present their project in an oral presentation.
Examination achievement
Course achievement
see module details
Compulsory requirement
keine

↑

Name of module	**Number of module**
Project management for engineers	11LE50MO-5803 ESE PO 2021
Responsible	
Prof. Dr.-Ing. Ulrike Wallrabe	
Organizer	
Department of Microsystems Engineering, Microactuators	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	each term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Projektmanagement für Ingenieure / Project management for engineers - Seminar	seminar	Core elective		2.0	

Qualification
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.
Examination achievement
none
Course achievement
written exam (90 minutes)

Grading
SL module, but grade is shown in transcript
Recommendation
WS: English, SS: German Please note: The pass/fail assessment (SL) will be graded
Usability
Compulsory elective module for students of the study program ■ M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Customized Course Selection ■ M.Sc.Microsytems Engineering (PO 2021) in Concentrations Area: Customized Course Selection ■ M.Sc. Mikrosystemtechnik (PO 2021) in Concentrations Area: Individuelle Ergänzung Elective module for students of the study program ■ M.Sc. Informatik / Computer Science (PO 2020) in Customized Course Selection, Courses offered in other departments of the University - Microsysteme Engineering

↑

Name of module	**Number of module**
Project management for engineers	11LE50MO-5803 ESE PO 2021
course	
Projektmanagement für Ingenieure / Project management for engineers - Seminar	
Event type	Number
seminar	11LE50P-5803
Organizer	
Department of Microsystems Engineering, Microactuators	

ECTS-Points	
Attendance	28 oder 32 Stunden
Hours of week	2.0
Recommended semester	
Frequency	each term
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
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.
Examination achievement
See module level
Course achievement
See module level
Literature
Regularly updated lecture notes are available.
Compulsory requirement

Teaching method
This course is offered in English in the winter semester, in German in the summer semester.

↑

Name of module	**Number of module**
Scientific writing and presentation	11LE50MO-5801 ESE PO 2021
Responsible	
Prof. Dr. Thomas Hanemann	
Organizer	
Department of Microsystems Engineering, Materials Processing	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	each term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Ergebnisse wissenschaftlich präsentieren / Scientific writing and presentation - Seminar	seminar	Core elective	3.0	2.0	

Qualification

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.

|
The students are
- informed about the importance of adhering to good scientific practice.
- enabled to write a laboratory journal and simple scientific reports
- informed about how to write a master's or doctoral thesis

- enabled to prepare and present a scientific talk (15 min), a short talk (3 min), a scientific poster and a promotional poster.

Examination achievement
none
Course achievement
In this seminar, the process and participation in a scientific conference is "simulated". After an input phase by the lecturer, students have to work on the following components during the semester and upload them on ILIAS: 1. abstract (half a page) 2. 15 min presentation 3. 3 min short presentation 4. scientific poster 5. poster for an open day 6. 6 page paper In terms of content, participants are allowed to use their respective bachelor theses. The presentations and the posters will be presented and discussed in the group and afterwards there will be a feedback by the group and the lecturer. The final grade is calculated by combining the individual components according to their respective weight.
Recommendation
SS: German, WS: English
Usability
Compulsory elective module for students of the study program ■ M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Customized Course Selection ■ M.Sc.Microsytems Engineering (PO 2021) in Concentrations Area: Customized Course Selection ■ M.Sc. Mikrosystemtechnik (PO 2021) in Concentrations Area: Individuelle Ergänzung

↑

Name of module	**Number of module**
Scientific writing and presentation	11LE50MO-5801 ESE PO 2021
course	
Ergebnisse wissenschaftlich präsentieren / Scientific writing and presentation - Seminar	
Event type	Number
seminar	11LE50S-5801

ECTS-Points	3.0
Attendance	28 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents

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

Examination achievement

see module details

Course achievement

see module details

Literature

- C. Ascheron, Die Kunst des wissenschaftlichen Präsentierens und Publizierens, Elsevier, München, 2007, ISBN-13: 978-3-8274-1741-1
- H.F. Ebel, C. Bliefert, W.E. Russey, The Art of Scientific Writing, Wiley-VCH, Weinheim, 2004, ISBN: 978-3-527-29829-7

Compulsory requirement

Teaching method

In the summer semester in German, in the winter semester in English.

