TUHH
Hamburg
University of
Technology

Module Manual

Bachelor of Science (B.Sc.)

Computational Science and Engineering

Cohort: Winter Term 2020

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Program description

Content

Engineering disciplines utilize the results of computer science and mathematics research to an ever greater extent, both in the development of products and in the products themselves. This trend will certainly continue. New results in computer science and mathematics thus become an important innovation factor in engineering and are therefore central areas of competence for an engineer and a technical university. This has a direct impact on the objectives of the computer science and engineering course.

Engineering education benefits significantly from computer science, and computer science benefits significantly from the modeling techniques used in engineering. To be prepared for the requirements of the future, the aim of the course is to offer combined training in computer science, mathematics and engineering. This is a particularly sustainable training principle, both for industry and for research. Computer engineering opens the line between hardware and software in the light of engineering applications. Decisions as to which parts of a system should be implemented more cheaply in hardware or better with the help of flexible software can only be made and carried out on the basis of solid knowledge of both disciplines, both IT and engineering. The aim of the course is to introduce the problem and to deal with both essential aspects.

The objectives of the basic qualification are to impart knowledge, skills and competences in the fields of computer science, mathematics and engineering to the students so that new areas of knowledge and thus also new products can be developed. Choices that support student in self-determined studiesination are offered in specialisation areas.

Career prospects

Successful completion of the bachelor's degree in computer science engineering at TUHH enables graduates to start a career in science, computer science engineering or a related subject, as well as an early career start in areas from trade, industry and administration (professional qualification). The graduates will then primarily work as engineers and system developers for software and hardware.

Because of their broad training, graduates are particularly requested in the job market, since the bridge between IT specialists and engineers is essential in system development. Depending on the chosen specialization, the course trains computer scientists with an engineering background or engineers with a computer science background, who find very good employment opportunities on the German and international job market largely regardless of economic trends.

Learning target

The learning objectives leading towards the described qualification are divided below into the categories knowledge, skills, social skills and independence.

Knowledge

The learned knowledge comprises facts, principles and theories in the subjects of computer science, engineering and mathematics.

1. Students can reproduce, define and explain known standard languages for representation used in computer science and mathematics (logic, automata theory, formal languages, graph theory, linear algebra, analysis, discrete algebraic structures, stochastics, systems theory, etc.) necessary for the formal modeling of application problems (syntax, semantics, decision problems).
2. Students can reproduce elementary data and index structures (vectors, matrices, relations, trees, files, pages) for sequential algorithms (also in hardware-related form) and show their advantages and disadvantages for special tasks. Students can specify algorithms to solve decision problems for formal modeling techniques. They can reproduce the basic structure of simple computing systems at different levels of abstraction in an architecture, so that you can explain how algorithms are executed on concrete systems.
3. The students are familiar with a whole range of classic applications of computer engineering and mathematical modeling techniques and can explain them.
4. Students know how problems can be broken down into smaller sub-problems (reductionist approach) and how partial results can be combined to form an overall result. Students can also describe problems that arise from error propagation and error accumulation and provide examples. Students can reproduce and justify that security, reliability, and maintenance of partial services in the event of an error (graceful degradation) can only result from concrete design decisions in an initial draft and cannot be integrated into an existing draft afterwards with reasonable effort.
5. Graduates are able to explain the importance of entrepreneurial planning and goals, to analyze the organizational and personnel structures as well as the production and procurement systems of companies, to classify pricing policy and other important instruments for system development (e.g. marketing).

Technical Skills

The course of Computer Science and Engineering teaches the ability to apply learned knowledge in order to complete tasks and thus solve problems in many facets.

1. Students can design and develop formal representation languages (syntax, semantics, decision problems), and they can assess and determine the expressiveness of the formalisms necessary for simple applications. Students can map decision problems of different formalisms onto one another and thus compare the expressiveness of formalisms.
2. Students can examine algorithms for decision problems for completeness and correctness or convergence behavior and approximation quality, and they can demonstrate whether an algorithm is optimal or for which types of inputs the worst case occurs with regard to the runtime behavior of an algorithm.
3. Students can implement algorithms in programming or hardware description languages, test them and integrate them into application systems using operating systems to manage resources and use databases to manage large amounts of data. Students can demonstrate that desired states of a system are reached (controllability, accessibility) and that undesired states are never reached (safety and liveliness properties). Students can implement computer structures in hardware-related units.
4. Students can use formal modeling techniques for engineering applications to create, review, or evaluate simple, prototypical systems to solve problems from an application context (in terms of a simulation, as a data management system, as an application, etc.). Students can explain how models, programs and systems are automatically translated into corresponding units at a lower level of abstraction.
5. Students can design interfaces that allow systems to be built from modules or layers, the internals of which can be adapted without changing the interfaces. Students are able to describe design criteria, how systems can be reused and can also be used in other systems.

Social skills

The ability and the will to work with others in a goal-oriented manner, to grasp their interests and social situations, to communicate and to help shape the working and living environment is broken down as follows for the degree course in Computer Science and Engineering:

1. Students understand that methods of computer science and mathematics are developed across all applications and that a major achievement of the computer science engineer is on the one hand in the professional application of the methods and on the other hand in demonstrating others (clients, project partners, colleagues, ...) that a method is (in a specific sense) optimal.
2. Students can form teams to work in groups, define and distribute subtasks, make appointments, integrate partial solutions. They are able to communicate, interact socially and behave appropriately in the event of conflicts.
3. Students explain the problems described in a scientific paper and the solutions developed in the paper in a field of computer science or

mathematics, evaluate the proposed solutions in a lecture and respond to scientific questions, additions and comments.
4. Students describe scientific questions in a field of computer science, engineering or mathematics and explain in a presentation an approach they have developed to solve it and respond appropriately to inquiries, additions and comments.

Competence to work independently

The ability and willingness to act independently and responsibly, to reflect on one's own actions and those of others, and also to further develop one's own ability to act, is broken down as follows into finer aspects.

1. The students independently evaluate the advantages and disadvantages of representation formalisms for specific tasks, compare different algorithms and data structures as well as programming languages and programming tools, and they independently select the best solution.
2. The graduates independently develop a small, very clearly defined scientific sub-area, can present it in a presentation and actively follow the presentations of other students, so that an interactive discourse on a scientific topic arises.
3. Students integrate themselves into a project context and assume responsibility for tasks in a software or hardware development project.

Program structure

The curriculum of the Bachelor's degree in Computer Science and Engineering is structured as follows. In addition to the compulsory courses from core qualification, a minimum number of credit points must be taken from each of the areas of computer science, mathematics and engineering:

1. Core qualification: 138 credit points
2. Computer science: 12 credit
3. Mathematics & Engineering: 6 credit points

To deepen their studies, students can choose lectures from the entire catalog of technical events at the TUHH. A total of 12 credit points must be achieved. The bachelor thesis is also rated with 12 credit points. This results in a total effort of 180 credit points.

The following four course plans describe special features of the IIW Bachelor's degree

E. Embedded systems
1. Core subjects in computer science
- Computer architecture
- Operating systems
2. Core subjects: mathematics and engineering
- Electronic components
3. Additional technical courses
- Semiconductor circuit technology
- Compiler construction

I. Smart grids
1. Core subjects in computer science
- Operating systems
- Software development
2. Core subjects: mathematics and engineering
- Electrical energy systems I
3. Additional technical courses
- Theoretical electrical engineering I
- Electrical engineering III: network theory and transients

M. Medical systems
1. Core subjects in computer science
- Introduction to information security
- Software engineering
2. Core subjects: mathematics and engineering
- Introduction to medical technology systems
3. Additional technical courses
- Cyber-physical systems laboratory
- Computer architecture

C. Computational Foundations
1. Core subjects in computer science
- Functional programming
- Predictability and complexity
2. Core subjects: mathematics and engineering
- Combinatorial structures and algorithms
3. Additional technical courses
- Solvers for sparse linear equation systems
- Mathematics IV

Core Qualification

Module M0561: Discrete Algebraic Structures

Courses

Title	Typ	Hrs/wk	CP
Discrete Algebraic Structures (L0164)	Lecture	2	3
Discrete Algebraic Structures (L0165)	Recitation Section (small)	2	3

Module Responsible	Prof. Karl-Heinz Zimmermann
Admission Requirements	None
Recommended Previous Knowledge	Mathematics from High School.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know the important basics of discrete algebraic structures including elementary combinatorial structures, monoids, groups, rings, fields, finite fields, and vector spaces. They also know specific structures like sub-. sum-, and quotient structures and homomorphisms.
Skills	Students are able to formalize and analyze basic discrete algebraic structures.
Personal Competence	
Social Competence	Students are able to solve specific problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire new knowledge from specific standard books and to associate the acquired knowledge to other classes.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory General Engineering Science (English program, 7 semester): Specialisation Computer Science: Compulsory Computational Science and Engineering: Core Qualification: Compulsory Orientierungsstudium: Core Qualification: Elective Compulsory

Course L0164: Discrete Algebraic Structures

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Karl-Heinz Zimmermann
Language	DE/EN
Cycle	WiSe
Content	
Literature	

Course L0165: Discrete Algebraic Structures

Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Karl-Heinz Zimmermann
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0850: Mathematics I

Courses

Title	Typ	Hrs/wk	CP
Analysis I (L1010)	Lecture	2	2
Analysis I (L1012)	Recitation Section (small)	1	1
Analysis I (L1013)	Recitation Section (large)	1	1
Linear Algebra I (L0912)	Lecture	2	2
Linear Algebra I (L0913)	Recitation Section (small)	1	1
Linear Algebra I (L0914)	Recitation Section (large)	1	1

Module Responsible	Prof. Anusch Taraz
Admission Requirements	None
Recommended Previous Knowledge	School mathematics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can name the basic concepts in analysis and linear algebra. They are able to explain them using appropriate examples. • Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples. • They know proof strategies and can reproduce them.
Skills	• Students can model problems in analysis and linear algebra with the help of the concepts studied in this course. Moreover, they are capable of solving them by applying established methods. • Students are able to discover and verify further logical connections between the concepts studied in the course. • For a given problem, the students can develop and execute a suitable approach, and are able to critically evaluate the results.
Personal Competence	
Social Competence	• Students are able to work together in teams. They are capable to use mathematics as a common language. • In doing so, they can communicate new concepts according to the needs of their cooperating partners. Moreover, they can design examples to check and deepen the understanding of their peers.
Autonomy	• Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them. • Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.
Workload in Hours	Independent Study Time 128, Study Time in Lecture 112
Credit points	8
Course achievement	None
Examination	Written exam
Examination duration and scale	60 min (Analysis I) + 60 min (Linear Algebra I)
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Core Qualification: Compulsory Civil- and Environmental Engineering: Core Qualification: Compulsory Bioprocess Engineering: Core Qualification: Compulsory Digital Mechanical Engineering: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Energy and Environmental Engineering: Core Qualification: Compulsory Computational Science and Engineering: Core Qualification: Compulsory Logistics and Mobility: Core Qualification: Compulsory Mechanical Engineering: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Orientierungsstudium: Core Qualification: Elective Compulsory Naval Architecture: Core Qualification: Compulsory Process Engineering: Core Qualification: Compulsory

Course L1010: Analysis I	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dozenten des Fachbereiches Mathematik der UHH
Language	DE
Cycle	WiSe
Content	Foundations of differential and integrational calculus of one variable • statements, sets and functions • natural and real numbers • convergence of sequences and series • continuous and differentiable functions • mean value theorems • Taylor series • calculus • error analysis • fixpoint iteration
Literature	• http://www.math.uni-hamburg.de/teaching/export/tuhh/index.html

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

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

Course L0912: Linear Algebra I	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Anusch Taraz, Prof. Marko Lindner
Language	DE
Cycle	WiSe
Content	• vectors: intuition, rules, inner and cross product, lines and planes • systems of linear equations: Gauß elimination, matrix product, inverse matrices, transformations, block matrices, determinants • orthogonal projection in R^n, Gram-Schmidt-Orthonormalization
Literature	• T. Arens u.a. : Mathematik, Spektrum Akademischer Verlag, Heidelberg 2009 • W. Mackens, H. Voß: Mathematik I für Studierende der Ingenieurwissenschaften, HECO-Verlag, Alsdorf 1994 • W. Mackens, H. Voß: Aufgaben und Lösungen zur Mathematik I für Studierende der Ingenieurwissenschaften, HECO-Verlag, Alsdorf 1994 • G. Strang: Lineare Algebra, Springer-Verlag, 2003 • G. und S. Teschl: Mathematik für Informatiker, Band 1, Springer-Verlag, 2013

Course L0913: Linear Algebra I	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Anusch Taraz, Prof. Marko Lindner
Language	DE
Cycle	WiSe
Content	• vectors: intuition, rules, inner and cross product, lines and planes • general vector spaces: subspaces, Euclidean vector spaces • systems of linear equations: Gauß-elimination, matrix product, inverse matrices, transformations, LR-decomposition, block matrices, determinants
Literature	• T. Arens u.a. : Mathematik, Spektrum Akademischer Verlag, Heidelberg 2009 • W. Mackens, H. Voß: Mathematik I für Studierende der Ingenieurwissenschaften, HECO-Verlag, Alsdorf 1994 • W. Mackens, H. Voß: Aufgaben und Lösungen zur Mathematik I für Studierende der Ingenieurwissenschaften, HECO-Verlag, Alsdorf 1994

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

Module M0575: Procedural Programming

Courses

Title	Typ	Hrs/wk	CP
Procedural Programming (L0197)	Lecture	1	2
Procedural Programming (L0201)	Recitation Section (large)	1	1
Procedural Programming (L0202)	Practical Course	2	3

Module Responsible Prof. Siegfried Rump

Admission Requirements None

Recommended Previous Knowledge

Elementary PC handling skills

Elementary mathematical skills

Educational Objectives After taking part successfully, students have reached the following learning results

Professional Competence

Knowledge

The students acquire the following knowledge:

- They know basic elements of the programming language C. They know the basic data types and know how to use them.
- They have an understanding of elementary compiler tasks, of the preprocessor and programming environment and know how those interact.
- They know how to bind programs and how to include external libraries to enhance software packages.
- They know how to use header files and how to declare function interfaces to create larger programming projects.
- The acquire some knowledge how the program interacts with the operating system. This allows them to develop programs interacting with the programming environment as well.
- They learnt several possibilities how to model and implement frequently occurring standard algorithms.

Skills

- The students know how to judge the complexity of an algorithms and how to program algorithms efficiently.
- The students are able to model and implement algorithms for a number of standard functionalities. Moreover, they are able to adapt a given API.

Personal Competence

Social Competence

The students acquire the following skills:

- They are able to work in small teams to solve given weekly tasks, to identify and analyze programming errors and to present their results.
- They are able to explain simple phenomena to each other directly at the PC.
- They are able to plan and to work out a project in small teams.
- They communicate final results and present programs to their tutor.

Autonomy

- The students take individual examinations as well as a final written examn to prove their programming skills and ability to solve new tasks.
- The students have many possibilities to check their abilities when solving several given programming exercises.
- In order to solve the given tasks efficiently, the students have to split those appropriately within their group, where every student solves his or her part individually.

