TUHH
Hamburg
University of
Technology

# Module Manual

Bachelor of Science (B.Sc.)

# Computer Science

Cohort: Winter Term 2019

Updated: 20th December 2023

# Table of Contents

## Program description

**Content**

# 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<br>Computer Science: Core Qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Computer Science: Compulsory<br>Computational Science and Engineering: Core Qualification: Compulsory<br>Orientierungsstudium: Core Qualification: Elective Compulsory<br>Technomathematics: Specialisation I. Mathematics: 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 |
| **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 |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## 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** / **Bonus** / **Form** / **Description**: Yes / 15 % / Excercises |
| **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<br>Computer Science: Core Qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory<br>Computational Science and Engineering: Specialisation I. Computer Science: Elective Compulsory<br>Computational Science and Engineering: Specialisation Computer Science: Elective Compulsory<br>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<br>• Conditional Expressions, Guarded Expressions, Pattern Matching, Lambda Expressions<br>• Types (simple, composite), Type Classes, Recursive Types, Algebraic Data Type<br>• Type Constructors: Tuples, Lists, Trees, Associative Lists (Dictionaries, Maps)<br>• Modules<br>• Interactive Programming<br>• Lazy Evaluation, Call-by-Value, Strictness<br>• Design Recipes<br>• Testing (axiom-based, invariant-based, against reference implementation)<br>• Reasoning about Programs (equation-based, inductive)<br>• Idioms of Functional Programming<br>• 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<br>• Conditional Expressions, Guarded Expressions, Pattern Matching, Lambda Expressions<br>• Types (simple, composite), Type Classes, Recursive Types, Algebraic Data Type<br>• Type Constructors: Tuples, Lists, Trees, Associative Lists (Dictionaries, Maps)<br>• Modules<br>• Interactive Programming<br>• Lazy Evaluation, Call-by-Value, Strictness<br>• Design Recipes<br>• Testing (axiom-based, invariant-based, against reference implementation)<br>• Reasoning about Programs (equation-based, inductive)<br>• Idioms of Functional Programming<br>• 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<br>• Conditional Expressions, Guarded Expressions, Pattern Matching, Lambda Expressions<br>• Types (simple, composite), Type Classes, Recursive Types, Algebraic Data Type<br>• Type Constructors: Tuples, Lists, Trees, Associative Lists (Dictionaries, Maps)<br>• Modules<br>• Interactive Programming<br>• Lazy Evaluation, Call-by-Value, Strictness<br>• Design Recipes<br>• Testing (axiom-based, invariant-based, against reference implementation)<br>• Reasoning about Programs (equation-based, inductive)<br>• Idioms of Functional Programming<br>• Haskell Syntax and Semantics |
| **Literature** | Graham Hutton, Programming in Haskell, Cambridge University Press 2007. |

## 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<br>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:<br>• They know basic elements of the programming language C. They know the basic data types and know how to use them.<br>• They have an understanding of elementary compiler tasks, of the preprocessor and programming environment and know how those interact.<br>• They know how to bind programs and how to include external libraries to enhance software packages.<br>• They know how to use header files and how to declare function interfaces to create larger programming projects.<br>• 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.<br>• 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.<br>• 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:<br>• They are able to work in small teams to solve given weekly tasks, to identify and analyze programming errors and to present their results.<br>• They are able to explain simple phenomena to each other directly at the PC.<br>• They are able to plan and to work out a project in small teams.<br>• 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.<br>• The students have many possibilities to check their abilities when solving several given programming exercises.<br>• 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<br>Electrical Engineering: Core Qualification: Compulsory<br>Computational Science and Engineering: Core Qualification: Compulsory<br>Logistics and Mobility: Specialisation Engineering Science: Elective Compulsory<br>Mechatronics: Core Qualification: Compulsory<br>Orientierungsstudium: Core Qualification: Elective Compulsory<br>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<br>• advanced data types (pointers, arrays, strings, structs, lists)<br>• operators (arithmetical operations, logical operations, bit operations)<br>• control flow (choice, loops, jumps)<br>• preprocessor directives (macros, conditional compilation, modular design)<br>• functions (function definitions/interface, recursive functions, "call by value" versus "call by reference", function pointers)<br>• essential standard libraries and functions (stdio.h, stdlib.h, math.h, string.h, time.h)<br>• file concept, streams<br>• basic algorithms (sorting functions, series expansion, uniformly distributed permutation)<br>• exercise programs to deepen the programming skills |
| **Literature** | **Kernighan, Brian W** (Ritchie, Dennis M.;)<br>The C programming language<br>ISBN: 9780131103702<br>*Upper Saddle River, NJ [u.a.] : Prentice Hall PTR, 2009*<br><br>**Sedgewick, Robert**<br>Algorithms in C<br>ISBN: 0201316633<br>*Reading, Mass. [u.a.] : Addison-Wesley, 2007*<br><br>**Kaiser, Ulrich** (Kecher, Christoph.;)<br>C/C++: Von den Grundlagen zur professionellen Programmierung<br>ISBN: 9783898428392<br>*Bonn : Galileo Press, 2010*<br><br>**Wolf, Jürgen**<br>C von A bis Z : das umfassende Handbuch<br>ISBN: 3836214113<br>*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