↑

Name of module	**Number of module**
Praktikum Informatik 1	11LE13MO-7110-1 ESE PO 2021
Responsible	
Prof. Dr. Hannah Bast	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	each term

Compulsory requirement
keine | none
Recommended requirement
allgmeine praktische und theoretische Grundlagen der Informatik, Programmierkenntnisse, themenspezifische Vorkenntnisse für den gewählten Themenbereich | general practical and theoretical foundations in Computer Science, programming skills, subject-specific knowledge for the chosen topics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload

Contents
Various topics from the research and teaching areas of the work groups/chairs at the Department of Computer Science
Qualification
While working with other students or members of the work groups/chairs at the Department of Computer Science on one of many topics they can choose from following their field of interest, students learn to complete given tasks taking into account the given technical conditions, conduct experiments and record and analyze the results in appropriate scientific manner and report on their work.
Examination achievement
keine | none *Für Studierende im **M.Ed. Informatik** sind Praktika benotete Prüfungleistungen. Details siehe entsprechendes Modulhandbuch.*

Course achievement
As a rule, the course work consists of the following components: - regular attendance of the practical parts of the course as well as (team) meetings and discussions with the supervisor - completing assigned tasks and experiments - creation of software or demonstrators - written report: lab report or protocol or sufficient documentation (according to the scientific standards) - oral presentation (usually 20 - 30 minutes)
Literature
Instructions and background literature are provided by the lecturers
Recommendation
Language is usually English, but might be negotiable (changed to German)
Usability
Compulsory module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) Compulsory elective module for students of the study program ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in the Customized Course Selection Wahlpflichtmodul für Studierende des Studiengangs ■ M.Ed. Informatik (PO 2018); Modul "Informatik - Vertiefung 2"

↑

Name of module	**Number of module**
Praktikum Informatik 2	11LE13MO-7110-2 ESE PO 2021
Responsible	
Prof. Dr. Hannah Bast	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	each term

Compulsory requirement
keine | none
Recommended requirement
allgmeine praktische und theoretische Grundlagen der Informatik, Programmierkenntnisse, themenspezifische Vorkenntnisse für den gewählten Themenbereich | general practical and theoretical foundations in Computer Science, programming skills, subject-specific knowledge for the chosen topics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload

Contents
Various topics from the research and teaching areas of the work groups/chairs at the Department of Computer Science
Qualification
While working with other students or members of the work groups/chairs at the Department of Computer Science on one of many topics they can choose from following their field of interest, students learn to complete given tasks taking into account the given technical conditions, conduct experiments and record and analyze the results in appropriate scientific manner and report on their work.
Examination achievement
keine | none *Für Studierende im **M.Ed. Informatik** sind Praktika benotete Prüfungleistungen. Details siehe entsprechendes Modulhandbuch.*

Course achievement
As a rule, the course work consists of the following components: - regular attendance of the practical parts of the course as well as (team) meetings and discussions with the supervisor - completing assigned tasks and experiments - creation of software or demonstrators - written report: lab report or protocol or sufficient documentation (according to the scientific standards) - oral presentation (usually 20 - 30 minutes)
Literature
Instructions and background literature are provided by the lecturers
Recommendation
Language is usually English, but might be negotiable (changed to German)
Usability
Compulsory module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) Compulsory elective module for students of the study program ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in the Customized Course Selection

↑

Name of module	Number of module
Praktikum Informatik 3	11LE13MO-7110-3 ESE PO 2021
Responsible	
Prof. Dr. Hannah Bast	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	each term

Compulsory requirement
keine | none
Recommended requirement
allgmeine praktische und theoretische Grundlagen der Informatik, Programmierkenntnisse, themenspezifische Vorkenntnisse für den gewählten Themenbereich | general practical and theoretical foundations in Computer Science, programming skills, subject-specific knowledge for the chosen topics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload

Contents
Various topics from the research and teaching areas of the work groups/chairs at the Department of Computer Science
Qualification
While working with other students or members of the work groups/chairs at the Department of Computer Science on one of many topics they can choose from following their field of interest, students learn to complete given tasks taking into account the given technical conditions, conduct experiments and record and analyze the results in appropriate scientific manner and report on their work.
Examination achievement
keine | none *Für Studierende im **M.Ed. Informatik** sind Praktika benotete Prüfungleistungen. Details siehe entsprechendes Modulhandbuch.*

Course achievement
As a rule, the course work consists of the following components: - regular attendance of the practical parts of the course as well as (team) meetings and discussions with the supervisor - completing assigned tasks and experiments - creation of software or demonstrators - written report: lab report or protocol or sufficient documentation (according to the scientific standards) - oral presentation (usually 20 - 30 minutes)
Literature
Instructions and background literature are provided by the lecturers
Recommendation
Language is usually English, but might be negotiable (changed to German)
Usability
Compulsory module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) Compulsory elective module for students of the study program ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in the Customized Course Selection