Workload in Hours Independent Study Time 124, Study Time in Lecture 56

Credit points 6

Course achievement None

Examination Written exam

Examination duration and scale 90 minutes

Assignment for the Following Curricula

Computer Science: Core Qualification: Compulsory
Data Science: Core Qualification: Compulsory
Electrical Engineering: Core Qualification: Compulsory
Computational Science and Engineering: Core Qualification: Compulsory
Logistics and Mobility: Specialisation Engineering Science: Elective Compulsory
Mechatronics: Core Qualification: Compulsory
Orientierungsstudium: Core Qualification: Elective Compulsory
Technomathematics: Core Qualification: Compulsory

Course L0197: Procedural Programming	
Typ	Lecture
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Siegfried Rump
Language	DE
Cycle	WiSe
Content	• basic data types (integers, floating point format, ASCII-characters) and their dependencies on the CPU architecture • advanced data types (pointers, arrays, strings, structs, lists) • operators (arithmetical operations, logical operations, bit operations) • control flow (choice, loops, jumps) • preprocessor directives (macros, conditional compilation, modular design) • functions (function definitions/interface, recursive functions, "call by value" versus "call by reference", function pointers) • essential standard libraries and functions (stdio.h, stdlib.h, math.h, string.h, time.h) • file concept, streams • basic algorithms (sorting functions, series expansion, uniformly distributed permutation) • exercise programs to deepen the programming skills
Literature	**Kernighan, Brian W** (Ritchie, Dennis M.;) The C programming language ISBN: 9780131103702 *Upper Saddle River, NJ [u.a.] : Prentice Hall PTR, 2009* **Sedgewick, Robert** Algorithms in C ISBN: 0201316633 *Reading, Mass. [u.a.] : Addison-Wesley, 2007* **Kaiser, Ulrich** (Kecher, Christoph.;) C/C++: Von den Grundlagen zur professionellen Programmierung ISBN: 9783898428392 *Bonn : Galileo Press, 2010* **Wolf, Jürgen** C von A bis Z : das umfassende Handbuch ISBN: 3836214113 *Bonn : Galileo Press, 2009*

Course L0201: Procedural Programming	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Siegfried Rump
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0202: Procedural Programming	
Typ	Practical Course
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Siegfried Rump
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0577: Non-technical Courses for Bachelors

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

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

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

Module M0743: Electrical Engineering I: Direct Current Networks and Electromagnetic Fields

Courses

Title	Typ	Hrs/wk	CP
Electrical Engineering I: Direct Current Networks and Electromagnetic Fields (L0675)	Lecture	3	5
Electrical Engineering I: Direct Current Networks and Electromagnetic Fields (L0676)	Recitation Section (small)	2	1

Module Responsible	Prof. Matthias Kuhl
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	
Skills	
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** No / 10 % / Excercises /
Examination	Written exam
Examination duration and scale	120 Minutes
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Core Qualification: Compulsory Data Science: Specialisation Electrical Engineering: Compulsory Electrical Engineering: Core Qualification: Compulsory Computational Science and Engineering: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Orientierungsstudium: Core Qualification: Elective Compulsory

Course L0675: Electrical Engineering I: Direct Current Networks and Electromagnetic Fields

Typ	Lecture
Hrs/wk	3
CP	5
Workload in Hours	Independent Study Time 108, Study Time in Lecture 42
Lecturer	Prof. Matthias Kuhl
Language	DE
Cycle	WiSe
Content	
Literature	1. M. Kasper, Skript zur Vorlesung Elektrotechnik 1, 2013 2. M. Albach: Grundlagen der Elektrotechnik 1, Pearson Education, 2004 3. F. Moeller, H. Frohne, K.H. Löcherer, H. Müller: Grundlagen der Elektrotechnik, Teubner, 2005 4. A. R. Hambley: Electrical Engineering, Principles and Applications, Pearson Education, 2008

Course L0676: Electrical Engineering I: Direct Current Networks and Electromagnetic Fields

Typ	Recitation Section (small)
Hrs/wk	2
CP	1
Workload in Hours	Independent Study Time 2, Study Time in Lecture 28
Lecturer	Prof. Matthias Kuhl
Language	DE
Cycle	WiSe
Content	
Literature	1. Übungsaufgaben zur Elektrotechnik 1, TUHH, 2013 2. Ch. Kautz: Tutorien zur Elektrotechnik, Pearson Studium, 2010

Module M0547: Electrical Engineering II: Alternating Current Networks and Basic Devices

Courses

Title	Typ	Hrs/wk	CP
Electrical Engineering II: Alternating Current Networks and Basic Devices (L0178)	Lecture	3	5
Electrical Engineering II: Alternating Current Networks and Basic Devices (L0179)	Recitation Section (small)	2	1

Module Responsible	Prof. Christian Becker
Admission Requirements	None
Recommended Previous Knowledge	Electrical Engineering I Mathematics I Direct current networks, complex numbers
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to reproduce and explain fundamental theories, principles, and methods related to the theory of alternating currents. They can describe networks of linear elements using a complex notation for voltages and currents. They can reproduce an overview of applications for the theory of alternating currents in the area of electrical engineering. Students are capable of explaining the behavior of fundamental passive and active devices as well as their impact on simple circuits.
Skills	Students are capable of calculating parameters within simple electrical networks at alternating currents by means of a complex notation for voltages and currents. They can appraise the fundamental effects that may occur within electrical networks at alternating currents. Students are able to analyze simple circuits such as oscillating circuits, filter, and matching networks quantitatively and dimension elements by means of a design. They can motivate and justify the fundamental elements of an electrical power supply (transformer, transmission line, compensation of reactive power, multiphase system) and are qualified to dimension their main features.
Personal Competence	
Social Competence	Students are able to work together on subject related tasks in small groups. They are able to present their results effectively.
Autonomy	Students are capable to gather necessary information from the references provided and relate that information to the context of the lecture. They are able to continually reflect their knowledge by means of activities that accompany the lecture, such as online-tests and exercises that are related to the exam. Based on respective feedback, students are expected to adjust their individual learning process. They are able to draw connections between their knowledge obtained in this lecture and the content of other lectures (e.g. Electrical Engineering I, Linear Algebra, and Analysis).
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** No / 10 % / Midterm /
Examination	Written exam
Examination duration and scale	90 - 150 minutes
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Core Qualification: Compulsory Data Science: Specialisation Electrical Engineering: Compulsory Electrical Engineering: Core Qualification: Compulsory Computational Science and Engineering: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Orientierungsstudium: Core Qualification: Elective Compulsory

Course L0178: Electrical Engineering II: Alternating Current Networks and Basic Devices	
Typ	Lecture
Hrs/wk	3
CP	5
Workload in Hours	Independent Study Time 108, Study Time in Lecture 42
Lecturer	Prof. Christian Becker
Language	DE
Cycle	SoSe
Content	- General time-dependency of electrical networks - Representation and properties of harmonic signals - RLC-elements at alternating currents/voltages - Complex notation for the representation of RLC-elements - Power in electrical networks at alternating currents, compensation of reactive power - Frequency response locus (Nyquist plot) and Bode-diagrams - Measurement instrumentation for assessing alternating currents - Oscillating circuits, filters, electrical transmission lines - Transformers, three-phase current, energy converters - Simple non-linear and active electrical devices
Literature	- M. Albach, "Elektrotechnik", Pearson Studium (2011) - T. Harriehausen, D. Schwarzenau, "Moeller Grundlagen der Elektrotechnik", Springer (2013) - R. Kories, H. Schmidt-Walter, "Taschenbuch der Elektrotechnik", Harri Deutsch (2010) - C. Kautz, "Tutorien zur Elektrotechnik", Pearson (2009) - A. Hambley, "Electrical Engineering: Principles and Applications", Pearson (2013) - R. Dorf, "The Electrical Engineering Handbook", CRC (2006)

Course L0179: Electrical Engineering II: Alternating Current Networks and Basic Devices	
Typ	Recitation Section (small)
Hrs/wk	2
CP	1
Workload in Hours	Independent Study Time 2, Study Time in Lecture 28
Lecturer	Prof. Christian Becker
Language	DE
Cycle	SoSe
Content	- General time-dependency of electrical networks - Representation and properties of harmonic signals - RLC-elements at alternating currents/voltages - Complex notation for the representation of RLC-elements - Power in electrical networks at alternating currents, compensation of reactive power - Frequency response locus (Nyquist plot) and Bode-diagrams - Measurement instrumentation for assessing alternating currents - Oscillating circuits, filters, electrical transmission lines - Transformers, three-phase current, energy converters - Simple non-linear and active electrical devices
Literature	- M. Albach, "Elektrotechnik", Pearson Studium (2011) - T. Harriehausen, D. Schwarzenau, "Moeller Grundlagen der Elektrotechnik", Springer (2013) - R. Kories, H. Schmidt-Walter, "Taschenbuch der Elektrotechnik", Harri Deutsch (2010) - C. Kautz, "Tutorien zur Elektrotechnik", Pearson (2009) - A. Hambley, "Electrical Engineering: Principles and Applications", Pearson (2013) - R. Dorf, "The Electrical Engineering Handbook", CRC (2006)

Module M0624: Automata Theory and Formal Languages

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Automata Theory and Formal Languages (L0332)	Lecture	2	4
Automata Theory and Formal Languages (L0507)	Recitation Section (small)	2	2

Module Responsible	Prof. Tobias Knopp
Admission Requirements	None
Recommended Previous Knowledge	Participating students should be able to - specify algorithms for simple data structures (such as, e.g., arrays) to solve computational problems - apply propositional logic and predicate logic for specifying and understanding mathematical proofs - apply the knowledge and skills taught in the module Discrete Algebraic Structures
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain syntax, semantics, and decision problems of propositional logic, and they are able to give algorithms for solving decision problems. Students can show correspondences to Boolean algebra. Students can describe which application problems are hard to represent with propositional logic, and therefore, the students can motivate predicate logic, and define syntax, semantics, and decision problems for this representation formalism. Students can explain unification and resolution for solving the predicate logic SAT decision problem. Students can also describe syntax, semantics, and decision problems for various kinds of temporal logic, and identify their application areas. The participants of the course can define various kinds of finite automata and can identify relationships to logic and formal grammars. The spectrum that students can explain ranges from deterministic and nondeterministic finite automata and pushdown automata to Turing machines. Students can name those formalism for which nondeterminism is more expressive than determinism. They are also able to demonstrate which decision problems require which expressivity, and, in addition, students can transform decision problems w.r.t. one formalism into decision problems w.r.t. other formalisms. They understand that some formalisms easily induce algorithms whereas others are best suited for specifying systems and their properties. Students can describe the relationships between formalisms such as logic, automata, or grammars.
Skills	Students can apply propositional logic as well as predicate logic resolution to a given set of formulas. Students analyze application problems in order to derive propositional logic, predicate logic, or temporal logic formulas to represent them. They can evaluate which formalism is best suited for a particular application problem, and they can demonstrate the application of algorithms for decision problems to specific formulas. Students can also transform nondeterministic automata into deterministic ones, or derive grammars from automata and vice versa. They can show how parsers work, and they can apply algorithms for the language emptiness problem in case of infinite words.
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory General Engineering Science (German program, 7 semester): Specialisation Computer Science: Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Engineering Science: Specialisation Mechatronics: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechatronics: Elective Compulsory Computational Science and Engineering: Core Qualification: Compulsory Orientierungsstudium: Core Qualification: Elective Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory

Course L0332: Automata Theory and Formal Languages	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Tobias Knopp
Language	EN
Cycle	SoSe
Content	1. Propositional logic, Boolean algebra, propositional resolution, SAT-2KNF 2. Predicate logic, unification, predicate logic resolution 3. Temporal Logics (LTL, CTL) 4. Deterministic finite automata, definition and construction 5. Regular languages, closure properties, word problem, string matching 6. Nondeterministic automata: Rabin-Scott transformation of nondeterministic into deterministic automata 7. Epsilon automata, minimization of automata, elimination of e-edges, uniqueness of the minimal automaton (modulo renaming of states) 8. Myhill-Nerode Theorem: Correctness of the minimization procedure, equivalence classes of strings induced by automata 9. Pumping Lemma for regular languages: provision of a tool which, in some cases, can be used to show that a finite automaton principally cannot be expressive enough to solve a word problem for some given language 10. Regular expressions vs. finite automata: Equivalence of formalisms, systematic transformation of representations, reductions 11. Pushdown automata and context-free grammars: Definition of pushdown automata, definition of context-free grammars, derivations, parse trees, ambiguities, pumping lemma for context-free grammars, transformation of formalisms (from pushdown automata to context-free grammars and back) 12. Chomsky normal form 13. CYK algorithm for deciding the word problem for context-free grammrs 14. Deterministic pushdown automata 15. Deterministic vs. nondeterministic pushdown automata: Application for parsing, LL(k) or LR(k) grammars and parsers vs. deterministic pushdown automata, compiler compiler 16. Regular grammars 17. Outlook: Turing machines and linear bounded automata vs general and context-sensitive grammars 18. Chomsky hierarchy 19. Mealy- and Moore automata: Automata with output (w/o accepting states), infinite state sequences, automata networks 20. Omega automata: Automata for infinite input words, Büchi automata, representation of state transition systems, verification w.r.t. temporal logic specifications (in particular LTL) 21. LTL safety conditions and model checking with Büchi automata, relationships between automata and logic 22. Fixed points, propositional mu-calculus 23. Characterization of regular languages by monadic second-order logic (MSO)
Literature	1. Logik für Informatiker Uwe Schöning, Spektrum, 5. Aufl. 2. Logik für Informatiker Martin Kreuzer, Stefan Kühling, Pearson Studium, 2006 3. Grundkurs Theoretische Informatik, Gottfried Vossen, Kurt-Ulrich Witt, Vieweg-Verlag, 2010. 4. Principles of Model Checking, Christel Baier, Joost-Pieter Katoen, The MIT Press, 2007

Course L0507: Automata Theory and Formal Languages	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Tobias Knopp
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0829: Foundations of Management

Courses

Title	Typ	Hrs/wk	CP
Management Tutorial (L0882)	Recitation Section (small)	2	3
Introduction to Management (L0880)	Lecture	3	3

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

	Engineering: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Product Development and Production: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory General Engineering Science (English program, 7 semester): Specialisation Naval Architecture: Compulsory General Engineering Science (English program, 7 semester): Specialisation Process Engineering: Compulsory General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: Compulsory Computational Science and Engineering: Core Qualification: Compulsory Logistics and Mobility: Core Qualification: Compulsory Mechanical Engineering: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Orientierungsstudium: Core Qualification: Elective Compulsory Naval Architecture: Core Qualification: Compulsory Technomathematics: Core Qualification: Compulsory Process Engineering: Core Qualification: Compulsory

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

Course L0880: Introduction to Management	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Christoph Ihl, Prof. Christian Lüthje, Prof. Christian Ringle, Prof. Cornelius Herstatt, Prof. Kathrin Fischer, Prof. Matthias Meyer, Prof. Thomas Wrona, Prof. Thorsten Blecker, Prof. Wolfgang Kersten
Language	DE
Cycle	WiSe/SoSe
Content	• Introduction to Business and Management, Business versus Economics, relevant areas in Business and Management • Important definitions from Management, • Developing Objectives for Business, and their relation to important Business functions • Business Functions: Functions of the Value Chain, e.g. Production and Procurement, Supply Chain Management, Innovation Management, Marketing and Sales Cross-sectional Functions, e.g. Organisation, Human Ressource Management, Supply Chain Management, Information Management • Definitions as information, information systems, aspects of data security and strategic information systems • Definition and Relevance of innovations, e.g. innovation opporunities, risks etc. • Relevance of marketing, B2B vs. B2C-Marketing • different techniques from the field of marketing (e.g. scenario technique), pricing strategies • important organizational structures • basics of human ressource management • Introduction to Business Planning and the steps of a planning process • Decision Analysis: Elements of decision problems and methods for solving decision problems • Selected Planning Tasks, e.g. Investment and Financial Decisions • Introduction to Accounting: Accounting, Balance-Sheets, Costing • Relevance of Controlling and selected Controlling methods • Important aspects of Entrepreneurship projects
Literature	Bamberg, G., Coenenberg, A.: Betriebswirtschaftliche Entscheidungslehre, 14. Aufl., München 2008 Eisenführ, F., Weber, M.: Rationales Entscheiden, 4. Aufl., Berlin et al. 2003 Heinhold, M.: Buchführung in Fallbeispielen, 10. Aufl., Stuttgart 2006. Kruschwitz, L.: Finanzmathematik. 3. Auflage, München 2001. Pellens, B., Fülbier, R. U., Gassen, J., Sellhorn, T.: Internationale Rechnungslegung, 7. Aufl., Stuttgart 2008. Schweitzer, M.: Planung und Steuerung, in: Bea/Friedl/Schweitzer: Allgemeine Betriebswirtschaftslehre, Bd. 2: Führung, 9. Aufl., Stuttgart 2005. Weber, J., Schäffer, U. : Einführung in das Controlling, 12. Auflage, Stuttgart 2008. Weber, J./Weißenberger, B.: Einführung in das Rechnungswesen, 7. Auflage, Stuttgart 2006.

Module M0851: Mathematics II

Courses

Title	Typ	Hrs/wk	CP
Analysis II (L1025)	Lecture	2	2
Analysis II (L1026)	Recitation Section (large)	1	1
Analysis II (L1027)	Recitation Section (small)	1	1
Linear Algebra II (L0915)	Lecture	2	2
Linear Algebra II (L0916)	Recitation Section (small)	1	1
Linear Algebra II (L0917)	Recitation Section (large)	1	1

Module Responsible: Prof. Anusch Taraz

Admission Requirements: None

Recommended Previous Knowledge: Mathematics I

Educational Objectives: After taking part successfully, students have reached the following learning results

Professional Competence

Knowledge

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

Skills

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

Personal Competence

Social Competence

- Students are able to work together in teams. They are capable to use mathematics as a common language.
- In doing so, they can communicate new concepts according to the needs of their cooperating partners. Moreover, they can design examples to check and deepen the understanding of their peers.

Autonomy

- Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them.
- Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.