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|---|---|
| **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)**<br><br>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.<br><br>**The Learning Architecture**<br><br>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.<br><br>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"<br><br>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.<br><br>**Teaching and Learning Arrangements**<br><br>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.<br><br>**Fields of Teaching**<br><br>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.<br><br>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.<br><br>**The Competence Level**<br><br>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.<br><br>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.<br><br>**Specialized Competence (Knowledge)**<br><br>Students can<br><br>• locate selected specialized areas with the relevant non-technical mother discipline,<br>• outline basic theories, categories, terminology, models, concepts or artistic techniques in the disciplines represented in the learning area,<br>• different specialist disciplines relate to their own discipline and differentiate it as well as make connections,<br>• 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,<br>• Can communicate in a foreign language in a manner appropriate to the subject. |
| *Skills* | **Professional Competence (Skills)**<br><br>In selected sub-areas students can<br><br>• apply basic methods of the said scientific disciplines,<br>• auestion a specific technical phenomena, models, theories from the viewpoint of another, aforementioned specialist discipline,<br>• to handle simple questions in aforementioned scientific disciplines in a sucsessful manner,<br>• 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)**<br><br>Students will be able<br><br>• to learn to collaborate in different manner, |

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|---|---|
| | • to present and analyze problems in the abovementioned fields in a partner or group situation in a manner appropriate to the addressees,<br>• 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),<br>• to explain nontechnical items to auditorium with technical background knowledge. |
| *Autonomy* | **Personal Competences (Self-reliance)**<br>Students are able in selected areas<br>• to reflect on their own profession and professionalism in the context of real-life fields of application<br>• to organize themselves and their own learning processes<br>• to reflect and decide questions in front of a broad education background<br>• to communicate a nontechnical item in a competent way in writen form or verbaly<br>• 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 M0736: Linear Algebra

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Linear Algebra (L0642) | Lecture | 4 | 4 |
| Linear Algebra (L0643) | Recitation Section (large) | 2 | 2 |
| Linear Algebra (L0645) | Recitation Section (small) | 2 | 2 |

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|---|---|
| **Module Responsible** | Prof. Marko Lindner |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | None |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | • Students can name the basic concepts in linear algebra. They are able to explain them using appropriate examples.<br>• Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples.<br>• They know proof strategies and can reproduce them. |
| *Skills* | • Students can model problems in linear algebra with the help of the concepts studied in this course. Moreover, they are capable of solving them by applying established methods.<br>• Students are able to discover and verify further logical connections between the concepts studied in the course.<br>• 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). |
| *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.<br><br>- Students can put their knowledge in relation to the contents of other lectures.<br><br>- 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** | 120 |
| **Assignment for the Following Curricula** | Computer Science: Core Qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Core Qualification: Compulsory |

### Course L0642: Linear Algebra

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|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 4 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 64, Study Time in Lecture 56 |
| **Lecturer** | Dr. Julian Großmann |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | Preliminaries<br><br>Vector spaces<br><br>Matrices and linear systems of equations<br><br>Scalar products and orthogonality<br><br>Basis transformation<br><br>Determinants<br><br>Eigen values |
| **Literature** | Strang: Linear Algebra<br><br>Beutelsbacher: Lineare Algebra |