↑

Name of module	**Number of module**
Kompetenzen für die erfolgreiche Abschlussarbeit	11LE50MO-5609 ESE PO 2021
Responsible	
Prof. Dr. Karsten Buse	
Organizer	
Department of Microsystems Engineering, Optical Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Kompetenzen für die erfolgreiche Abschlussarbeit	lecture course	Core elective	3.0	2.0	90 Stunden | hours

Qualification

- die Grundlagen des wissenschaftlichen Arbeites und der guten wissenschaftlichen Praxis
- Projekt-, Zeit- und Selbstmanagement
- ansprechende und verständliche wissenschaftliche Graphiken erstellen
- gute wissenschaftliche Präsentationen vorbereiten
- gute wissenschaftliche Texte schreiben
- die Grundlagen zu Patenten, Literaturrecherche und wissenschaftlichem Publizieren
- die Grundlagen des Scientific Computing

|

- the basics of scientific work and good scientific practice
- project, time and self-management
- create appealing and comprehensible scientific graphics
- prepare good scientific presentations
- write good scientific texts

- the basics of patents, literature research and scientific publishing
- the basics of scientific computing

Examination achievement
keine | none
Course achievement
Prüfungsgespräch | oral exam
Literature
Wird für jedes Thema individuell zur Verfügung gestellt. | Provided individually for each topic.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Customized Course Selection ■ M.Sc. Mikrosystemtechnik (PO 2021) in Concentrations Area: Individuelle Ergänzung

↑

Name of module	Number of module
Kompetenzen für die erfolgreiche Abschlussarbeit	11LE50MO-5609 ESE PO 2021
course	
Kompetenzen für die erfolgreiche Abschlussarbeit	
Event type	Number
lecture course	11LE50V-5609 PO 2021
Organizer	
Department of Microsystems Engineering, Optical Systems	

ECTS-Points	3.0
Workload	90 Stunden | hours
Attendance	60 Stunden | hours
Independent study	30 Stunden | hours
Hours of week	2.0
Recommended semester	3
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	german

Contents
Best Practices für das wissenschaftliche Arbeiten und Schreiben, für Projektmanagement, Datenauswertung und graphische Darstellung von Ergebnissen. | Best practices for scientific work and writing, project management, data analysis and graphical presentation of results.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Literature
Wird für jedes Thema individuell zur Verfügung gestellt. | Provided individually for each topic.
Compulsory requirement
keine | none
Recommended requirement
keine | none

↑

Epilogue

Modules in the context of the study areas

Area of **Essential Lectures in Computer Science** (with at least 18 ECTS credits to an optional maximum of 36 ECTS credits):

Here students have to choose 3 from the 9 lectures from Computer Science shown in the following list:

- Algorithm Theory
- Cyber-Physical Systems – Discrete Models
- Databases and Information Systems
- Introduction to Embedded Systems
- Machine Learning
- Computer Architecture
- Foundations of Artificial Intelligence
- Image Processing and Computer Graphics
- Software Engineering

These courses cover essential topics that are relevant for students aiming to work in the field of embedded systems. Some of the knowledge base laid in these courses might have been part of the under graduate studies of the individual students, so the students are expected to choose courses that complement their already existing fundamental proficiencies. Students who want to take more than three modules in this area can achieve this by using some or all of the 18 ECTS credits from the elective area here.

The modules are all lectures with exercises, that finish with a graded assessment (PL), which in these cases always is a written exam. All the modules have a size of 6 ECTS credits and usually also require some kind of coursework (SL).

Area of **Advanced Microsystems Engineering** (with at least 18 ECTS credits to an optional maximum of 36 ECTS credits):

Students have to choose 3 from the 8 lectures from Microsystems Engineering shown in the following list:

- Assembly and Packaging Technology
- Micro-electronics
- Micro-mechanics
- Micro-optics
- Modelling and System Identifcation
- MST Technologies and Processes
- Sensors
- Signal Processing

The knowledge gained in these courses is fundamental for engineers working in the field of embedded systems. Again, students can choose to take more than the required 3 modules here by using some or all of the 18 ECTS credits from the elective area (in this case, the module “Probability and Statistics” can be chosen here, as well). All 8 modules have an equivalent of 6 ECTS credits and are finalized with a written exam (graded assessment (PL)). Depending on the course concept, additional coursework can be required.