Workload in Hours: Independent Study Time 128, Study Time in Lecture 112

Credit points: 8

Course achievement: None

Examination: Written exam

Examination duration and scale: 60 min (Analysis II) + 60 min (Linear Algebra II)

Assignment for the Following Curricula:

General Engineering Science (German program, 7 semester): Core Qualification: Compulsory
Civil- and Environmental Engineering: Core Qualification: Compulsory
Bioprocess Engineering: Core Qualification: Compulsory
Digital Mechanical Engineering: Core Qualification: Compulsory
Electrical Engineering: Core Qualification: Compulsory
Energy and Environmental Engineering: Core Qualification: Compulsory
Computational Science and Engineering: Core Qualification: Compulsory
Logistics and Mobility: Core Qualification: Compulsory
Mechanical Engineering: Core Qualification: Compulsory
Mechatronics: Core Qualification: Compulsory
Orientierungsstudium: Core Qualification: Elective Compulsory
Naval Architecture: Core Qualification: Compulsory
Process Engineering: Core Qualification: Compulsory

Course L1025: Analysis II	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dozenten des Fachbereiches Mathematik der UHH
Language	DE
Cycle	SoSe
Content	• power series and elementary functions • interpolation • integration (proper integrals, fundamental theorem, integration rules, improper integrals, parameter dependent integrals • applications of integration (volume and surface of bodies of revolution, lines and arc length, line integrals • numerical quadrature • periodic functions
Literature	• http://www.math.uni-hamburg.de/teaching/export/tuhh/index.html

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

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

Course L0915: Linear Algebra II	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Anusch Taraz, Prof. Marko Lindner
Language	DE
Cycle	SoSe
Content	• general vector spaces: subspaces, Euclidean vector spaces • linear mappings: basis transformation, orthogonal projection, orthogonal matrices, householder matrices • linear regression: normal equations, linear discrete approximation • eigenvalues: diagonalising matrices, normal matrices, symmetric and Hermite matrices • system of linear differential equations • matrix factorizations: LR-decomposition, QR-decomposition, Schur decomposition, Jordan normal form, singular value decomposition
Literature	• T. Arens u.a. : Mathematik, Spektrum Akademischer Verlag, Heidelberg 2009 • W. Mackens, H. Voß: Mathematik I für Studierende der Ingenieurwissenschaften, HECO-Verlag, Alsdorf 1994 • W. Mackens, H. Voß: Aufgaben und Lösungen zur Mathematik I für Studierende der Ingenieurwissenschaften, HECO-Verlag, Alsdorf 1994 • G. Strang: Lineare Algebra, Springer-Verlag, 2003 • G. und S. Teschl: Mathematik für Informatiker, Band 1, Springer-Verlag, 2013

Course L0916: Linear Algebra II	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Anusch Taraz, Prof. Marko Lindner
Language	DE
Cycle	SoSe
Content	• linear mappings: basis transformation, orthogonal projection, orthogonal matrices, householder matrices • linear regression: QR-decomposition, normal equations, linear discrete approximation • eigenvalues: diagonalising matrices, normal matrices, symmetric and Hermite matrices, Jordan normal form, singular value decomposition • system of linear differential equations
Literature	• W. Mackens, H. Voß: Mathematik I für Studierende der Ingenieurwissenschaften, HECO-Verlag, Alsdorf 1994 • W. Mackens, H. Voß: Aufgaben und Lösungen zur Mathematik I für Studierende der Ingenieurwissenschaften, HECO-Verlag, Alsdorf 1994

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

Module M1432: Programming Paradigms

Courses

Title	Typ	Hrs/wk	CP
Programming Paradigms (L2169)	Lecture	2	2
Programming Paradigms (L2170)	Recitation Section (large)	1	1
Programming Paradigms (L2171)	Practical Course	2	3

Module Responsible	NN
Admission Requirements	None
Recommended Previous Knowledge	Lecture on procedural programming or equivalent programming skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students have a fundamental understanding of object orientated and generic programming and can apply it in small programming projects. The can design own class hierarchies and differentiate between different ways of inheritance. They have a fundamental understanding of polymorphism and can differentiate between run-time and compile-time polymorphism. The students know the concept of information hiding and can design interfaces with public and private methods. They can use exceptions and apply generic programming in order to make existing data structures generic. The students know the pros and cons of both programming paradigms.
Skills	Students can break down a medium-sized problem into subproblems and create their own classes in an object-oriented programming language based on these subproblems. They can design a public and private interface and implement the implementation generically and extensible by abstraction. They can distinguish different language constructs of a modern programming language and use these suitably in the implementation. They can design and implement unit tests.
Personal Competence	
Social Competence	Students can work in teams and communicate in forums.
Autonomy	In a programming internship, students learn object-oriented programming under supervision. In exercises they develop individual and independent solutions and receive feedback.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Computational Science and Engineering: Core Qualification: Compulsory

Course L2169: Programming Paradigms

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dozenten des SD E
Language	DE/EN
Cycle	SoSe
Content	• fundamentals behind object orientated programming • classes and objects • inheritance (single, multiple) • interfaces • information hiding • exception handling • generic programming and the implementation in the compiler • excursus in programming with dynamically typed programming languages
Literature	Skript

Course L2170: Programming Paradigms	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dozenten des SD E
Language	DE/EN
Cycle	SoSe
Content	• fundamentals behind object orientated programming • classes and objects • inheritance (single, multiple) • interfaces • information hiding • exception handling • generic programming and the implementation in the compiler • excursus in programming with dynamically typed programming languages
Literature	Skript

Course L2171: Programming Paradigms	
Typ	Practical Course
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dozenten des SD E
Language	DE/EN
Cycle	SoSe
Content	• fundamentals behind object orientated programming • classes and objects • inheritance (single, multiple) • interfaces • information hiding • exception handling • generic programming and the implementation in the compiler • excursus in programming with dynamically typed programming languages
Literature	Skript

Module M0834: Computernetworks and Internet Security

Courses

Title	Typ	Hrs/wk	CP
Computer Networks and Internet Security (L1098)	Lecture	3	5
Computer Networks and Internet Security (L1099)	Recitation Section (small)	1	1

Module Responsible	Prof. Andreas Timm-Giel
Admission Requirements	None
Recommended Previous Knowledge	Basics of Computer Science
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to explain important and common Internet protocols in detail and classify them, in order to be able to analyse and develop networked systems in further studies and job.
Skills	Students are able to analyse common Internet protocols and evaluate the use of them in different domains.
Personal Competence	
Social Competence	
Autonomy	Students can select relevant parts out of high amount of professional knowledge and can independently learn and understand it.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Elective Compulsory Electrical Engineering: Core Qualification: Elective Compulsory Engineering Science: Specialisation Mechatronics: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechatronics: Elective Compulsory Computational Science and Engineering: Core Qualification: Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory

Course L1098: Computer Networks and Internet Security

Typ	Lecture
Hrs/wk	3
CP	5
Workload in Hours	Independent Study Time 108, Study Time in Lecture 42
Lecturer	Prof. Andreas Timm-Giel, Dr.-Ing. Koojana Kuladinithi, Prof. Dieter Gollmann
Language	EN
Cycle	WiSe
Content	In this class an introduction to computer networks with focus on the Internet and its security is given. Basic functionality of complex protocols are introduced. Students learn to understand these and identify common principles. In the exercises these basic principles and an introduction to performance modelling are addressed using computing tasks and (virtual) labs. In the second part of the lecture an introduction to Internet security is given. This class comprises: • Application layer protocols (HTTP, FTP, DNS) • Transport layer protocols (TCP, UDP) • Network Layer (Internet Protocol, routing in the Internet) • Data link layer with media access at the example of Ethernet • Multimedia applications in the Internet • Network management • Internet security: IPSec • Internet security: Firewalls
Literature	• Kurose, Ross, Computer Networking - A Top-Down Approach, 6th Edition, Addison-Wesley • Kurose, Ross, Computernetzwerke - Der Top-Down-Ansatz, Pearson Studium; Auflage: 6. Auflage • W. Stallings: Cryptography and Network Security: Principles and Practice, 6th edition Further literature is announced at the beginning of the lecture.

Course L1099: Computer Networks and Internet Security	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Andreas Timm-Giel, Prof. Dieter Gollmann
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0662: Numerical Mathematics I

Courses

Title	Typ	Hrs/wk	CP
Numerical Mathematics I (L0417)	Lecture	2	3
Numerical Mathematics I (L0418)	Recitation Section (small)	2	3

Module Responsible	Prof. Sabine Le Borne
Admission Requirements	None
Recommended Previous Knowledge	• Mathematik I + II for Engineering Students (german or english) **or** Analysis & Linear Algebra I + II for Technomathematicians • basic MATLAB/Python knowledge
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to • name numerical methods for interpolation, integration, least squares problems, eigenvalue problems, nonlinear root finding problems and to explain their core ideas, • repeat convergence statements for the numerical methods, • explain aspects for the practical execution of numerical methods with respect to computational and storage complexitx.
Skills	Students are able to • implement, apply and compare numerical methods using MATLAB/Python, • justify the convergence behaviour of numerical methods with respect to the problem and solution algorithm, • select and execute a suitable solution approach for a given problem.
Personal Competence	
Social Competence	Students are able to • work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge), explain theoretical foundations and support each other with practical aspects regarding the implementation of algorithms.
Autonomy	Students are capable • to assess whether the supporting theoretical and practical excercises are better solved individually or in a team, • to assess their individual progess and, if necessary, to ask questions and seek help.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory General Engineering Science (German program, 7 semester): Specialisation Biomedical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Aircraft Systems Engineering: Elective Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Elective Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Energy Systems: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Computer Science: Specialisation Computational Mathematics: Elective Compulsory Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory Data Science: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Elective Compulsory Engineering Science: Core Qualification: Compulsory Engineering Science: Core Qualification: Compulsory General Engineering Science (English program, 7 semester): Core Qualification: Compulsory General Engineering Science (English program, 7 semester): Specialisation Computer Science: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Elective Compulsory

	Computational Science and Engineering: Core Qualification: Compulsory Mechanical Engineering: Specialisation Theoretical Mechanical Engineering: Compulsory Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Mechanical Engineering: Specialisation Mechatronics: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course Core Studies: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0417: Numerical Mathematics I	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sabine Le Borne
Language	EN
Cycle	WiSe
Content	1. Finite precision arithmetic, error analysis, conditioning and stability 2. Linear systems of equations: LU and Cholesky factorization, condition 3. Interpolation: polynomial, spline and trigonometric interpolation 4. Nonlinear equations: fixed point iteration, root finding algorithms, Newton's method 5. Linear and nonlinear least squares problems: normal equations, Gram Schmidt and Householder orthogonalization, singular value decomposition, regularizatio, Gauss-Newton and Levenberg-Marquardt methods 6. Eigenvalue problems: power iteration, inverse iteration, QR algorithm 7. Numerical differentiation 8. Numerical integration: Newton-Cotes rules, error estimates, Gauss quadrature, adaptive quadrature
Literature	• Gander/Gander/Kwok: Scientific Computing: An introduction using Maple and MATLAB, Springer (2014) • Stoer/Bulirsch: Numerische Mathematik 1, Springer • Dahmen, Reusken: Numerik für Ingenieure und Naturwissenschaftler, Springer

Course L0418: Numerical Mathematics I	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sabine Le Borne, Dr. Jens-Peter Zemke
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0730: Computer Engineering

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Computer Engineering (L0321)	Lecture	3	4
Computer Engineering (L0324)	Recitation Section (small)	1	2

Module Responsible	Prof. Heiko Falk
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in electrical engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	This module deals with the foundations of the functionality of computing systems. It covers the layers from the assembly-level programming down to gates. The module includes the following topics: • Introduction • Combinational logic: Gates, Boolean algebra, Boolean functions, hardware synthesis, combinational networks • Sequential logic: Flip-flops, automata, systematic hardware design • Technological foundations • Computer arithmetic: Integer addition, subtraction, multiplication and division • Basics of computer architecture: Programming models, MIPS single-cycle architecture, pipelining • Memories: Memory hierarchies, SRAM, DRAM, caches • Input/output: I/O from the perspective of the CPU, principles of passing data, point-to-point connections, busses
Skills	The students perceive computer systems from the architect's perspective, i.e., they identify the internal structure and the physical composition of computer systems. The students can analyze, how highly specific and individual computers can be built based on a collection of few and simple components. They are able to distinguish between and to explain the different abstraction layers of today's computing systems - from gates and circuits up to complete processors. After successful completion of the module, the students are able to judge the interdependencies between a physical computer system and the software executed on it. In particular, they shall understand the consequences that the execution of software has on the hardware-centric abstraction layers from the assembly language down to gates. This way, they will be enabled to evaluate the impact that these low abstraction levels have on an entire system's performance and to propose feasible options.
Personal Competence	
Social Competence	Students are able to solve similar problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire new knowledge from specific literature and to associate this knowledge with other classes.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** 10 %; **Form** Excercises; **Description**
Examination	Written exam
Examination duration and scale	90 minutes, contents of course and labs
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Compulsory General Engineering Science (German program, 7 semester): Specialisation Civil Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Aircraft Systems Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Product Development and Production: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Energy Systems: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory General Engineering Science (German program, 7 semester): Specialisation Naval Architecture: Compulsory General Engineering Science (German program, 7 semester): Specialisation Biomedical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Bioprocess Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Electrical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Green Technologies, Focus Renewable Energy: Elective Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Elective Compulsory Electrical Engineering: Core Qualification: Compulsory General Engineering Science (English program, 7 semester): Specialisation Civil Engineering: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Aircraft Systems

	Engineering: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Product Development and Production: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory Computational Science and Engineering: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory

Course L0321: Computer Engineering	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	WiSe
Content	• Introduction • Combinational Logic • Sequential Logic • Technological Foundations • Representations of Numbers, Computer Arithmetics • Foundations of Computer Architecture • Memories • Input/Output
Literature	• A. Clements. The Principles of Computer Hardware. 3. Auflage, Oxford University Press, 2000. • A. Tanenbaum, J. Goodman. Computerarchitektur. Pearson, 2001. • D. Patterson, J. Hennessy. Rechnerorganisation und -entwurf. Elsevier, 2005.

Course L0324: Computer Engineering	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0853: Mathematics III

Courses

Title	Typ	Hrs/wk	CP
Analysis III (L1028)	Lecture	2	2
Analysis III (L1029)	Recitation Section (small)	1	1
Analysis III (L1030)	Recitation Section (large)	1	1
Differential Equations 1 (Ordinary Differential Equations) (L1031)	Lecture	2	2
Differential Equations 1 (Ordinary Differential Equations) (L1032)	Recitation Section (small)	1	1
Differential Equations 1 (Ordinary Differential Equations) (L1033)	Recitation Section (large)	1	1

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

Course L1028: Analysis III	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dozenten des Fachbereiches Mathematik der UHH
Language	DE
Cycle	WiSe
Content	Main features of differential and integrational calculus of several variables • Differential calculus for several variables • Mean value theorems and Taylor's theorem • Maximum and minimum values • Implicit functions • Minimization under equality constraints • Newton's method for multiple variables • Double integrals over general regions • Line and surface integrals • Theorems of Gauß and Stokes
Literature	• http://www.math.uni-hamburg.de/teaching/export/tuhh/index.html

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

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

Course L1031: Differential Equations 1 (Ordinary Differential Equations)	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dozenten des Fachbereiches Mathematik der UHH
Language	DE
Cycle	WiSe
Content	Main features of the theory and numerical treatment of ordinary differential equations • Introduction and elementary methods • Exsitence and uniqueness of initial value problems • Linear differential equations • Stability and qualitative behaviour of the solution • Boundary value problems and basic concepts of calculus of variations • Eigenvalue problems • Numerical methods for the integration of initial and boundary value problems • Classification of partial differential equations
Literature	• http://www.math.uni-hamburg.de/teaching/export/tuhh/index.html

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

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

Module M1423: Algorithms and Data Structures

Courses

Title	Typ	Hrs/wk	CP
Algorithms and Data Structures (L2046)	Lecture	4	4
Algorithms and Data Structures (L2047)	Recitation Section (small)	1	2

Module Responsible	Prof. Matthias Mnich
Admission Requirements	None
Recommended Previous Knowledge	• Discrete Algebraic Structures • Mathematics I • Mathematics II • Procedual Programming • Objectoriented Programming
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can name the basic concepts in algorithm design, algorithm analysis and problem reductions. They are able to explain them using appropriate examples. • Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples. • They know proof strategies and can reproduce them.
Skills	• Students can model discrete decision, search and optimization problems with the help of the concepts studied in this course. Moreover, they are capable of solving them, and reducing them to each other, by applying established methods. • Students are able to discover and verify further logical connections between the concepts studied in the course. • For a given problem, the students can develop and execute a suitable approach, and are able to critically evaluate the results.
Personal Competence	
Social Competence	• Students are able to work together in teams. They are capable to use mathematics as a common language. • In doing so, they can communicate new concepts according to the needs of their cooperating partners. Moreover, they can design examples to check and deepen the understanding of their peers.
Autonomy	• Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them. • Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	60 min
Assignment for the Following Curricula	Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Computational Science and Engineering: Core Qualification: Compulsory Logistics and Mobility: Specialisation Information Technology: Elective Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory Engineering and Management - Major in Logistics and Mobility: Specialisation Information Technology: Elective Compulsory

Course L2046: Algorithms and Data Structures	
Typ	Lecture
Hrs/wk	4
CP	4
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Lecturer	Prof. Matthias Mnich
Language	DE/EN
Cycle	WiSe
Content	• Insertion sort • Register machines • Asymptotic analysis, Landau notation • Polynomial-time algorithms and NP-completeness • Divide-and-conquer, merge sort • Strassen algorithm • Greedy algorithm • Dynamic programming • Quick sort • AVL-trees, B-trees • Hashing • Depth first search, breadth first search • Shortest paths • Flow problems, Ford-Fulkerson algorithm
Literature	• T. Cormen, Ch. Leiserson, R. Rivest, C. Stein: Introduction to Algorithms. MIT Press, 2013 • S. Skiena: The Algorithm Design Manual. Springer, 2008 • J. M. Kleinberg and É. Tardos. Algorithm Design. Addison-Wesley, 2005.