| Course L0643: Linear Algebra | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Julian Großmann, Jan Meichsner |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L0645: Linear Algebra | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Julian Großmann |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## 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<br>- specify algorithms for simple data structures (such as, e.g., arrays) to solve computational problems<br>- apply propositional logic and predicate logic for specifying and understanding mathematical proofs<br>- 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<br>Computer Science: Core Qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory<br>Computational Science and Engineering: Core Qualification: Compulsory<br>Orientierungsstudium: Core Qualification: Elective Compulsory<br>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<br>2. Predicate logic, unification, predicate logic resolution<br>3. Temporal Logics (LTL, CTL)<br>4. Deterministic finite automata, definition and construction<br>5. Regular languages, closure properties, word problem, string matching<br>6. Nondeterministic automata:<br>Rabin-Scott transformation of nondeterministic into deterministic automata<br>7. Epsilon automata, minimization of automata,<br>elimination of e-edges, uniqueness of the minimal automaton (modulo renaming of states)<br>8. Myhill-Nerode Theorem:<br>Correctness of the minimization procedure, equivalence classes of strings induced by automata<br>9. Pumping Lemma for regular languages:<br>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<br>10. Regular expressions vs. finite automata:<br>Equivalence of formalisms, systematic transformation of representations, reductions<br>11. Pushdown automata and context-free grammars:<br>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)<br>12. Chomsky normal form<br>13. CYK algorithm for deciding the word problem for context-free grammrs<br>14. Deterministic pushdown automata<br>15. Deterministic vs. nondeterministic pushdown automata:<br>Application for parsing, LL(k) or LR(k) grammars and parsers vs. deterministic pushdown automata, compiler compiler<br>16. Regular grammars<br>17. Outlook: Turing machines and linear bounded automata vs general and context-sensitive grammars<br>18. Chomsky hierarchy<br>19. Mealy- and Moore automata:<br>Automata with output (w/o accepting states), infinite state sequences, automata networks<br>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)<br>21. LTL safety conditions and model checking with Büchi automata, relationships between automata and logic<br>22. Fixed points, propositional mu-calculus<br>23. Characterization of regular languages by monadic second-order logic (MSO) |
| **Literature** | 1. Logik für Informatiker Uwe Schöning, Spektrum, 5. Aufl.<br>2. Logik für Informatiker Martin Kreuzer, Stefan Kühling, Pearson Studium, 2006<br>3. Grundkurs Theoretische Informatik, Gottfried Vossen, Kurt-Ulrich Witt, Vieweg-Verlag, 2010.<br>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 M0737: Mathematical Analysis

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Mathematical Analysis (L0647) | Lecture | 4 | 4 |
| Mathematical Analysis (L0648) | Recitation Section (large) | 2 | 2 |
| Mathematical Analysis (L0649) | Recitation Section (small) | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Marko Lindner |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | None |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | • Students can name the basic concepts in analysis. They are able to explain them using appropriate examples.<br>• Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples.<br>• They know proof strategies and can reproduce them. |
| *Skills* | • Students can model problems in analysis with the help of the concepts studied in this course. Moreover, they are capable of solving them by applying established methods.<br>• Students are able to discover and verify further logical connections between the concepts studied in the course.<br>• 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). |
| *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.<br><br>- Students can put their knowledge in relation to the contents of other lectures.<br><br>- 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** | 120 minutes |
| **Assignment for the Following Curricula** | Computer Science: Core Qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Core Qualification: Compulsory |

### Course L0647: Mathematical Analysis

| | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 4 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 64, Study Time in Lecture 56 |
| **Lecturer** | Dr. Julian Großmann |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | Convergence, sequences, and series<br><br>Continuity<br><br>Elementary functions<br><br>Differential calculus<br><br>Integral calculus<br><br>Sequences of functions |
| **Literature** | Königsberger: Analysis<br><br>Forster: Analysis |