Elective area in Computer Science (with at least 18 ECTS credits to an optional maximum of 36 ECTS credits):

In addition to the Essential Lectures in Computer Science students have to complete courses with a scope of at least 18 ECTS credits by taking appropriate **Specialization Courses**in Computer Science. The Specialization Courses in Computer Science are principally offered either as lectures with exercise, lectures with a seminar or as lectures with an exercise and seminar. According to the

individual concepts of the Specialization Courses in Computer Science it is possible that additional coursework will be requested. A graded assessment of a Specialization Course in Computer Science is either represented by a written exam or by an oral exam.
Alternative to the Specialization Courses up to two seminars can be completed as part of the Elective Courses in Computer Science. **Seminars**are awarded with 3 ECTS credits. They comprise graded assessments and will be finalised with an oral presentation. In seminars, active participation is required as coursework, which implies mandatory attendance.
Or students can opt to take a **Study project** in this elective area in Computer Science, which is awarded with 18 ECTS credits after some coursework and a graded assessment have been completed successfully. Depending on the project's topic, the graded assessment can be a written report, the development of software or the creation of a hardware demonstrator.
This big variety of both lectures covering many different topics in Computer Science as well as different course types to choose from provides the opportunity to sharpen one's personal field of expertise in various ways.

Microsystems Engineering Concentrations area (with at least 18 ECTS credits to an optional maximum of 36 ECTS credits):
Here, students have to choose courses with a scope of at least 18 ECTS credits in one of the four Concentration areas offered in Microsystems Engineering:
- **Circuits and Systems**
- **Materials and Fabrication**
- **Biomedical Engineering**
- **Photonics**

The modules can be selected from the teaching portfolio of the Department of Microsystems Engineering as published in the module handbook especially representing the Concentrations areas. The courses comprise lectures, (practical) exercises and lab courses as well as individual project work and bring either 3 or 6 ECTS credits each. A student selects one of the four Concentration Areas and finishes modules of his own choice from the course portfolio provided in that concentration. The kind of graded assessments (usually written or oral exams) and potential additional coursework depends on the chosen courses.

Customized Course Selection (optional, with a maximum of 18 ECTS credits):
Instead of doing more than the required minimum of 18 ECTS credits in one or more of the four compulsory areas, and covering the 18 ECTS credits from the elective area like this, the students can also choose to acquire up to 18 ECTS credits by doing courses in the area of Customized Course Selection. For the Customized Course Selection, modules from the portfolio of the Master programs in Computer Science or Microsystems Engineering, that are not part of the Master ESE curriculum can be chosen, if they are offered as pass/fail courses, like the lab courses in the Master of Computer Science, for instance. Students can attend one language course offered by the Faculty of Philology and the Faculty of Humanities (chosen from the courses provided for students from all faculties). Also, modules or courses from the portfolio of selected other subjects offered at the University of Freiburg can be taken. The responsible body of the Faculty of Engineering (usually the dean of academic affairs together with the program coordinator) will consult about the suitability of courses from other subjects with the offering unit of the university and decide on their clearance. In all the modules from the Customized Course Selection only pass/fail assessments will be requested.

Spezialization
While doing there Master studies in Embedded Systems Engineering, students can opt to specialize in one of six areas:
- Artificial Intelligence (from CS)

- Cyber-Physical Systems (from CS)
- Circuits and Systems (from MSE)
- Materials and Fabrication (from MSE)
- Biomedical Engineering (from MSE)
- Photonics (from MSE)

If one of these six areas has been selected as the specialization for the diploma, modules with a total of at least 30 ECTS credits must be completed in that area, and also the master thesis must have been assigned to the respective field. The degree awarded will be “Master of Science in Embedded Engineering, Specialization in…” accordingly completed with the respective area (Artificial Intelligence, Cyber-Physical Systems, Circuits and Systems, Materials and Fabrication, Biomedical Engineering or Photonics).

The affiliation of a course with one of the specialization areas is mentioned in the detailed module descriptions. As the MSE specialization areas correspond to the respective Concentrations areas, the association is obvious; potential exemptions would be mentioned accordingly. For the specialization areas in Computer Science (AI and CPS), an overview of the lectures and courses that are assigned to the respective area is shown via PDF documents in the Curriculum section on the program website:

https://www.tf.uni-freiburg.de/en/study-programs/embedded-systems-engineering/m-sc-embedded-systems-engineering

Some modules can belong to more than one specialization.