Course L2047: Algorithms and Data Structures	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Matthias Mnich
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1578: Seminars Computer Science

Courses

Title	Typ	Hrs/wk	CP
Introductory Seminar Computer Science I (L2362)	Seminar	2	3
Introductory Seminar Computer Science II (L2361)	Seminar	2	3

Module Responsible	Prof. Karl-Heinz Zimmermann
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of Computer Science and Mathematics at the Bachelor's level.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to • explicate a specific topic in the field of Computer Science, • describe complex issues, • present different views and evaluate in a critical way.
Skills	The students are able to • familiarize in a specific topic of Computer Science in limited time, • realize a literature survey on the specific topic and cite in a correct way, • elaborate a presentation and give a lecture to a selected audience, • sum up the presentation in 10-15 lines, • answer questions in the final discussion.
Personal Competence	
Social Competence	The students are able to • elaborate and introduce a topic for a certain audience, • discuss the topic, content and structure of the presentation with the instructor, • discuss certain aspects with the audience, and • as the lecturer listen and respond to questions from the audience.
Autonomy	The students are able to • define the task in question in an autonomous way, • develop the necessary knowledge, • use appropriate work equipment, and • guided by an instructor critically check the working status.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Presentation
Examination duration and scale	x
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory Computer Science: Core Qualification: Compulsory General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory Computational Science and Engineering: Core Qualification: Compulsory

Course L2362: Introductory Seminar Computer Science I

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Karl-Heinz Zimmermann
Language	DE/EN
Cycle	WiSe/SoSe
Content	
Literature	

Course L2361: Introductory Seminar Computer Science II

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Karl-Heinz Zimmermann
Language	DE/EN
Cycle	WiSe/SoSe
Content	
Literature	

Module M0672: Signals and Systems

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Signals and Systems (L0432)	Lecture	3	4
Signals and Systems (L0433)	Recitation Section (small)	2	2

Module Responsible	Prof. Gerhard Bauch
Admission Requirements	None
Recommended Previous Knowledge	Mathematics 1-3 The modul is an introduction to the theory of signals and systems. Good knowledge in maths as covered by the moduls Mathematik 1-3 is expected. Further experience with spectral transformations (Fourier series, Fourier transform, Laplace transform) is useful but not required.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to classify and describe signals and linear time-invariant (LTI) systems using methods of signal and system theory. They are able to apply the fundamental transformations of continuous-time and discrete-time signals and systems. They can describe and analyse deterministic signals and systems mathematically in both time and image domain. In particular, they understand the effects in time domain and image domain which are caused by the transition of a continuous-time signal to a discrete-time signal.
Skills	The students are able to describe and analyse deterministic signals and linear time-invariant systems using methods of signal and system theory. They can analyse and design basic systems regarding important properties such as magnitude and phase response, stability, linearity etc.. They can assess the impact of LTI systems on the signal properties in time and frequency domain.
Personal Competence	
Social Competence	The students can jointly solve specific problems.
Autonomy	The students are able to acquire relevant information from appropriate literature sources. They can control their level of knowledge during the lecture period by solving tutorial problems, software tools, clicker system.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Core Qualification: Compulsory Computer Science: Core Qualification: Compulsory Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory Data Science: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Computational Science and Engineering: Core Qualification: Compulsory Mechanical Engineering: Specialisation Mechatronics: Elective Compulsory Mechatronics: Core Qualification: Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory

Course L0432: Signals and Systems

Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Gerhard Bauch
Language	DE/EN
Cycle	SoSe
Content	see below

Content

- Introduction to signal and system theory
- Signals
  - Classification of signals
    - Continuous-time and discrete-time signals
    - Analog and digital signals
    - Deterministic and random signals
  - Description of LTI systems by differential equations or difference equations, respectively
  - Basic properties of signals and operations on signals
  - Elementary signals
  - Distributions (Generalized Functions)
  - Power and energy of signals
  - Correlation functions of deterministic signals
    - Autocorrelation function
    - Crosscorrelation function
    - Orthogonal signals
    - Applications of correlation
- Linear time-invariant (LTI) systems
  - Linearity
  - Time-invariance

	- Description of LTI systems by impulse response and frequency response - Convolution - Convolution and correlation - Properties of LTI-systems - Causal systems - Stable systems - Memoryless systems • Fourier Series and Fourier Transform - Fourier transform of continuous-time signals, discrete-time signals, periodic signals, non-periodic signals - Properties of the Fourier transform - Fourier transform of some basic signals - Parseval's theorem • Analysis of LTI-systems and signals in the frequency domain - Frequency response, magnitude response and phase response - Transmission factor, attenuation, gain - Frequency-flat and frequency-selective LTI-systems - Bandwidth definitions - Basic types of systems (filters), lowpass, highpass, bandpass, bandstop systems - Phase delay and group delay - Linear-phase systems - Distortion-free systems - Spectrum analysis with limited observation window: Leakage effect • Laplace Transform - Relation of Fourier transform and Laplace transform - Properties of the Laplace transform - Laplace transform of some basic signals • Analysis of LTI-systems in the s-domain - Transfer function of LTI-systems - Relation of Laplace transform, magnitude response and phase response - Analysis of LTI-systems using pole-zero plots - Allpass filters - Minimum-phase, maximum-phase and mixed phase filters - Stable systems • Sampling - Sampling theorem - Reconstruction of continuous-time signals in frequency domain and time domain - Oversampling - Aliasing - Sampling with pulses of finite duration, sample and hold - Decimation and interpolation • Discrete-Time Fourier Transform (DTFT) - Relation of Fourier transform and DTFT - Properties of the DTFT • Discrete Fourier Transform (DFT) - Relation of DTFT and DFT - Cyclic properties of the DFT - DFT matrix - Zero padding - Cyclic convolution - Fast Fourier Transform (FFT) - Application of the DFT: Orthogonal Frequency Division Multiplex (OFDM) • Z-Transform - Relation of Laplace transform, DTFT, and z-transform - Properties of the z-transform - Z-transform of some basic discrete-time signals • Discrete-time systems, digital filters - FIR and IIR filters - Z-transform of digital filters - Analysis of discrete-time systems using pole-zero plots in the z-domain - Stability - Allpass filters - Minimum-phase, maximum-phase and mixed-phase filters - Linear phase filters
Literature	• T. Frey , M. Bossert , Signal- und Systemtheorie, B.G. Teubner Verlag 2004 • K. Kammeyer, K. Kroschel, Digitale Signalverarbeitung, Teubner Verlag. • B. Girod ,R. Rabensteiner , A. Stenger , Einführung in die Systemtheorie, B.G. Teubner, Stuttgart, 1997 • J.R. Ohm, H.D. Lüke , Signalübertragung, Springer-Verlag 8. Auflage, 2002 • S. Haykin, B. van Veen: Signals and systems. Wiley. • Oppenheim, A.S. Willsky: Signals and Systems. Pearson. • Oppenheim, R. W. Schafer: Discrete-time signal processing. Pearson.

Course L0433: Signals and Systems	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Gerhard Bauch
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0803: Embedded Systems

Courses

Title	Typ	Hrs/wk	CP
Embedded Systems (L0805)	Lecture	3	4
Embedded Systems (L0806)	Recitation Section (small)	1	2

Module Responsible	Prof. Heiko Falk
Admission Requirements	None
Recommended Previous Knowledge	Computer Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Embedded systems can be defined as information processing systems embedded into enclosing products. This course teaches the foundations of such systems. In particular, it deals with an introduction into these systems (notions, common characteristics) and their specification languages (models of computation, hierarchical automata, specification of distributed systems, task graphs, specification of real-time applications, translations between different models). Another part covers the hardware of embedded systems: Sonsors, A/D and D/A converters, real-time capable communication hardware, embedded processors, memories, energy dissipation, reconfigurable logic and actuators. The course also features an introduction into real-time operating systems, middleware and real-time scheduling. Finally, the implementation of embedded systems using hardware/software co-design (hardware/software partitioning, high-level transformations of specifications, energy-efficient realizations, compilers for embedded processors) is covered.
Skills	After having attended the course, students shall be able to realize simple embedded systems. The students shall realize which relevant parts of technological competences to use in order to obtain a functional embedded systems. In particular, they shall be able to compare different models of computations and feasible techniques for system-level design. They shall be able to judge in which areas of embedded system design specific risks exist.
Personal Competence	
Social Competence	Students are able to solve similar problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire new knowledge from specific literature and to associate this knowledge with other classes.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** 10 %; **Form** Subject theoretical and practical work; **Description**
Examination	Written exam
Examination duration and scale	90 minutes, contents of course and labs
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Compulsory Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Electrical Engineering: Core Qualification: Elective Compulsory Engineering Science: Specialisation Mechatronics: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechatronics: Elective Compulsory Computational Science and Engineering: Core Qualification: Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Microelectronics and Microsystems: Specialisation Embedded Systems: Elective Compulsory

Course L0805: Embedded Systems

Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Heiko Falk
Language	EN
Cycle	SoSe
Content	• Introduction • Specifications and Modeling • Embedded/Cyber-Physical Systems Hardware • System Software • Evaluation and Validation • Mapping of Applications to Execution Platforms • Optimization
Literature	• Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2 nd Edition, Springer, 2012., Springer, 2012.

Course L0806: Embedded Systems	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Heiko Falk
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0727: Stochastics

Courses

Title	Typ	Hrs/wk	CP
Stochastics (L0777)	Lecture	2	4
Stochastics (L0778)	Recitation Section (small)	2	2

Module Responsible	Prof. Matthias Schulte
Admission Requirements	None
Recommended Previous Knowledge	• Calculus • Discrete algebraic structures (combinatorics) • Propositional logic
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can name the basic concepts in Stochastics. They are able to explain them using appropriate examples. • Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples. • They know proof strategies and can reproduce them.
Skills	• Students can model problems from stochastics with the help of the concepts studied in this course. Moreover, they are capable of solving them by applying established methods. • Students are able to discover and verify further logical connections between the concepts studied in the course. • For a given problem, the students can develop and execute a suitable approach, and are able to critically evaluate the results.
Personal Competence	
Social Competence	• Students are able to work together (e.g. on their regular home work) in heterogeneously composed teams (i.e., teams from different study programs and background knowledge) and to present their results appropriately (e.g. during exercise class). • In doing so, they can communicate new concepts according to the needs of their cooperating partners. Moreover, they can design examples to check and deepen the understanding of their peers.
Autonomy	• Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them. • Students can put their knowledge in relation to the contents of other lectures. • Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Computational Science and Engineering: Core Qualification: Compulsory Logistics and Mobility: Specialisation Engineering Science: Elective Compulsory Logistics and Mobility: Specialisation Information Technology: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory Engineering and Management - Major in Logistics and Mobility: Specialisation Information Technology: Elective Compulsory

Course L0777: Stochastics	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Matthias Schulte
Language	DE/EN
Cycle	SoSe
Content	• Definitions of probability, conditional probability • Random variables, dependencies, independence assumptions, • Marginal and joint probabilities • Distributions and density functions • Characteristics: expected values, variance, standard deviation, moments • Multivariate distributions • Law of large numbers and central limit theorem • Basic notions of stochastic processes • Basic concepts of statistics (point estimators, confidence intervals, hypothesis testing)
Literature	1. Methoden der statistischen Inferenz, Likelihood und Bayes, Held, L., Spektrum 2008 2. Stochastik für Informatiker, Dümbgen, L., Springer 2003 3. Statistik: Der Weg zur Datenanalyse, Fahrmeir, L., Künstler R., Pigeot, I, Tutz, G., Springer 2010 4. Stochastik, Georgii, H.-O., deGruyter, 2009 5. Probability and Random Processes, Grimmett, G., Stirzaker, D., Oxford University Press, 2001 6. Programmieren mit R, Ligges, U., Springer 2008

Course L0778: Stochastics	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Matthias Schulte
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1431: Practical Course IIW

Courses

Title	Typ	Hrs/wk	CP
Practical Course IIW (L2160)	Project-/problem-based Learning	8	6

Module Responsible	Prof. Görschwin Fey
Admission Requirements	None
Recommended Previous Knowledge	Successful participation in the modules: • Procedural Programming • Algorithms and Data Structures • Embedded Systems • Computer Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students get to know tools used by development teams to • plan development flows, • manage task distribution, • manage source code, and • test software.
Skills	Students work in teams on a larger project. The required competences are learned and practically applied. These are for example: • specifying software based on user requirements • creating a software architecture • implementing and testing software in a team, and • using the related development tools.
Personal Competence	
Social Competence	Team work has its own challenges with respect to interaction of team members as well as finding the necessary agreement during joint software development. During the project students learn the required competences and experience the practical needs.
Autonomy	During team work it is mandatory to take and explain a certain position, to independently complete assigned tasks, and to present results to the team. Open issues must be identified and returned into the team to find an agreed resolution.
Workload in Hours	Independent Study Time 68, Study Time in Lecture 112
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	Evaluation of engagement, project report and final presentation
Assignment for the Following Curricula	Computer Science in Engineering: Core Qualification: Compulsory

Course L2160: Practical Course IIW

Typ	Project-/problem-based Learning
Hrs/wk	8
CP	6
Workload in Hours	Independent Study Time 68, Study Time in Lecture 112
Lecturer	NN, Dozenten des SD E
Language	DE/EN
Cycle	WiSe
Content	A software program, an embedded system or cyber physical system is developed during the course of the project. The respective lecturer provides the concrete task description. Participating students work as a team to solve the task. This induces a typical project flow as it occurs in enterprises as well. Typical steps like defining a specification, creating a hardware-software-architecture as well as implementation and testing are mandatory. Students are also responsible for project planning, defining and assigning sub tasks to team members. Common development tools supporting planning, management and realization are used within the project. The project is split into regular plenary sessions and into independent team work.
Literature	Wird durch die jeweiligen DozentInnen zur Verfügung gestellt. Supplied by the respective lecturer.