| Course L0648: Mathematical Analysis | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Julian Großmann, Jan Meichsner |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L0649: Mathematical Analysis | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Julian Großmann |
| **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 (large) | 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<br>• explain the differences between Economics and Management and the sub-disciplines in Management and to name important definitions from the field of Management<br>• explain the most important aspects of and goals in Management and name the most important aspects of entreprneurial projects<br>• 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<br>• 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<br>• 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<br>• analyse Management goals and structure them appropriately<br>• analyse organisational and staff structures of companies<br>• apply methods for decision making under multiple objectives, under uncertainty and under risk<br>• analyse production and procurement systems and Business information systems<br>• analyse and apply basic methods of marketing<br>• select and apply basic methods from mathematical finance to predefined problems<br>• apply basic methods from accounting, costing and controlling to predefined problems |
| **Personal Competence** | |
| *Social Competence* | Students are able to<br>• work successfully in a team of students<br>• to apply their knowledge from the lecture to an entrepreneurship project and write a coherent report on the project<br>• to communicate appropriately and<br>• to cooperate respectfully with their fellow students. |
| *Autonomy* | Students are able to<br>• work in a team and to organize the team themselves<br>• 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): Specialisation Electrical Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Biomedical Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Naval Architecture: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Computer Science: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Civil Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Energy and Enviromental Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Aircraft Systems Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory<br>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<br>Civil- and Environmental Engineering: Core Qualification: Compulsory<br>Bioprocess Engineering: Core Qualification: Compulsory<br>Computer Science: Core Qualification: Compulsory<br>Electrical Engineering: Core Qualification: Compulsory<br>Energy and Environmental Engineering: Core Qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Electrical Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Process Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Naval Architecture: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Computer Science: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Civil Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Energy and Enviromental Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Aircraft Systems Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Product Development and Production: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Energy Systems: Compulsory<br>Computational Science and Engineering: Core Qualification: Compulsory<br>Logistics and Mobility: Core Qualification: Compulsory<br>Mechanical Engineering: Core Qualification: Compulsory<br>Mechatronics: Core Qualification: Compulsory<br>Orientierungsstudium: Core Qualification: Elective Compulsory<br>Naval Architecture: Core Qualification: Compulsory<br>Technomathematics: Core Qualification: Compulsory<br>Process Engineering: Core Qualification: Compulsory<br>Process Engineering: Core Qualification: Compulsory |

| **Course L0882: Management Tutorial** | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Christoph Ihl, Katharina Roedelius, Tobias Vlcek |
| **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.<br><br>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<br>• Important definitions from Management,<br>• Developing Objectives for Business, and their relation to important Business functions<br>• Business Functions: Functions of the Value Chain, e.g. Production and Procurement, Supply Chain Management, Innovation Management, Marketing and Sales<br>Cross-sectional Functions, e.g. Organisation, Human Ressource Management, Supply Chain Management, Information Management<br>• Definitions as information, information systems, aspects of data security and strategic information systems<br>• Definition and Relevance of innovations, e.g. innovation opporunities, risks etc.<br>• Relevance of marketing, B2B vs. B2C-Marketing<br>• different techniques from the field of marketing (e.g. scenario technique), pricing strategies<br>• important organizational structures<br>• basics of human ressource management<br>• Introduction to Business Planning and the steps of a planning process<br>• Decision Analysis: Elements of decision problems and methods for solving decision problems<br>• Selected Planning Tasks, e.g. Investment and Financial Decisions<br>• Introduction to Accounting: Accounting, Balance-Sheets, Costing<br>• Relevance of Controlling and selected Controlling methods<br>• Important aspects of Entrepreneurship projects |
| **Literature** | Bamberg, G., Coenenberg, A.: Betriebswirtschaftliche Entscheidungslehre, 14. Aufl., München 2008<br><br>Eisenführ, F., Weber, M.: Rationales Entscheiden, 4. Aufl., Berlin et al. 2003<br><br>Heinhold, M.: Buchführung in Fallbeispielen, 10. Aufl., Stuttgart 2006.<br><br>Kruschwitz, L.: Finanzmathematik. 3. Auflage, München 2001.<br><br>Pellens, B., Fülbier, R. U., Gassen, J., Sellhorn, T.: Internationale Rechnungslegung, 7. Aufl., Stuttgart 2008.<br><br>Schweitzer, M.: Planung und Steuerung, in: Bea/Friedl/Schweitzer: Allgemeine Betriebswirtschaftslehre, Bd. 2: Führung, 9. Aufl., Stuttgart 2005.<br><br>Weber, J., Schäffer, U. : Einführung in das Controlling, 12. Auflage, Stuttgart 2008.<br><br>Weber, J./Weißenberger, B.: Einführung in das Rechnungswesen, 7. Auflage, Stuttgart 2006. |

## Module M0553: Objectoriented Programming, Algorithms and Data Structures

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Objectoriented Programming, Algorithms and Data Structures (L0131) | Lecture | 4 | 4 |
| Objectoriented Programming, Algorithms and Data Structures (L0132) | Recitation Section (small) | 1 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Rolf-Rainer Grigat |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | This lecture requires proficiency in the German language. For further requirements please refer to the German description. |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can explain the essentials of software design and the design of a class architecture with reference to existing class libraries and design patterns.<br><br>Students can describe fundamental data structures of discrete mathematics and assess the complexity of important algorithms for sorting and searching. |
| *Skills* | Students are able to<br>• Design software using given design patterns and applying class hierarchies and polymorphism<br>• Carry out software development and tests using version management systems and Google Test<br>• Sort and search for data efficiently<br>• Assess the complexity of algorithms. |
| **Personal Competence** | |
| *Social Competence* | Students can work in teams and communicate in forums. |
| *Autonomy* | Students are able to solve programming tasks such as LZW data compression using SVN Repository and Google Test independently and over a period of two to three weeks. |
| **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 Minutes, Content of Lecture, exercises and material in StudIP |
| **Assignment for the Following Curricula** | General Engineering Science (German program, 7 semester): Specialisation Computer Science: Compulsory<br>Computer Science: Core Qualification: Compulsory<br>Electrical Engineering: Core Qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Computer Science: Compulsory<br>Logistics and Mobility: Specialisation Engineering Science: Elective Compulsory<br>Orientierungsstudium: Core Qualification: Elective Compulsory |

| Course L0131: Objectoriented Programming, 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. Rolf-Rainer Grigat |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | **Object oriented analysis and design:**<br>• Objectoriented programming in C++ and Java<br>• generic programming<br>• UML<br>• design patterns<br>**Data structures and algorithmes:**<br>• complexity of algorithms<br>• searching, sorting, hash tables,<br>• stack, queues, lists,<br>• trees (AVL, heap, 2-3-4, Trie, Huffman, Patricia, B),<br>• sets, priority queues,<br>• directed and undirected graphs (spanning trees, shortest and longest path) |
| **Literature** | Skriptum |

| Course L0132: Objectoriented Programming, 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. Rolf-Rainer Grigat |
| **Language** | DE |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## 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<br>Computer Science: Core Qualification: Compulsory<br>Data Science: Core Qualification: Elective Compulsory<br>Electrical Engineering: Core Qualification: Elective Compulsory<br>Engineering Science: Specialisation Mechatronics: Elective Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechatronics: Elective Compulsory<br>Computational Science and Engineering: Core Qualification: Compulsory<br>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.<br><br>In the second part of the lecture an introduction to Internet security is given.<br><br>This class comprises:<br><br>• Application layer protocols (HTTP, FTP, DNS)<br>• Transport layer protocols (TCP, UDP)<br>• Network Layer (Internet Protocol, routing in the Internet)<br>• Data link layer with media access at the example of Ethernet<br>• Multimedia applications in the Internet<br>• Network management<br>• Internet security: IPSec<br>• Internet security: Firewalls |
| **Literature** | • Kurose, Ross, Computer Networking - A Top-Down Approach, 6th Edition, Addison-Wesley<br>• Kurose, Ross, Computernetzwerke - Der Top-Down-Ansatz, Pearson Studium; Auflage: 6. Auflage<br>• W. Stallings: Cryptography and Network Security: Principles and Practice, 6th edition<br><br>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 M0953: Introduction to Information Security

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Introduction to Information Security (L1114) | Lecture | 3 | 3 |
| Introduction to Information Security (L1115) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Dieter Gollmann |
| **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 can<br>• name the main security risks when using Information and Communication Systems and name the fundamental security mechanisms,<br>• describe commonly used methods for risk and security analysis,<br>• name the fundamental principles of data protection. |
| *Skills* | Students can<br>• evaluate the strenghts and weaknesses of the fundamental security mechanisms and of the commonly used methods for risk and security analysis,<br>• apply the fundamental principles of data protection to concrete cases. |
| **Personal Competence** | |
| *Social Competence* | Students are capable of appreciating the impact of security problems on those affected and of the potential responsibilities for their resolution. |
| *Autonomy* | None |
| **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** | 120 minutes |
| **Assignment for the Following Curricula** | Computer Science: Core Qualification: Compulsory<br>Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory<br>Data Science: Core Qualification: Compulsory<br>Computational Science and Engineering: Specialisation Computer Science: Elective Compulsory |

### Course L1114: Introduction to Information Security

| | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 3 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 48, Study Time in Lecture 42 |
| **Lecturer** | Prof. Dieter Gollmann |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Fundamental concepts<br>• Passwords & biometrics<br>• Introduction to cryptography<br>• Sessions, SSL/TLS<br>• Certificates, electronic signatures<br>• Public key infrastructures<br>• Side-channel analysis<br>• Access control<br>• Privacy<br>• Software security basics<br>• Security management & risk analysis<br>• Security evaluation: Common Criteria |
| **Literature** | D. Gollmann: Computer Security, Wiley & Sons, third edition, 2011<br>Ross Anderson: Security Engineering, Wiley & Sons, second edition, 2008 |