Module M0833: Introduction to Control Systems

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Introduction to Control Systems (L0654)	Lecture	2	4
Introduction to Control Systems (L0655)	Recitation Section (small)	2	2

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	Representation of signals and systems in time and frequency domain, Laplace transform
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can represent dynamic system behavior in time and frequency domain, and can in particular explain properties of first and second order systems • They can explain the dynamics of simple control loops and interpret dynamic properties in terms of frequency response and root locus • They can explain the Nyquist stability criterion and the stability margins derived from it. • They can explain the role of the phase margin in analysis and synthesis of control loops • They can explain the way a PID controller affects a control loop in terms of its frequency response • They can explain issues arising when controllers designed in continuous time domain are implemented digitally
Skills	• Students can transform models of linear dynamic systems from time to frequency domain and vice versa • They can simulate and assess the behavior of systems and control loops • They can design PID controllers with the help of heuristic (Ziegler-Nichols) tuning rules • They can analyze and synthesize simple control loops with the help of root locus and frequency response techniques • They can calculate discrete-time approximations of controllers designed in continuous-time and use it for digital implementation • They can use standard software tools (Matlab Control Toolbox, Simulink) for carrying out these tasks
Personal Competence	
Social Competence	Students can work in small groups to jointly solve technical problems, and experimentally validate their controller designs
Autonomy	Students can obtain information from provided sources (lecture notes, software documentation, experiment guides) and use it when solving given problems. They can assess their knowledge in weekly on-line tests and thereby control their learning progress.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Core Qualification: Compulsory Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Data Science: Core Qualification: Elective Compulsory Data Science: Specialisation II. Application: Elective Compulsory Electrical Engineering: Core Qualification: Compulsory Energy and Environmental Engineering: Core Qualification: Compulsory Green Technologies: Energy, Water, Climate: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Integrated Building Technology: Core Qualification: Elective Compulsory Logistics and Mobility: Specialisation Engineering Science: Elective Compulsory Logistics and Mobility: Specialisation Information Technology: Elective Compulsory Logistics and Mobility: Specialisation Traffic Planning and Systems: Elective Compulsory Logistics and Mobility: Specialisation Production Management and Processes: Elective Compulsory Mechanical Engineering: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course Core Studies: Elective Compulsory Process Engineering: Core Qualification: Compulsory Engineering and Management - Major in Logistics and Mobility: Specialisation Information Technology: Elective Compulsory Engineering and Management - Major in Logistics and Mobility: Specialisation Traffic Planning and Systems: Elective Compulsory Engineering and Management - Major in Logistics and Mobility: Specialisation Production Management and Processes: Elective Compulsory

Course L0654: Introduction to Control Systems	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	DE
Cycle	WiSe
Content	Signals and systems • Linear systems, differential equations and transfer functions • First and second order systems, poles and zeros, impulse and step response • Stability Feedback systems • Principle of feedback, open-loop versus closed-loop control • Reference tracking and disturbance rejection • Types of feedback, PID control • System type and steady-state error, error constants • Internal model principle Root locus techniques • Root locus plots • Root locus design of PID controllers Frequency response techniques • Bode diagram • Minimum and non-minimum phase systems • Nyquist plot, Nyquist stability criterion, phase and gain margin • Loop shaping, lead lag compensation • Frequency response interpretation of PID control Time delay systems • Root locus and frequency response of time delay systems • Smith predictor Digital control • Sampled-data systems, difference equations • Tustin approximation, digital implementation of PID controllers Software tools • Introduction to Matlab, Simulink, Control toolbox • Computer-based exercises throughout the course
Literature	• Werner, H., Lecture Notes „Introduction to Control Systems“ • G.F. Franklin, J.D. Powell and A. Emami-Naeini "Feedback Control of Dynamic Systems", Addison Wesley, Reading, MA, 2009 • K. Ogata "Modern Control Engineering", Fourth Edition, Prentice Hall, Upper Saddle River, NJ, 2010 • R.C. Dorf and R.H. Bishop, "Modern Control Systems", Addison Wesley, Reading, MA 2010

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

Module M0675: Introduction to Communications and Random Processes

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Introduction to Communications and Random Processes (L0442)	Lecture	3	4
Introduction to Communications and Random Processes (L0443)	Recitation Section (large)	1	1
Introduction to Communications and Random Processes (L2354)	Recitation Section (small)	1	1

Module Responsible	Prof. Gerhard Bauch
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics 1-3 • Signals and Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know and understand the fundamental building blocks of a communications system. They can describe and analyse the individual building blocks using knowledge of signal and system theory as well as the theory of stochastic processes. The are aware of the essential resources and evaluation criteria of information transmission and are able to design and evaluate a basic communications system. The students are familiar with the contents of lecture and tutorials. They can explain and apply them to new problems.
Skills	The students are able to design and evaluate a basic communications system. In particular, they can estimate the required resources in terms of bandwidth and power. They are able to assess essential evaluation parameters of a basic communications system such as bandwidth efficiency or bit error rate and to decide for a suitable transmission method.
Personal Competence	
Social Competence	The students can jointly solve specific problems.
Autonomy	The students are able to acquire relevant information from appropriate literature sources. They can control their level of knowledge during the lecture period by solving tutorial problems, software tools, clicker system.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Electrical Engineering: Compulsory Data Science: Core Qualification: Elective Compulsory Data Science: Specialisation I. Mathematics/Computer Science: Elective Compulsory Electrical Engineering: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory

Course L0442: Introduction to Communications and Random Processes

Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Gerhard Bauch
Language	DE/EN
Cycle	WiSe

Content	• Introduction to communications engineering
	• Open Systems Interconnection (OSI) reference model
	• Components of a digital communications system
	• Fundamentals of signals and systems
	  ◦ Analog and digital signals
	  ◦ Principles of Analog-to-digital (A/D) conversion
	  ◦ Deterministic and random signals
	  ◦ Power and energy of signals
	  ◦ Linear time-invariant (LTI) systems
	  ◦ Quadrature amplitude modulation (QAM)
	• Introduction to stochastics
	• Probability theory
	  ◦ Random experiments
	  ◦ Probability model, probability space, sample space
	  ◦ Definitions of probability
	    ▪ Probability according to Bernoulli/Laplace
	    ▪ Probability according to van Mises, relative frequency
	    ▪ Bertrand's paradox
	    ▪ Axiomatic definition of probability according to Kolmogorov
	    ▪ Probability of disjoint and non-disjoint events
	    ▪ Venn diagrams
	  ◦ Continuous and discrete random variables

        - Probability density function (pdf), cululative distribution function (cdf)
        - Expected value, mean, median, quadratic mean, variance, standard deviation, higher moments
        - Examples for probability distributions (Bernoulli distribution, two-point distribution, uniform distribution, Gaussian (normal) distribution, Rayleigh distribution, etc.)
    - Multiple random variables
        - Conditional probability, joint probability
        - Conditional and joint probability density function
        - Bayes' rule
        - Correlation coefficient
        - Two-dimensional Gaussian distribution
        - Statistically independent, uncorrelated and orthogonal random variables
        - Independent identically distributed (iid) random variables
        - Properties of expected value and variance
        - Covariance
        - Probability density function (pdf) and cumulative distribution function (cdf) of the sum of statistically independent random variables
        - Central limit theorem
    - Probability density functions (pdfs) in data transmission
- Continuous-time and discrete-time random processes
    - Examples for random processes
    - Ensemble average and time average
    - Ergodic random processes
    - Quadratic mean and variance
    - Probability density function (pdf) and cumulative distribution function (cdf)
    - Joint probability density function (pdf) and joint cumulative distribution function (cdf)
    - Statistically independent, uncorrelated and orthogonal random processes
    - Stationary random processes
    - Correlation functions: Autocorrelation function, crosscorrelation function, average autocorrelation function of non-stationary random processes, autocorrelation and crosscorrelation function of stationary processes, autocovariance function, crosscovariance function
    - Autocorrelation matrix, crosscorrelation matrix, autocovariance matrix, crosscovariance matrix
    - Pseudo-noise sequences, example: Code division multiple access (CDMA)
    - Autocorrelation function, power spectral density (psd), signal power, Einstein-Wiener-Khintchine relations
    - White (Gaussian) noise
- Filtering of random processes by LTI systems
    - Transformation of the probability density function (pdf)
    - Transformation of the mean
    - Transformation of the power spectral density (psd)
    - Correlation functions of input and output signal
    - Filtering of white Gaussian noise
    - Bandlimitation for noise power limitation
    - Preemphasis and deemphasis
- Companding, mu-law, A-law
- Functions of random variables
    - Transformation of probabilities and of the probability density function (pdf)
    - Application: Non-linear amplifiers
- Functions of two random variables
    - Probability density function
    - Examples: Rayleigh distribution, magnitude of an OFDM signal, magnitude of a received radio signal
- Transmission channels and channel models
    - Wireline channels: Telephone cable, coaxial cable, optical fiber
    - Wireless channels: Fading radio channel, underwater channels
    - Frequency-flat and frequency-selective channels
    - Additive white Gaussian noise (AWGN) channel
    - Signal to noise power ratio (SNR)
    - Discrete-time channel models
    - Discrete memoryless channels (DMC)
- Analog-to-digital conversion
    - Sampling
        - Sampling theorem
    - Pulse modulation
        - Pulse-amplitude modulation (PAM)
        - Pulse-duration modulation (PDM), pulse-width modulation (PWM)
        - Pulse-position modulation (PPM)
        - Pulse-code modulation (PCM)
    - Quantization
        - Linear quantizaton, midtread and midrise characteristic
        - Quantization error, quantization noise
        - Signal-to-quantization noise ratio
        - Non-linear quantization, compressor characteristics, mu-law, A-law
        - Speech transmission with PCM
    - Differential pulse-code modulation (DPCM)
        - Linear prediction according to the minimum mean squared error (MMSE) criterion.
        - DPCM with forward prediction and backward prediction
        - SNR gain of DPCM over PCM

	- Delta modulation
	• Fundamentals of information theory and coding
	  ◦ Definitions of information: Self-information, entropy
	  ◦ Binary entropy function
	  ◦ Source coding theorem
	  ◦ Source coding: Huffman code
	  ◦ Mutual information and channel capacity
	  ◦ Channel capacity of the AWGN channel and the binary input AWGN channel
	  ◦ Channel coding theorem
	  ◦ Principles of channel coding: Code rate and data rate, Hamming distance, minimum Hamming distance, error detection and error correction
	  ◦ Examples for channel codes: Block codes and convolutional codes, repetition code, single parity check code, Hamming code, Turbo codes
	• Combinatorics
	  ◦ Variation with and without repetition
	  ◦ Combination with and without repetition
	  ◦ Permutation, Permutation of multisets
	  ◦ Word error probabilities of linear block codes
	• Baseband transmission
	  ◦ Pulse shaping: Non-return to zero (NRZ) rectangular pulses, Manchester pulses, raised-cosine pulses, square-root raised-cosine pulses, Gaussian pulses
	  ◦ Transmit signal energy, average energy per symbol
	  ◦ Power spectral density (psd) of baseband signals
	  ◦ Definitions of signal bandwidth
	  ◦ Bandwidth efficiency
	  ◦ Intersymbol interference (ISI)
	  ◦ First and second Nyquist criterion
	  ◦ Eye patterns
	  ◦ Receive filter design: Matched filter
	  ◦ Matched-filter receiver and correlation receiver
	  ◦ Square-root Nyquist pulse shaping
	  ◦ Discrete-time AWGN channel model
	• Maximum a posteriori probability (MAP) and maximum likelihood (ML) detection
	• Bit error probability in AWGN channels for binary antipodal and on-off signaling
	• Band-pass transmission via carrier modulation
	  ◦ Amplitude modulation, frequency modulation, phase modulation
	  ◦ Linear digital modulation methods: On-off keying (OOK), phase-shift keying (PSK), amplitude shift keying (ASK), quadrature amplitude shift keying (QAM)
	•

Literature	K. Kammeyer: Nachrichtenübertragung, Teubner P.A. Höher: Grundlagen der digitalen Informationsübertragung, Teubner. M. Bossert: Einführung in die Nachrichtentechnik, Oldenbourg. J.G. Proakis, M. Salehi: Grundlagen der Kommunikationstechnik. Pearson Studium. J.G. Proakis, M. Salehi: Digital Communications. McGraw-Hill. S. Haykin: Communication Systems. Wiley J.G. Proakis, M. Salehi: Communication Systems Engineering. Prentice-Hall. J.G. Proakis, M. Salehi, G. Bauch, Contemporary Communication Systems. Cengage Learning.

Course L0443: Introduction to Communications and Random Processes	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Gerhard Bauch
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L2354: Introduction to Communications and Random Processes	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Gerhard Bauch
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Specialization I. Computer Science

Module M0731: Functional Programming

Courses

Title	Typ	Hrs/wk	CP
Functional Programming (L0624)	Lecture	2	2
Functional Programming (L0625)	Recitation Section (large)	2	2
Functional Programming (L0626)	Recitation Section (small)	2	2

Module Responsible	Prof. Sibylle Schupp
Admission Requirements	None
Recommended Previous Knowledge	Discrete mathematics at high-school level
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students apply the principles, constructs, and simple design techniques of functional programming. They demonstrate their ability to read Haskell programs and to explain Haskell syntax as well as Haskell's read-eval-print loop. They interpret warnings and find errors in programs. They apply the fundamental data structures, data types, and type constructors. They employ strategies for unit tests of functions and simple proof techniques for partial and total correctness. They distinguish laziness from other evaluation strategies.
Skills	Students break a natural-language description down in parts amenable to a formal specification and develop a functional program in a structured way. They assess different language constructs, make conscious selections both at specification and implementations level, and justify their choice. They analyze given programs and rewrite them in a controlled way. They design and implement unit tests and can assess the quality of their tests. They argue for the correctness of their program.
Personal Competence	
Social Competence	Students practice peer programming with varying peers. They explain problems and solutions to their peer. They defend their programs orally. They communicate in English.
Autonomy	In programming labs, students learn under supervision (a.k.a. "Betreutes Programmieren") the mechanics of programming. In exercises, they develop solutions individually and independently, and receive feedback.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** 15 %; **Form** Excercises; **Description**
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Elective Compulsory Data Science: Specialisation I. Mathematics/Computer Science: Elective Compulsory Engineering Science: Specialisation Mechatronics: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechatronics: Elective Compulsory Computer Science in Engineering: Specialisation I. Computer Science: Elective Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory

Course L0624: Functional Programming	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Sibylle Schupp
Language	EN
Cycle	WiSe
Content	• Functions, Currying, Recursive Functions, Polymorphic Functions, Higher-Order Functions • Conditional Expressions, Guarded Expressions, Pattern Matching, Lambda Expressions • Types (simple, composite), Type Classes, Recursive Types, Algebraic Data Type • Type Constructors: Tuples, Lists, Trees, Associative Lists (Dictionaries, Maps) • Modules • Interactive Programming • Lazy Evaluation, Call-by-Value, Strictness • Design Recipes • Testing (axiom-based, invariant-based, against reference implementation) • Reasoning about Programs (equation-based, inductive) • Idioms of Functional Programming • Haskell Syntax and Semantics
Literature	Graham Hutton, Programming in Haskell, Cambridge University Press 2007.

Course L0625: Functional Programming	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Sibylle Schupp
Language	EN
Cycle	WiSe
Content	• Functions, Currying, Recursive Functions, Polymorphic Functions, Higher-Order Functions • Conditional Expressions, Guarded Expressions, Pattern Matching, Lambda Expressions • Types (simple, composite), Type Classes, Recursive Types, Algebraic Data Type • Type Constructors: Tuples, Lists, Trees, Associative Lists (Dictionaries, Maps) • Modules • Interactive Programming • Lazy Evaluation, Call-by-Value, Strictness • Design Recipes • Testing (axiom-based, invariant-based, against reference implementation) • Reasoning about Programs (equation-based, inductive) • Idioms of Functional Programming • Haskell Syntax and Semantics
Literature	Graham Hutton, Programming in Haskell, Cambridge University Press 2007.

Course L0626: Functional Programming	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Sibylle Schupp
Language	EN
Cycle	WiSe
Content	• Functions, Currying, Recursive Functions, Polymorphic Functions, Higher-Order Functions • Conditional Expressions, Guarded Expressions, Pattern Matching, Lambda Expressions • Types (simple, composite), Type Classes, Recursive Types, Algebraic Data Type • Type Constructors: Tuples, Lists, Trees, Associative Lists (Dictionaries, Maps) • Modules • Interactive Programming • Lazy Evaluation, Call-by-Value, Strictness • Design Recipes • Testing (axiom-based, invariant-based, against reference implementation) • Reasoning about Programs (equation-based, inductive) • Idioms of Functional Programming • Haskell Syntax and Semantics
Literature	Graham Hutton, Programming in Haskell, Cambridge University Press 2007.

Module M0625: Databases

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Databases (L0337)	Lecture	3	5
Databases (L1150)	Recitation Section (small)	1	1

Module Responsible	Prof. Stefan Schulte
Admission Requirements	None
Recommended Previous Knowledge	Students should have basic knowledge in the following areas: • Discrete Algebraic Structures • Procedural Programming • Automata Theory and Formal Languages • Programming Paradigms
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After successful completion of the course, students know: • Design instruments for relational databases • The relational model • Relational query languages, especially SQL • Requirements on data integrity • Possibilities for query optimization • Aspects of transaction handling, fault handling and concurrency/synchronization in database systems • Specific attributes and differences of object-oriented and object-relational databases • Paradigms and concepts of current technologies for data modelling and database systems
Skills	The students acquire the ability to model a database and to work with it. This comprises especially the application of design methodologies and query and definition languages. Furthermore, students are able to apply basic functionalities needed to run a database.
Personal Competence	
Social Competence	Students can work on complex problems both independently and in teams. They can exchange ideas with each other and use their individual strengths to solve the problem.
Autonomy	Students are able to independently investigate a complex problem and assess which competencies are required to solve it.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Computer Science: Core Qualification: Compulsory Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Data Science: Core Qualification: Compulsory Computer Science in Engineering: Specialisation I. Computer Science: Elective Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory

Course L0337: Databases	
Typ	Lecture
Hrs/wk	3
CP	5
Workload in Hours	Independent Study Time 108, Study Time in Lecture 42
Lecturer	Prof. Stefan Schulte
Language	EN
Cycle	WiSe
Content	• Introduction to database systems • Database design, especially entity-relationship • The relational model • Relational query languages • Data integrity and temporal data • Query processing • Transaction management • Fault tolerance • Concurrency control • Object-oriented databases • Object-relational databases • XML data modelling • NoSQL databases • Big data (Overview)
Literature	• R. Ramakrishnan, J. Gehrke, Database Management Systems, McGraw Hill, 2003 • A. Kemper, A. Eickler, Datenbanksysteme, 10. Auflage, De Gruyter, Oldenbourg, 2015

Course L1150: Databases	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Stefan Schulte
Language	EN
Cycle	WiSe
Content	• Introduction to database systems • Database design, especially entity-relationship • The relational model • Relational query languages • Data integrity and temporal data • Query processing • Transaction management • Fault tolerance • Concurrency control • Object-oriented databases • Object-relational databases • XML data modelling • NoSQL databases • Big data (Overview)
Literature	• R. Ramakrishnan, J. Gehrke, Database Management Systems, McGraw Hill, 2003 • A. Kemper, A. Eickler, Datenbanksysteme, 10. Auflage, De Gruyter, Oldenbourg, 2015

Module M0791: Computer Architecture

Courses

Title	Typ	Hrs/wk	CP
Computer Architecture (L0793)	Lecture	2	3
Computer Architecture (L0794)	Project-/problem-based Learning	2	2
Computer Architecture (L1864)	Recitation Section (small)	1	1

Module Responsible	Prof. Heiko Falk
Admission Requirements	None
Recommended Previous Knowledge	Module "Computer Engineering"
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	This module presents advanced concepts from the discipline of computer architecture. In the beginning, a broad overview over various programming models is given, both for general-purpose computers and for special-purpose machines (e.g., signal processors). Next, foundational aspects of the micro-architecture of processors are covered. Here, the focus particularly lies on the so-called pipelining and the methods used for the acceleration of instruction execution used in this context. The students get to know concepts for dynamic scheduling, branch prediction, superscalar execution of machine instructions and for memory hierarchies.
Skills	The students are able to describe the organization of processors. They know the different architectural principles and programming models. The students examine various structures of pipelined processor architectures and are able to explain their concepts and to analyze them w.r.t. criteria like, e.g., performance or energy efficiency. They evaluate different structures of memory hierarchies, know parallel computer architectures and are able to distinguish between instruction- and data-level parallelism.
Personal Competence	
Social Competence	Students are able to solve similar problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire new knowledge from specific literature and to associate this knowledge with other classes.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** No / 15 % / Subject theoretical and practical work /
Examination	Written exam
Examination duration and scale	90 minutes, contents of course and 4 attestations from the PBL "Computer architecture"
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Computer Science in Engineering: Specialisation I. Computer Science: Elective Compulsory Microelectronics and Microsystems: Specialisation Embedded Systems: Elective Compulsory

Course L0793: Computer Architecture

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	WiSe
Content	• Introduction • VHDL Basics • Programming Models • Realization of Elementary Data Types • Dynamic Scheduling • Branch Prediction • Superscalar Machines • Memory Hierarchies The theoretical tutorials amplify the lecture's content by solving and discussing exercise sheets and thus serve as exam preparation. Practical aspects of computer architecture are taught in the FPGA-based PBL on computer architecture whose attendance is mandatory.
Literature	• D. Patterson, J. Hennessy. Rechnerorganisation und -entwurf. Elsevier, 2005. • A. Tanenbaum, J. Goodman. Computerarchitektur. Pearson, 2001.

Course L0794: Computer Architecture	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1864: Computer Architecture	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0562: Computability and Complexity Theory

Courses

Title	Typ	Hrs/wk	CP
Computability and Complexity Theory (L0166)	Lecture	2	3
Computability and Complexity Theory (L0167)	Recitation Section (small)	2	3

Module Responsible	Prof. Martin Kliesch
Admission Requirements	None
Recommended Previous Knowledge	Discrete Algebraic Structures, Automata Theory, Logic, and Formal Language Theory.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Basic models of computation (finite state machines, Turing machines) • Decision problems and formal languages • Gödel numbering of computations • Universal computability • Decidable and undecidable problems • Reductions, diagonalization, Rice's theorem • Time and space complexity • The complexity classes P and NP • Hierarchy theorems • Polynomial time reductions, NP-completeness • Cook-Levin theorem • Uniform circuit families
Skills	After completing this module, students are able to • reproduce the knowledge taught in the course, • reproduce simpler proofs of the course and reproduce the ideas of the more complicated ones, • establish connections between the concepts taught, and • apply the learned knowledge to concrete problems.
Personal Competence	
Social Competence	Students are able to solve specific problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire new knowledge from newer literature and to associate the acquired knowledge with other classes.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Elective Compulsory Data Science: Specialisation I. Mathematics/Computer Science: Elective Compulsory Computer Science in Engineering: Specialisation I. Computer Science: Elective Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory

Course L0166: Computability and Complexity Theory

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Martin Kliesch
Language	DE/EN
Cycle	SoSe
Content	
Literature	

Course L0167: Computability and Complexity Theory	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Martin Kliesch
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0754: Compiler Construction

Courses

Title	Typ	Hrs/wk	CP
Compiler Construction (L0703)	Lecture	2	2
Compiler Construction (L0704)	Recitation Section (small)	2	4

Module Responsible	Prof. Sibylle Schupp
Admission Requirements	None
Recommended Previous Knowledge	• Practical programming experience • Automata theory and formal languages • Functional programming or procedural programming • Object-oriented programming, algorithms, and data structures • Basic knowledge of software engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students explain the workings of a compiler and break down a compilation task in different phases. They apply and modify the major algorithms for compiler construction and code improvement. They can re-write those algorithms in a programming language, run and test them. They choose appropriate internal languages and representations and justify their choice. They explain and modify implementations of existing compiler frameworks and experiment with frameworks and tools.
Skills	Students design and implement arbitrary compilation phases. They integrate their code in existing compiler frameworks. They organize their compiler code properly as a software project. They generalize algorithms for compiler construction to algorithms that analyze or synthesize software.
Personal Competence	
Social Competence	Students develop the software in a team. They explain problems and solutions to their team members. They present and defend their software in class. They communicate in English.
Autonomy	Students develop their software independently and define milestones by themselves. They receive feedback throughout the entire project. They organize the software project so that they can assess their progress themselves.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	Software (Compiler)
Assignment for the Following Curricula	Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Computer Science in Engineering: Specialisation I. Computer Science: Elective Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory

Course L0703: Compiler Construction

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Sibylle Schupp
Language	EN
Cycle	SoSe
Content	• Lexical and syntactic analysis • Semantic analysis • High-level optimization • Intermediate languages and code generation • Compilation pipeline
Literature	Alfred Aho, Jeffrey Ullman, Ravi Sethi, and Monica S. Lam, Compilers: Principles, Techniques, and Tools, 2nd edition Aarne Ranta, Implementing Programming Languages, An Introduction to Compilers and Interpreters, with an appendix coauthored by Markus Forsberg, College Publications, London, 2012

Course L0704: Compiler Construction

Typ	Recitation Section (small)
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Sibylle Schupp
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0732: Software Engineering

Courses

Title	Typ	Hrs/wk	CP
Software Engineering (L0627)	Lecture	2	3
Software Engineering (L0628)	Recitation Section (small)	2	3

Module Responsible	Prof. Sibylle Schupp
Admission Requirements	None
Recommended Previous Knowledge	• Automata theory and formal languages • Procedural programming or Functional programming • Object-oriented programming, algorithms, and data structures
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students explain the phases of the software life cycle, describe the fundamental terminology and concepts of software engineering, and paraphrase the principles of structured software development. They give examples of software-engineering tasks of existing large-scale systems. They write test cases for different test strategies and devise specifications or models using different notations, and critique both. They explain simple design patterns and the major activities in requirements analysis, maintenance, and project planning.
Skills	For a given task in the software life cycle, students identify the corresponding phase and select an appropriate method. They choose the proper approach for quality assurance. They design tests for realistic systems, assess the quality of the tests, and find errors at different levels. They apply and modify non-executable artifacts. They integrate components based on interface specifications.
Personal Competence	
Social Competence	Students practice peer programming. They explain problems and solutions to their peer. They communicate in English.
Autonomy	Using on-line quizzes and accompanying material for self study, students can assess their level of knowledge continuously and adjust it appropriately. Working on exercise problems, they receive additional feedback.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** 15 %; **Form** Excercises; **Description**
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory Computer Science: Core Qualification: Compulsory Data Science: Specialisation I. Mathematics/Computer Science: Elective Compulsory Computer Science in Engineering: Specialisation I. Computer Science: Elective Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory

Course L0627: Software Engineering

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sibylle Schupp
Language	EN
Cycle	SoSe

Content	• Model-based software engineering
	  ◦ Information modeling (use case diagrams)
	  ◦ Behavioral modeling (finite state machines, Petri Nets, behavioral UML diagrams)
	  ◦ Structural modeling (OOA, UML class diagrams, OCL)
	  ◦ Model-based testing
	• Engineering software products
	  ◦ Agile processes
	  ◦ Architecture
	  ◦ Code-based testing
	  ◦ System-level testing
	• Software management
	  ◦ Maintenance
	  ◦ Project management
	  ◦ Software processes

Literature	Ian Sommerville, Engineering Software Products: An Introduction to Modern Software Engineering, Pearson 2020. Kassem A. Saleh, Software Engineering, J. Ross Publishing 2009.

Course L0628: Software Engineering	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sibylle Schupp
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1300: Software Development

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Software Development (L1790)	Project-/problem-based Learning	2	5
Software Development (L1789)	Lecture	1	1

Module Responsible	Prof. Sibylle Schupp
Admission Requirements	None
Recommended Previous Knowledge	• Introduction to Software Engineering • Programming Skills • Experience with Developing Small to Medium-Size Programs
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students explain the fundamental concepts of agile methods, describe the process of test-driven development, and explain how continuous integration can be used in different scenarios. They give examples of selected pitfalls in software development, regarding scalability and other non-functional requirements. They write unit tests and build scripts and combine them in a corresponding integration environment. They explain major activities in requirements analysis, program comprehension, and agile project development.
Skills	For a given task on a legacy system, students identify the corresponding parts in the system and select an appropriate method for understanding the details. They choose the proper approach of splitting a task in independent testable and extensible pieces and, thus, solve the task with proper methods for quality assurance. They design tests for legacy systems, create automated builds, and find errors at different levels. They integrate the resulting artifacts in a continuous development environment
Personal Competence	
Social Competence	Students discuss different design decisions in a group. They defend their solutions orally. They communicate in English.
Autonomy	Using accompanying tools, students can assess their level of knowledge continuously and adjust it appropriately. Within limits, they can set their own goals. Upon successful completion, students can identify and formulate concrete problems of software systems and propose solutions. Within this field, t conduct independent studies to acquire the necessary competencies. They can devise plans to arrive at new solutions or assess existing ones.
Workload in Hours	Independent Study Time 138, Study Time in Lecture 42
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	Software
Assignment for the Following Curricula	Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Computer Science in Engineering: Specialisation I. Computer Science: Elective Compulsory

Course L1790: Software Development	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	5
Workload in Hours	Independent Study Time 122, Study Time in Lecture 28
Lecturer	Prof. Sibylle Schupp
Language	EN
Cycle	SoSe
Content	• Agile Methods • Test-Driven Development and Unit Testing • Continuous Integration • Web Services • Scalability • From Defects to Failure
Literature	Duvall, Paul M. Continuous Integration. Pearson Education India, 2007. Humble, Jez, and David Farley. Continuous delivery: reliable software releases through build, test, and deployment automation. Pearson Education, 2010. Martin, Robert Cecil. Agile software development: principles, patterns, and practices. Prentice Hall PTR, 2003. http://scrum-kompakt.de/ Myers, Glenford J., Corey Sandler, and Tom Badgett. The art of software testing. John Wiley & Sons, 2011.

Course L1789: Software Development	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Sibylle Schupp
Language	EN
Cycle	SoSe
Content	• Agile Methods • Test-Driven Development and Unit Testing • Continuous Integration • Web Services • Scalability • From Defects to Failure
Literature	Duvall, Paul M. Continuous Integration. Pearson Education India, 2007. Humble, Jez, and David Farley. Continuous delivery: reliable software releases through build, test, and deployment automation. Pearson Education, 2010. Martin, Robert Cecil. Agile software development: principles, patterns, and practices. Prentice Hall PTR, 2003. http://scrum-kompakt.de/ Myers, Glenford J., Corey Sandler, and Tom Badgett. The art of software testing. John Wiley & Sons, 2011.

Module M0971: Operating Systems

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Operating Systems (L1153)	Lecture	2	3
Operating Systems (L1154)	Recitation Section (small)	2	3

Module Responsible	Prof. Volker Turau
Admission Requirements	None
Recommended Previous Knowledge	• Object-oriented programming, algorithms, and data structures • Procedural programming • Experience in using tools related to operating systems such as editors, linkers, compilers • Experience in using C-libraries
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students explain the main abstractions process, virtual memory, deadlock, lifelock, and file of operations systems, describe the process states and their transitions, and paraphrase the architectural variants of operating systems. They give examples of existing operating systems and explain their architectures. The participants of the course write concurrent programs using threads, conditional variables and semaphores. Students can describe the variants of realizing a file system. Students explain at least three different scheduling algorithms.
Skills	Students are able to use the POSIX libraries for concurrent programming in a correct and efficient way. They are able to judge the efficiency of a scheduling algorithm for a given scheduling task in a given environment.
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Computer Science in Engineering: Specialisation I. Computer Science: Elective Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory

Course L1153: Operating Systems

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Volker Turau
Language	DE
Cycle	SoSe
Content	• Architectures for Operating Systems • Processes • Concurrency • Deadlocks • Memory organization • Scheduling • File systems
Literature	1. Operating Systems, William Stallings, Pearson International Edition 2. Moderne Betriebssysteme, Andrew Tanenbaum, Pearson Studium

Course L1154: Operating Systems

Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Volker Turau
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Specialization II. Mathematics & Engineering Science

Module M1235: Electrical Power Systems I: Introduction to Electrical Power Systems

Courses

Title	Typ	Hrs/wk	CP
Electrical Power Systems I: Introduction to Electrical Power Systems (L1670)	Lecture	3	4
Electrical Power Systems I: Introduction to Electrical Power Systems (L1671)	Recitation Section (small)	2	2

Module Responsible	Prof. Christian Becker
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of Electrical Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to give an overview of conventional and modern electric power systems. They can explain in detail and critically evaluate technologies of electric power generation, transmission, storage, and distribution as well as integration of equipment into electric power systems.
Skills	With completion of this module the students are able to apply the acquired skills in applications of the design, integration, development of electric power systems and to assess the results.
Personal Competence	
Social Competence	The students can participate in specialized and interdisciplinary discussions, advance ideas and represent their own work results in front of others.
Autonomy	Students can independently tap knowledge of the emphasis of the lectures.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 - 150 minutes
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Electrical Engineering: Elective Compulsory General Engineering Science (German program, 7 semester): Specialisation Green Technologies, Focus Renewable Energy: Elective Compulsory Data Science: Core Qualification: Elective Compulsory Electrical Engineering: Core Qualification: Elective Compulsory Energy Systems: Specialisation Energy Systems: Elective Compulsory Engineering Science: Specialisation Electrical Engineering: Elective Compulsory Green Technologies: Energy, Water, Climate: Specialisation Energy Systems: Elective Compulsory Computer Science in Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory Integrated Building Technology: Core Qualification: Compulsory Renewable Energies: Core Qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory

Course L1670: Electrical Power Systems I: Introduction to Electrical Power Systems	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Christian Becker
Language	DE
Cycle	WiSe

Content	• fundamentals and current development trends in electric power engineering
	• tasks and history of electric power systems
	• symmetric three-phase systems
	• fundamentals and modelling of eletric power systems
	   ◦ lines
	   ◦ transformers
	   ◦ synchronous machines
	   ◦ induction machines
	   ◦ loads and compensation
	   ◦ grid structures and substations
	• fundamentals of energy conversion
	   ◦ electro-mechanical energy conversion
	   ◦ thermodynamics
	   ◦ power station technology
	   ◦ renewable energy conversion systems
	• steady-state network calculation
	   ◦ network modelling
	   ◦ load flow calculation
	   ◦ (n-1)-criterion
	• symmetric failure calculations, short-circuit power
	• control in networks and power stations
	• grid protection
	• grid planning
	• power economy fundamentals