| Course L1115: Introduction to Information Security | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Dieter Gollmann |
| **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:<br>• Introduction<br>• Combinational logic: Gates, Boolean algebra, Boolean functions, hardware synthesis, combinational networks<br>• Sequential logic: Flip-flops, automata, systematic hardware design<br>• Technological foundations<br>• Computer arithmetic: Integer addition, subtraction, multiplication and division<br>• Basics of computer architecture: Programming models, MIPS single-cycle architecture, pipelining<br>• Memories: Memory hierarchies, SRAM, DRAM, caches<br>• 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.<br><br>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** / **Bonus** / **Form** / **Description**<br>Yes / 10 % / Excercises |
| **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<br>General Engineering Science (German program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Naval Architecture: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Electrical Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Biomedical Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Energy and Enviromental Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Process Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Aircraft Systems Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Product Development and Production: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Energy Systems: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Energy Systems: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Civil Engineering: Compulsory<br>Computer Science: Core Qualification: Compulsory<br>Data Science: Core Qualification: Elective Compulsory<br>Electrical Engineering: Core Qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Electrical Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Civil Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Bioprocess Engineering: Compulsory |

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|---|---|
| | General Engineering Science (English program, 7 semester): Specialisation Energy and Enviromental Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Computer Science: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Energy Systems: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Aircraft Systems Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Product Development and Production: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Naval Architecture: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Process Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: Compulsory<br>Computational Science and Engineering: Core Qualification: Compulsory<br>Mechatronics: Core Qualification: Compulsory<br>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<br>• Combinational Logic<br>• Sequential Logic<br>• Technological Foundations<br>• Representations of Numbers, Computer Arithmetics<br>• Foundations of Computer Architecture<br>• Memories<br>• Input/Output |
| **Literature** | • A. Clements. The Principles of Computer Hardware. 3. Auflage, Oxford University Press, 2000.<br>• A. Tanenbaum, J. Goodman. Computerarchitektur. Pearson, 2001.<br>• 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.<br>• Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples.<br>• 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.<br>• Students are able to discover and verify further logical connections between the concepts studied in the course.<br>• 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.<br>• 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.<br>• 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<br>Civil- and Environmental Engineering: Core Qualification: Compulsory<br>Bioprocess Engineering: Core Qualification: Compulsory<br>Computer Science: Core Qualification: Compulsory<br>Data Science: Core Qualification: Compulsory<br>Digital Mechanical Engineering: Core Qualification: Compulsory<br>Electrical Engineering: Core Qualification: Compulsory<br>Energy and Environmental Engineering: Core Qualification: Compulsory<br>Engineering Science: Core Qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Core Qualification: Compulsory<br>Computational Science and Engineering: Core Qualification: Compulsory<br>Mechanical Engineering: Core Qualification: Compulsory<br>Mechatronics: Core Qualification: Compulsory<br>Naval Architecture: Core Qualification: Compulsory<br>Process Engineering: Core Qualification: 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<br>• Differential calculus for several variables<br>• Mean value theorems and Taylor's theorem<br>• Maximum and minimum values<br>• Implicit functions<br>• Minimization under equality constraints<br>• Newton's method for multiple variables<br>• Double integrals over general regions<br>• Line and surface integrals<br>• 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<br>• Introduction and elementary methods<br>• Exsitence and uniqueness of initial value problems<br>• Linear differential equations<br>• Stability and qualitative behaviour of the solution<br>• Boundary value problems and basic concepts of calculus of variations<br>• Eigenvalue problems<br>• Numerical methods for the integration of initial and boundary value problems<br>• 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 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. Karl-Heinz Zimmermann |
| **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* | The students known the important machine models of computability, the class of partial recursive functions, universal computability, Gödel numbering of computations, the theorems of Kleene, Rice, and Rice-Shapiro, the concept of decidable and undecidable sets, the word problems for semi-Thue systems, Thue systems, semi-groups, and Post correspondence systems, Hilbert's 10-th problem, and the basic concepts of complexity theory. |
| *Skills* | Students are able to investigate the computability of sets and functions and to analyze the complexity of computable functions. |
| **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** | 60 min |
| **Assignment for the Following Curricula** | General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory<br>Computer Science: Core Qualification: Compulsory<br>Data Science: Core Qualification: Elective Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory<br>Computational Science and Engineering: Specialisation I. Computer Science: Elective Compulsory<br>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. Karl-Heinz Zimmermann |
| **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. Karl-Heinz Zimmermann |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | |
| **Literature** | |