Literature	K. Heuck, K.-D. Dettmann, D. Schulz: "Elektrische Energieversorgung", Vieweg + Teubner, 9. Auflage, 2013 A. J. Schwab: "Elektroenergiesysteme", Springer, 5. Auflage, 2017 R. Flosdorff: "Elektrische Energieverteilung" Vieweg + Teubner, 9. Auflage, 2008

Course L1671: Electrical Power Systems I: Introduction to Electrical Power Systems	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Christian Becker
Language	DE
Cycle	WiSe

Content	• fundamentals and current development trends in electric power engineering
	• tasks and history of electric power systems
	• symmetric three-phase systems
	• fundamentals and modelling of eletric power systems
	  ◦ lines
	  ◦ transformers
	  ◦ synchronous machines
	  ◦ induction machines
	  ◦ loads and compensation
	  ◦ grid structures and substations
	• fundamentals of energy conversion
	  ◦ electro-mechanical energy conversion
	  ◦ thermodynamics
	  ◦ power station technology
	  ◦ renewable energy conversion systems
	• steady-state network calculation
	  ◦ network modelling
	  ◦ load flow calculation
	  ◦ (n-1)-criterion
	• symmetric failure calculations, short-circuit power
	• control in networks and power stations
	• grid protection
	• grid planning
	• power economy fundamentals

Literature	K. Heuck, K.-D. Dettmann, D. Schulz: "Elektrische Energieversorgung", Vieweg + Teubner, 9. Auflage, 2013 A. J. Schwab: "Elektroenergiesysteme", Springer, 5. Auflage, 2017 R. Flosdorff: "Elektrische Energieverteilung" Vieweg + Teubner, 9. Auflage, 2008

Module M0760: Electronic Devices

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Electronic Devices (L0720)	Lecture	3	4
Electronic Devices (L0721)	Project-/problem-based Learning	2	2

Module Responsible	Prof. Hoc Khiem Trieu
Admission Requirements	None
Recommended Previous Knowledge	Atomic model and quantum theory, electrical currents in solid state materials, basics in solid-state physics Successful participation of Physics for Engineers and Materials in Electrical Engineering or courses with equivalent contents
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able • to represent the basics of semiconductor physics, • to explain the operating principle of important semiconductor devices, • to outline device characteristics and equivalent circuits as well as to explain their derivation and • to discuss the limitation of device models.
Skills	Students are capable • to apply devices in basic circuits, • to realize the physical context and to solve complex problems by oneself
Personal Competence	
Social Competence	Students are able to prepare and perform their lab experiments in team work as well as to present and discuss the results in front of audience.
Autonomy	Students are capable to acquire knowledge based on literature in order to prepare their experiments.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory**: Yes; **Bonus**: 10 %; **Form**: Subject theoretical and practical work; **Description**: Studierenden erarbeiten in Kleingruppen Wissen zu einem bestimmten Thema, demonstrieren dieses in Form eines Versuches mit Präsentation und Diskussion. Darüber hinaus betreut jede Gruppe eine Übungsaufgabe, die inhaltlich zu dem jeweiligen Versuch gehört.
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Electrical Engineering: Compulsory Electrical Engineering: Core Qualification: Compulsory Engineering Science: Specialisation Electrical Engineering: Compulsory General Engineering Science (English program, 7 semester): Specialisation Electrical Engineering: Compulsory Computer Science in Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory

Course L0720: Electronic Devices	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Hoc Khiem Trieu
Language	DE
Cycle	WiSe
Content	• Uniformly doped semiconductor (semiconductor, crystal structure, energy band diagram, effective mass, density of state, probability of occupancy, mass action law, generation and recombination processes, generation and recombination lifetime, carrier transport mechanisms: drift current, diffusion current; equilibriums in semiconductor, semiconductor equations) • pn-junction (zero applied bias, energy band diagram in thermal equilibrium, current-voltage characteristics, derivation of diode equation, consideration of space charge recombination, transient behaviour, breakdown mechanisms, various types of diodes: Zener diode, tunnel diode, backward diode, photo diode, LED, laser diode) • Bipolar transistor (principle of operation, current-voltage characteristics: calculation of base, collector and emitter current, operating modes; non-ideality: actual doping profile, Early effect, breakdown, generation and recombination current and high injection; Ebers-Moll model: family of characteristics, equivalent circuit; frequency response, switching characteristics, heterojunction bipolar transistor) • Unipolar devices (surface effects: surface states, work function, energy band diagram; metal-semiconductor junctions: Schottky contact, current-voltage characteristics, ohmic contact; junction field effect transistor: operating principle, current-voltage characteristics, small-signal model, breakdown characteristics; MESFET: operating principle, depletion mode and enhancement mode MESFET; MIS structure: accumulation, depletion, inversion, strong inversion, flatband voltage, oxide charges, threshold voltage, capacitance voltage characteristics; MOSFET: basic structure, principle of operation, current voltage characteristics, frequency response, subthreshold behaviour, threshold voltage, device scaling; CMOS)
Literature	S.M. Sze: Semiconductor devices, Physics and Technology, John Wiley & Sons (1985)F. Thuselt: Physik der Halbleiterbauelemente, Springer (2011) T. Thille, D. Schmitt-Landsiedel: Mikroelektronik, Halbleiterbauelemente und deren Anwendung in elektronischen Schaltungen, Springer (2004) B.L. Anderson, R.L. Anderson: Fundamentals of Semiconductor Devices, McGraw-Hill (2005) D.A. Neamen: Semiconductor Physics and Devices, McGraw-Hill (2011) M. Shur: Introduction to Electronic Devices, John Wiley & Sons (1996) S.M. Sze: Physics of semiconductor devices, John Wiley & Sons (2007) H. Schaumburg: Halbleiter, B.G. Teubner (1991) A. Möschwitzer: Grundlagen der Halbleiter-&Mikroelektronik, Bd1 Elektronische Halbleiterbauelemente, Carl Hanser (1992) H.-G. Unger, W. Schultz, G. Weinhausen: Elektronische Bauelemente und Netzwerke I, Physikalische Grundlagen der Halbleiterbauelemente, Vieweg (1985)

Course L0721: Electronic Devices	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Hoc Khiem Trieu
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0708: Electrical Engineering III: Circuit Theory and Transients

Courses

Title	Typ	Hrs/wk	CP
Circuit Theory (L0566)	Lecture	3	4
Circuit Theory (L0567)	Recitation Section (small)	2	2

Module Responsible	Prof. Alexander Kölpin
Admission Requirements	None
Recommended Previous Knowledge	Electrical Engineering I and II, Mathematics I and II
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to explain the basic methods for calculating electrical circuits. They know the Fourier series analysis of linear networks driven by periodic signals. They know the methods for transient analysis of linear networks in time and in frequency domain, and they are able to explain the frequency behaviour and the synthesis of passive two-terminal-circuits.
Skills	The students are able to calculate currents and voltages in linear networks by means of basic methods, also when driven by periodic signals. They are able to calculate transients in electrical circuits in time and frequency domain and are able to explain the respective transient behaviour. They are able to analyse and to synthesize the frequency behaviour of passive two-terminal-circuits.
Personal Competence	
Social Competence	Students work on exercise tasks in small guided groups. They are encouraged to present and discuss their results within the group.
Autonomy	The students are able to find out the required methods for solving the given practice problems. Possibilities are given to test their knowledge during the lectures continuously by means of short-time tests. This allows them to control independently their educational objectives. They can link their gained knowledge to other courses like Electrical Engineering I and Mathematics I.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	150 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Compulsory General Engineering Science (German program, 7 semester): Specialisation Electrical Engineering: Compulsory Electrical Engineering: Core Qualification: Compulsory Engineering Science: Specialisation Electrical Engineering: Compulsory Computer Science in Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory Mechatronics: Core Qualification: Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory

Course L0566: Circuit Theory	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Alexander Kölpin, Dr. Fabian Lurz
Language	DE
Cycle	WiSe
Content	- Circuit theorems - N-port circuits - Periodic excitation of linear circuits - Transient analysis in time domain - Transient analysis in frequency domain; Laplace Transform - Frequency behaviour of passive one-ports
Literature	- M. Albach, "Grundlagen der Elektrotechnik 1", Pearson Studium (2011) - M. Albach, "Grundlagen der Elektrotechnik 2", Pearson Studium (2011) - L. P. Schmidt, G. Schaller, S. Martius, "Grundlagen der Elektrotechnik 3", Pearson Studium (2011) - T. Harriehausen, D. Schwarzenau, "Moeller Grundlagen der Elektrotechnik", Springer (2013) - A. Hambley, "Electrical Engineering: Principles and Applications", Pearson (2008) - R. C. Dorf, J. A. Svoboda, "Introduction to electrical circuits", Wiley (2006) - L. Moura, I. Darwazeh, "Introduction to Linear Circuit Analysis and Modeling", Amsterdam Newnes (2005)

Course L0567: Circuit Theory	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Alexander Kölpin, Dr. Fabian Lurz
Language	DE
Cycle	WiSe
Content	see interlocking course
Literature	siehe korrespondierende Lehrveranstaltung

Module M0941: Combinatorial Structures and Algorithms

Courses

Title	Typ	Hrs/wk	CP
Combinatorial Structures and Algorithms (L1100)	Lecture	3	4
Combinatorial Structures and Algorithms (L1101)	Recitation Section (small)	1	2

Module Responsible	Prof. Anusch Taraz
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics I + II • Discrete Algebraic Structures • Graph Theory and Optimization
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can name the basic concepts in Combinatorics and Algorithms. They are able to explain them using appropriate examples. • Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples. • They know proof strategies and can reproduce them.
Skills	• Students can model problems in Combinatorics and Algorithms with the help of the concepts studied in this course. Moreover, they are capable of solving them by applying established methods. • Students are able to discover and verify further logical connections between the concepts studied in the course. • For a given problem, the students can develop and execute a suitable approach, and are able to critically evaluate the results.
Personal Competence	
Social Competence	• Students are able to work together in teams. They are capable to use mathematics as a common language. • In doing so, they can communicate new concepts according to the needs of their cooperating partners. Moreover, they can design examples to check and deepen the understanding of their peers.
Autonomy	• Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them. • Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory Data Science: Core Qualification: Elective Compulsory Data Science: Specialisation I. Mathematics/Computer Science: Elective Compulsory Computer Science in Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory

Course L1100: Combinatorial Structures and Algorithms	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Anusch Taraz, Dr. Dennis Clemens
Language	DE/EN
Cycle	WiSe
Content	• Counting • Structural Graph Theory • Analysis of Algorithms • Extremal Combinatorics • Random discrete structures
Literature	• M. Aigner: Diskrete Mathematik, Vieweg, 6. Aufl., 2006 • J. Matoušek & J. Nešetřil: Diskrete Mathematik - Eine Entdeckungsreise, Springer, 2007 • A. Steger: Diskrete Strukturen - Band 1: Kombinatorik, Graphentheorie, Algebra, Springer, 2. Aufl. 2007 • A. Taraz: Diskrete Mathematik, Birkhäuser, 2012.

Course L1101: Combinatorial Structures and Algorithms	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Anusch Taraz
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1802: Engineering Mechanics I (Stereostatics)

Courses

Title	Typ	Hrs/wk	CP
Engineering Mechanics I (Statics) (L1001)	Lecture	2	3
Engineering Mechanics I (Statics) (L1003)	Recitation Section (large)	1	1
Engineering Mechanics I (Statics) (L1002)	Recitation Section (small)	2	2

Module Responsible	Prof. Benedikt Kriegesmann
Admission Requirements	None
Recommended Previous Knowledge	Solid school knowledge in mathematics and physics.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can • describe the axiomatic procedure used in mechanical contexts; • explain important steps in model design; • present technical knowledge in stereostatics.
Skills	The students can • explain the important elements of mathematical / mechanical analysis and model formation, and apply it to the context of their own problems; • apply basic statical methods to engineering problems; • estimate the reach and boundaries of statical methods and extend them to be applicable to wider problem sets.
Personal Competence	
Social Competence	The students can work in groups and support each other to overcome difficulties.
Autonomy	Students are capable of determining their own strengths and weaknesses and to organize their time and learning based on those.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Core Qualification: Compulsory Civil- and Environmental Engineering: Core Qualification: Compulsory Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Data Science: Specialisation II. Application: Elective Compulsory Electrical Engineering: Core Qualification: Elective Compulsory Green Technologies: Energy, Water, Climate: Core Qualification: Compulsory Computer Science in Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory Integrated Building Technology: Core Qualification: Compulsory Mechanical Engineering: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Orientation Studies: Core Qualification: Elective Compulsory Naval Architecture: Core Qualification: Compulsory Process Engineering: Core Qualification: Compulsory Engineering and Management - Major in Logistics and Mobility: Core Qualification: Compulsory

Course L1001: Engineering Mechanics I (Statics)	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	NN
Language	DE
Cycle	WiSe
Content	• Tasks in Mechanics • Modelling and model elements • Vector calculus for forces and torques • Forces and equilibrium in space • Constraints and reactions, characterization of constraint systems • Planar and spatial truss structures • Internal forces and moments for beams and frames • Center of mass, volumn, area and line • Computation of center of mass by intergals, joint bodies • Friction (sliding and sticking) • Friction of ropes
Literature	**K. Magnus, H.H. Müller-Slany: Grundlagen der Technischen Mechanik. 7. Auflage, Teubner (2009).** **D. Gross, W. Hauger, J. Schröder, W. Wall: Technische Mechanik 1. 11. Auflage, Springer (2011).**

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

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

Module M0634: Introduction into Medical Technology and Systems

Courses

Title	Typ	Hrs/wk	CP
Introduction into Medical Technology and Systems (L0342)	Lecture	2	3
Introduction into Medical Technology and Systems (L0343)	Project Seminar	2	2
Introduction into Medical Technology and Systems (L1876)	Recitation Section (large)	1	1

Module Responsible	Prof. Alexander Schlaefer
Admission Requirements	None
Recommended Previous Knowledge	principles of math (algebra, analysis/calculus) principles of stochastics principles of programming, R/Matlab
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can explain principles of medical technology, including imaging systems, computer aided surgery, and medical information systems. They are able to give an overview of regulatory affairs and standards in medical technology.
Skills	The students are able to evaluate systems and medical devices in the context of clinical applications.
Personal Competence	
Social Competence	The students describe a problem in medical technology as a project, and define tasks that are solved in a joint effort. The students can critically reflect on the results of other groups and make constructive suggestions for improvement.
Autonomy	The students can assess their level of knowledge and document their work results. They can critically evaluate the results achieved and present them in an appropriate manner.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	see below
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Biomedical Engineering: Compulsory Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory Data Science: Specialisation II. Application: Elective Compulsory Data Science: Core Qualification: Elective Compulsory Electrical Engineering: Core Qualification: Elective Compulsory Engineering Science: Specialisation Biomedical Engineering: Compulsory General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: Compulsory Computer Science in Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory

Course achievement:

Compulsory	Bonus	Form	Description
Yes	10 %	Written elaboration	
Yes	10 %	Presentation	

Course L0342: Introduction into Medical Technology and Systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	DE
Cycle	SoSe
Content	- imaging systems - computer aided surgery - medical sensor systems - medical information systems - regulatory affairs - standard in medical technology The students will work in groups to apply the methods introduced during the lecture using problem based learning.
Literature	Bernhard Priem, "Visual Computing for Medicine", 2014 Heinz Handels, "Medizinische Bildverarbeitung", 2009 (https://katalog.tub.tuhh.de/Record/745558097) Valery Tuchin, "Tissue Optics - Light Scattering Methods and Instruments for Medical Diagnosis", 2015 Olaf Drössel, "Biomedizinische Technik - Medizinische Bildgebung", 2014 H. Gross, "Handbook of Optical Systems", 2008 (https://katalog.tub.tuhh.de/Record/856571687) Wolfgang Drexler, "Optical Coherence Tomography", 2008 Kramme, "Medizintechnik", 2011 Thorsten M. Buzug, "Computed Tomography", 2008 Otmar Scherzer, "Handbook of Mathematical Methods in Imaging", 2015 Weishaupt, "Wie funktioniert MRI?", 2014 Paul Suetens, "Fundamentals of Medical Imaging", 2009 Vorlesungsunterlagen