## 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<br>• Procedural programming or Functional programming<br>• 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<br>Computer Science: Core Qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory<br>Computational Science and Engineering: Specialisation I. Computer Science: Elective Compulsory<br>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** | • Software Life Cycle Models (Waterfall, V-Model, Evolutionary Models, IncrementalModels, Iterative Models, Agile Processes)<br>• Requirements (Elicitation Techniques, UML Use Case Diagrams, Functional and Non-Functional Requirements)<br>• Specification (Finite State Machines, Extended FSMs, Petri Nets, Behavioral UML Diagrams, Data Modeling)<br>• Design (Design Concepts, Modules, (Agile) Design Principles)<br>• Object-Oriented Analysis and Design (Object Identification, UML Interaction Diagrams, UML Class Diagrams, Architectural Patterns)<br>• Testing (Blackbox Testing, Whitebox Testing, Control-Flow Testing, Data-Flow Testing, Testing in the Large)<br>• Maintenance and Evolution (Regression Testing, Reverse Engineering, Reengineering)<br>• Project Management (Blackbox Estimation Techniques, Whitebox Estimation Techniques, Project Plans, Gantt Charts, PERT Charts) |
| **Literature** | 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 M0727: Stochastics

**Courses**

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

| | |
|---|---|
| **Module Responsible** | Prof. Marko Lindner |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Calculus<br>• Discrete algebraic structures (combinatorics)<br>• Propositional logic |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can explain the main definitions of probability, and they can give basic definitions of modeling elements (random variables, events, dependence, independence assumptions) used in discrete and continuous settings (joint and marginal distributions, density functions). Students can describe characteristic notions such as expected values, variance, standard deviation, and moments. Students can define decision problems and explain algorithms for solving these problems (based on the chain rule or Bayesian networks). Algorithms, or estimators as they are caller, can be analyzed in terms of notions such as bias of an estimator, etc. Student can describe the main ideas of stochastic processes and explain algorithms for solving decision and computation problem for stochastic processes. Students can also explain basic statistical detection and estimation techniques. |
| *Skills* | Students can apply algorithms for solving decision problems, and they can justify whether approximation techniques are good enough in various application contexts, i.e., students can derive estimators and judge whether they are applicable or reliable. |
| **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). |
| *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.<br><br>- Students can put their knowledge in relation to the contents of other lectures.<br><br>- 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<br>Computer Science: Core Qualification: Compulsory<br>Data Science: Core Qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Computer Science: Compulsory<br>Computational Science and Engineering: Core Qualification: Compulsory<br>Computational Science and Engineering: Core Qualification: Compulsory<br>Logistics and Mobility: Specialisation Engineering Science: Elective Compulsory<br>Theoretical Mechanical Engineering: Core Qualification: 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** | Dr. Christian Seifert |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | Foundations of probability theory<br>• Definitions of probability, conditional probability<br>• Random variables, dependencies, independence assumptions,<br>• Marginal and joint probabilities<br>• Distributions and density functions<br>• Characteristics: expected values, variance, standard deviation, moments<br>Practical representations for joint probabilities<br>• Bayessche Netzwerke<br>• Semantik, Entscheidungsprobleme, exakte und approximative Algorithmen<br>Stochastic processes<br>• Stationarity, ergodicity<br>• Correlations<br>• Dynamic Bayesian networks, Hidden Markov networks, Kalman filters, queues<br>Detection & estimation<br>• Detectors<br>• Estimation rules and procedures<br>• Hypothesis and distribution tests<br>• Stochastic regression |
| **Literature** | 1. Methoden der statistischen Inferenz, Likelihood und Bayes, Held, L., Spektrum 2008<br>2. Stochastik für Informatiker, Dümbgen, L., Springer 2003<br>3. Statistik: Der Weg zur Datenanalyse, Fahrmeir, L., Künstler R., Pigeot, I, Tutz, G., Springer 2010<br>4. Stochastik, Georgii, H.-O., deGruyter, 2009<br>5. Probability and Random Processes, Grimmett, G., Stirzaker, D., Oxford University Press, 2001<br>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** | Dr. Christian Seifert |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## 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<br>• Procedural programming<br>• Experience in using tools related to operating systems such as editors, linkers, compilers<br>• 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<br>Computer Science: Core Qualification: Compulsory<br>Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory<br>Computational Science and Engineering: Specialisation I. Computer Science: Elective Compulsory<br>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<br>• Processes<br>• Concurrency<br>• Deadlocks<br>• Memory organization<br>• Scheduling<br>• File systems |
| **Literature** | 1. Operating Systems, William Stallings, Pearson International Edition<br>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 |