Course L0343: Introduction into Medical Technology and Systems	
Typ	Project Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L1876: Introduction into Medical Technology and Systems	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Alexander Schlaefer
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0715: Solvers for Sparse Linear Systems

Courses

Title	Typ	Hrs/wk	CP
Solvers for Sparse Linear Systems (L0583)	Lecture	2	3
Solvers for Sparse Linear Systems (L0584)	Recitation Section (small)	2	3

Module Responsible	Prof. Sabine Le Borne
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics I + II for Engineering students or Analysis & Lineare Algebra I + II for Technomathematicians • Programming experience in C
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can • list classical and modern iteration methods and their interrelationships, • repeat convergence statements for iterative methods, • explain aspects regarding the efficient implementation of iteration methods.
Skills	Students are able to • analyse, implement, test, and compare iterative methods, • analyse the convergence behaviour of iterative methods and, if applicable, compute congergence rates.
Personal Competence	
Social Competence	Students are able to • work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge), explain theoretical foundations and support each other with practical aspects regarding the implementation of algorithms.
Autonomy	Students are capable • to assess whether the supporting theoretical and practical excercises are better solved individually or in a team, • to work on complex problems over an extended period of time, • to assess their individual progess and, if necessary, to ask questions and seek help.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory Data Science: Core Qualification: Elective Compulsory Data Science: Specialisation I. Mathematics/Computer Science: Elective Compulsory Computer Science in Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory

Course L0583: Solvers for Sparse Linear Systems

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sabine Le Borne
Language	EN
Cycle	SoSe
Content	1. Sparse systems: Orderings and storage formats, direct solvers 2. Classical methods: basic notions, convergence 3. Projection methods 4. Krylov space methods 5. Preconditioning (e.g. ILU) 6. Multigrid methods 7. Domain Decomposition Methods
Literature	1. Y. Saad. Iterative methods for sparse linear systems 2. M. Olshanskii, E. Tyrtyshnikov. Iterative methods for linear systems: theory and applications

Course L0584: Solvers for Sparse Linear Systems	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sabine Le Borne
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0777: Semiconductor Circuit Design

Courses

Title	Typ	Hrs/wk	CP
Semiconductor Circuit Design (L0763)	Lecture	3	4
Semiconductor Circuit Design (L0864)	Recitation Section (small)	1	2

Module Responsible	Prof. Matthias Kuhl
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of electrical engineering Basics of physics, especially semiconductor physics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students are able to explain the functionality of different MOS devices in electronic circuits. • Students are able to explain how analog circuits functions and where they are applied. • Students are able to explain the functionality of fundamental operational amplifiers and their specifications. • Students know the fundamental digital logic circuits and can discuss their advantages and disadvantages. • Students have knowledge about memory circuits and can explain their functionality and specifications. • Students know the appropriate fields for the use of bipolar transistors.
Skills	• Students can calculate the specifications of different MOS devices and can define the parameters of electronic circuits. • Students are able to develop different logic circuits and can design different types of logic circuits. • Students can use MOS devices, operational amplifiers and bipolar transistors for specific applications.
Personal Competence	
Social Competence	• Students are able work efficiently in heterogeneous teams. • Students working together in small groups can solve problems and answer professional questions.
Autonomy	• Students are able to assess their level of knowledge.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Electrical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Compulsory Data Science: Core Qualification: Elective Compulsory Electrical Engineering: Core Qualification: Compulsory Engineering Science: Specialisation Electrical Engineering: Compulsory Engineering Science: Specialisation Mechatronics: Compulsory General Engineering Science (English program, 7 semester): Specialisation Electrical Engineering: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechatronics: Compulsory Computer Science in Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory Mechanical Engineering: Specialisation Mechatronics: Compulsory Mechatronics: Core Qualification: Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory

Course L0763: Semiconductor Circuit Design	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Matthias Kuhl
Language	DE
Cycle	SoSe
Content	• Repetition Semiconductorphysics and Diodes • Functionality and characteristic curve of bipolar transistors • Basic circuits with bipolar transistors • Functionality and characteristic curve of MOS transistors • Basic circuits with MOS transistors for amplifiers • Operational amplifiers and their applications • Typical applications for analog and digital circuits • Realization of logical functions • Basic circuits with MOS transistors for combinational logic • Memory circuits • Basic circuits with MOS transistors for sequential logic • Basic concepts of analog-to-digital and digital-to-analog-converters
Literature	U. Tietze und Ch. Schenk, E. Gamm, Halbleiterschaltungstechnik, Springer Verlag, 14. Auflage, 2012, ISBN 3540428496 R. J. Baker, CMOS - Circuit Design, Layout and Simulation, J. Wiley & Sons Inc., 3. Auflage, 2011, ISBN: 047170055S H. Göbel, Einführung in die Halbleiter-Schaltungstechnik, Berlin, Heidelberg Springer-Verlag Berlin Heidelberg, 2011, ISBN: 9783642208874 ISBN: 9783642208867 URL: http://site.ebrary.com/lib/alltitles/docDetail.action?docID=10499499 URL: http://dx.doi.org/10.1007/978-3-642-20887-4 URL: http://ebooks.ciando.com/book/index.cfm/bok_id/319955 URL: http://www.ciando.com/img/bo

Course L0864: Semiconductor Circuit Design	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Matthias Kuhl, Weitere Mitarbeiter
Language	DE
Cycle	SoSe
Content	• Basic circuits and characteristic curves of bipolar transistors • Basic circuits and characteristic curves of MOS transistors for amplifiers • Realization and dimensioning of operational amplifiers • Realization of logic functions • Basic circuits with MOS transistors for combinational and sequential logic • Memory circuits • Circuits for analog-to-digital and digital-to-analog converters • Design of exemplary circuits
Literature	U. Tietze und Ch. Schenk, E. Gamm, Halbleiterschaltungstechnik, Springer Verlag, 14. Auflage, 2012, ISBN 3540428496 R. J. Baker, CMOS - Circuit Design, Layout and Simulation, J. Wiley & Sons Inc., 3. Auflage, 2011, ISBN: 047170055S H. Göbel, Einführung in die Halbleiter-Schaltungstechnik, Berlin, Heidelberg Springer-Verlag Berlin Heidelberg, 2011, ISBN: 9783642208874 ISBN: 9783642208867 URL: http://site.ebrary.com/lib/alltitles/docDetail.action?docID=10499499 URL: http://dx.doi.org/10.1007/978-3-642-20887-4 URL: http://ebooks.ciando.com/book/index.cfm/bok_id/319955 URL: http://www.ciando.com/img/bo

Module M1269: Lab Cyber-Physical Systems

Courses

Title	Typ	Hrs/wk	CP
Lab Cyber-Physical Systems (L1740)	Project-/problem-based Learning	4	6

Module Responsible	Prof. Heiko Falk
Admission Requirements	None
Recommended Previous Knowledge	Module "Embedded Systems"
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Cyber-Physical Systems (CPS) are tightly integrated with their surrounding environment, via sensors, A/D and D/A converters, and actors. Due to their particular application areas, highly specialized sensors, processors and actors are common. Accordingly, there is a large variety of different specification approaches for CPS - in contrast to classical software engineering approaches. Based on practical experiments using robot kits and computers, the basics of specification and modelling of CPS are taught. The lab introduces into the area (basic notions, characteristical properties) and their specification techniques (models of computation, hierarchical automata, data flow models, petri nets, imperative approaches). Since CPS frequently perform control tasks, the lab's experiments will base on simple control applications. The experiments will use state-of-the-art industrial specification tools (MATLAB/Simulink, LabVIEW, NXC) in order to model cyber-physical models that interact with the environment via sensors and actors.
Skills	After successful attendance of the lab, students are able to develop simple CPS. They understand the interdependencies between a CPS and its surrounding processes which stem from the fact that a CPS interacts with the environment via sensors, A/D converters, digital processors, D/A converters and actors. The lab enables students to compare modelling approaches, to evaluate their advantages and limitations, and to decide which technique to use for a concrete task. They will be able to apply these techniques to practical problems. They obtain first experiences in hardware-related software development, in industry-relevant specification tools and in the area of simple control applications.
Personal Competence	
Social Competence	Students are able to solve similar problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire new knowledge from specific literature and to associate this knowledge with other classes.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Execution and documentation of all lab experiments
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory Computer Science in Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory

Course L1740: Lab Cyber-Physical Systems

Typ	Project-/problem-based Learning
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	SoSe
Content	• Experiment 1: Programming in NXC • Experiment 2: Programming the Robot in Matlab/Simulink • Experiment 3: Programming the Robot in LabVIEW
Literature	• Peter Marwedel. Embedded System Design - Embedded System Foundations of Cyber-Physical Systems. 2 nd Edition, Springer, 2012. • Begleitende Foliensätze

Module M0854: Mathematics IV

Courses

Title	Typ	Hrs/wk	CP
Differential Equations 2 (Partial Differential Equations) (L1043)	Lecture	2	1
Differential Equations 2 (Partial Differential Equations) (L1044)	Recitation Section (small)	1	1
Differential Equations 2 (Partial Differential Equations) (L1045)	Recitation Section (large)	1	1
Complex Functions (L1038)	Lecture	2	1
Complex Functions (L1041)	Recitation Section (small)	1	1
Complex Functions (L1042)	Recitation Section (large)	1	1

Module Responsible	Prof. Anusch Taraz
Admission Requirements	None
Recommended Previous Knowledge	Mathematics I - III
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can name the basic concepts in Mathematics IV. They are able to explain them using appropriate examples. • Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples. • They know proof strategies and can reproduce them.
Skills	• Students can model problems in Mathematics IV with the help of the concepts studied in this course. Moreover, they are capable of solving them by applying established methods. • Students are able to discover and verify further logical connections between the concepts studied in the course. • For a given problem, the students can develop and execute a suitable approach, and are able to critically evaluate the results.
Personal Competence	
Social Competence	• Students are able to work together in teams. They are capable to use mathematics as a common language. • In doing so, they can communicate new concepts according to the needs of their cooperating partners. Moreover, they can design examples to check and deepen the understanding of their peers.
Autonomy	• Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them. • Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.
Workload in Hours	Independent Study Time 68, Study Time in Lecture 112
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	60 min (Complex Functions) + 60 min (Differential Equations 2)
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Electrical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Compulsory General Engineering Science (German program, 7 semester): Specialisation Naval Architecture: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Elective Compulsory Electrical Engineering: Core Qualification: Compulsory General Engineering Science (English program, 7 semester): Specialisation Electrical Engineering: Compulsory Computer Science in Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory Mechanical Engineering: Specialisation Mechatronics: Compulsory Mechanical Engineering: Specialisation Theoretical Mechanical Engineering: Elective Compulsory Mechatronics: Core Qualification: Compulsory Naval Architecture: Core Qualification: Compulsory Theoretical Mechanical Engineering: Technical Complementary Course Core Studies: Elective Compulsory

Course L1043: Differential Equations 2 (Partial Differential Equations)	
Typ	Lecture
Hrs/wk	2
CP	1
Workload in Hours	Independent Study Time 2, Study Time in Lecture 28
Lecturer	Dozenten des Fachbereiches Mathematik der UHH
Language	DE
Cycle	SoSe
Content	Main features of the theory and numerical treatment of partial differential equations • Examples of partial differential equations • First order quasilinear differential equations • Normal forms of second order differential equations • Harmonic functions and maximum principle • Maximum principle for the heat equation • Wave equation • Liouville's formula • Special functions • Difference methods • Finite elements
Literature	• http://www.math.uni-hamburg.de/teaching/export/tuhh/index.html

Course L1044: Differential Equations 2 (Partial Differential Equations)	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dozenten des Fachbereiches Mathematik der UHH
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L1045: Differential Equations 2 (Partial Differential Equations)	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dozenten des Fachbereiches Mathematik der UHH
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L1038: Complex Functions	
Typ	Lecture
Hrs/wk	2
CP	1
Workload in Hours	Independent Study Time 2, Study Time in Lecture 28
Lecturer	Dozenten des Fachbereiches Mathematik der UHH
Language	DE
Cycle	SoSe
Content	Main features of complex analysis • Functions of one complex variable • Complex differentiation • Conformal mappings • Complex integration • Cauchy's integral theorem • Cauchy's integral formula • Taylor and Laurent series expansion • Singularities and residuals • Integral transformations: Fourier and Laplace transformation
Literature	• http://www.math.uni-hamburg.de/teaching/export/tuhh/index.html

Course L1041: Complex Functions	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dozenten des Fachbereiches Mathematik der UHH
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L1042: Complex Functions	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dozenten des Fachbereiches Mathematik der UHH
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0567: Theoretical Electrical Engineering I: Time-Independent Fields

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Theoretical Electrical Engineering I: Time-Independent Fields (L0180)	Lecture	3	5
Theoretical Electrical Engineering I: Time-Independent Fields (L0181)	Recitation Section (small)	2	1

Module Responsible	Prof. Christian Schuster
Admission Requirements	None
Recommended Previous Knowledge	Basic principles of electrical engineering and advanced mathematics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the fundamental formulas, relations, and methods of the theory of time-independent electromagnetic fields. They can explicate the principal behavior of electrostatic, magnetostatic, and current density fields with regard to respective sources. They can describe the properties of complex electromagnetic fields by means of superposition of solutions for simple fields. The students are aware of applications for the theory of time-independent electromagnetic fields and are able to explicate these.
Skills	Students can apply Maxwell's Equations in integral notation in order to solve highly symmetrical, time-independent, electromagnetic field problems. Furthermore, they are capable of applying a variety of methods that require solving Maxwell's Equations for more general problems. The students can assess the principal effects of given time-independent sources of fields and analyze these quantitatively. They can deduce meaningful quantities for the characterization of electrostatic, magnetostatic, and electrical flow fields (capacitances, inductances, resistances, etc.) from given fields and dimension them for practical applications.
Personal Competence	
Social Competence	Students are able to work together on subject related tasks in small groups. They are able to present their results effectively (e.g. during exercise sessions).
Autonomy	Students are capable to gather necessary information from provided references and relate this information to the lecture. They are able to continually reflect their knowledge by means of activities that accompany the lecture, such as short oral quizzes during the lectures and exercises that are related to the exam. Based on respective feedback, students are expected to adjust their individual learning process. They are able to draw connections between their knowledge obtained in this lecture and the content of other lectures (e.g. Electrical Engineering I, Linear Algebra, and Analysis).
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90-150 minutes
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Electrical Engineering: Compulsory Electrical Engineering: Core Qualification: Compulsory Computer Science in Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory

Course L0180: Theoretical Electrical Engineering I: Time-Independent Fields	
Typ	Lecture
Hrs/wk	3
CP	5
Workload in Hours	Independent Study Time 108, Study Time in Lecture 42
Lecturer	Prof. Christian Schuster
Language	DE
Cycle	SoSe
Content	- Maxwell’s Equations in integral and differential notation - Boundary conditions - Laws of conservation for energy and charge - Classification of electromagnetic field properties - Integral characteristics of time-independent fields (R, L, C) - Generic approaches to solving Poisson’s Equation - Electrostatic fields and specific methods of solving - Magnetostatic fields and specific methods of solving - Fields of electrical current density and specific methods of solving - Action of force within time-independent fields - Numerical methods for solving time-independent problems The practical application of numerical methods will be trained within specifically prepared lectures in an interactive manner using small MATLAB programs.
Literature	- G. Lehner, "Elektromagnetische Feldtheorie: Für Ingenieure und Physiker", Springer (2010) - H. Henke, "Elektromagnetische Felder: Theorie und Anwendung", Springer (2011) - W. Nolting, "Grundkurs Theoretische Physik 3: Elektrodynamik", Springer (2011) - D. Griffiths, "Introduction to Electrodynamics", Pearson (2012) - J. Edminister, " Schaum's Outline of Electromagnetics", Mcgraw-Hill (2013) - Richard Feynman, "Feynman Lectures on Physics: Volume 2", Basic Books (2011)

Course L0181: Theoretical Electrical Engineering I: Time-Independent Fields	
Typ	Recitation Section (small)
Hrs/wk	2
CP	1
Workload in Hours	Independent Study Time 2, Study Time in Lecture 28
Lecturer	Prof. Christian Schuster
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Specialization III. Subject Specific Focus

Module M1433: Technical Complementary Course for Computational Science and Engineering Bachelor

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

Module Responsible	Prof. Görschwin Fey
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	
Skills	
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Depends on choice of courses
Credit points	12
Assignment for the Following Curricula	Computer Science in Engineering: Specialisation III. Subject Specific Focus: Elective Compulsory

Thesis

Module M-001: Bachelor Thesis

Courses			
Title	Typ	Hrs/wk	CP

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

	Engineering and Management - Major in Logistics and Mobility: Thesis: Compulsory