## Module M0852: Graph Theory and Optimization

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Graph Theory and Optimization (L1046) | Lecture | 2 | 3 |
| Graph Theory and Optimization (L1047) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Anusch Taraz |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Discrete Algebraic Structures<br>• Mathematics I |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | • Students can name the basic concepts in Graph Theory and Optimization. They are able to explain them using appropriate examples.<br>• Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples.<br>• They know proof strategies and can reproduce them. |
| *Skills* | • Students can model problems in Graph Theory and Optimization with the help of the concepts studied in this course. Moreover, they are capable of solving them by applying established methods.<br>• Students are able to discover and verify further logical connections between the concepts studied in the course.<br>• 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.<br>• 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.<br>• 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<br>Computer Science: Core Qualification: Compulsory<br>Computer Science: Core Qualification: Compulsory<br>Data Science: Core Qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Computer Science: Compulsory<br>Logistics and Mobility: Specialisation Engineering Science: Elective Compulsory<br>Technomathematics: Specialisation I. Mathematics: Elective Compulsory |

| Course L1046: Graph Theory and Optimization | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Anusch Taraz |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | • Graphs, search algorithms for graphs, trees<br>• planar graphs<br>• shortest paths<br>• minimum spanning trees<br>• maximum flow and minimum cut<br>• theorems of Menger, König-Egervary, Hall<br>• NP-complete problems<br>• backtracking and heuristics<br>• linear programming<br>• duality<br>• integer linear programming |
| **Literature** | • M. Aigner: Diskrete Mathematik, Vieweg, 2004<br>• T. Cormen, Ch. Leiserson, R. Rivest, C. Stein: Algorithmen - Eine Einführung, Oldenbourg, 2013<br>• J. Matousek und J. Nesetril: Diskrete Mathematik, Springer, 2007<br>• A. Steger: Diskrete Strukturen (Band 1), Springer, 2001<br>• A. Taraz: Diskrete Mathematik, Birkhäuser, 2012<br>• V. Turau: Algorithmische Graphentheorie, Oldenbourg, 2009<br>• K.-H. Zimmermann: Diskrete Mathematik, BoD, 2006 |

| Course L1047: Graph Theory and Optimization | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Anusch Taraz |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0873: Software Industrial Internship

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|

| | |
|---|---|
| **Module Responsible** | Prof. Karl-Heinz Zimmermann |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Foundations of Software Engineering |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students know the important aspects and phases of software development. |
| *Skills* | Students can describe the typical phases of software development and are able to contribute to a software project. |
| **Personal Competence** | |
| *Social Competence* | Students are able to specify, implement, and analyze specific basic topics in software development and present them 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 180, Study Time in Lecture 0 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Written elaboration (accord. to Internship Regulations) |
| **Examination duration and scale** | Die Ausarbeitung wird von der Betreuerin bzw. dem Betreuer der Bachelorarbeit bewertet. |
| **Assignment for the Following Curricula** | Computer Science: Core Qualification: Compulsory |

## Module M0793: Seminars Computer Science and Mathematics

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Seminar Computer Science/Engineering Mathematics (L1781) | Seminar | 2 | 2 |
| Seminar Computational Engineering Science (L0796) | Seminar | 2 | 2 |
| Seminar Computer Science/Mathematics (L0797) | Seminar | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Karl-Heinz Zimmermann |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basic knowledge in Computer Science, Mathematics, and eventually Engineering Science. |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students are able to<br>• explicate a specific topic in the field of Computer Science (or a closely related field),<br>• describe complex issues,<br>• present different views and evaluate in a critical way. |
| *Skills* | The students are able to<br>• familiarize in a specific topic of Computer Science in limited time,<br>• realize a literature survey on the specific topic and cite in a correct way,<br>• elaborate a presentation and give a lecture to a selected audience,<br>• sum up the presentation in 10-15 lines,<br>• answer questions in the final discussion. |
| **Personal Competence** | |
| *Social Competence* | The students are able to<br>• elaborate and introduce a topic for a certain audience,<br>• discuss the topic, content and structure of the presentation with the instructor,<br>• discuss certain aspects with the audience, and<br>• as the lecturer listen and respond to questions from the audience. |
| *Autonomy* | The students are able to<br>• define the task in question in an autonomous way,<br>• develop the necessary knowledge,<br>• use appropriate work equipment, and<br>• guided by an instructor critically check the working status. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Course achievement** | None |
| **Examination** | Presentation |
| **Examination duration and scale** | Presentation 20 min and discussion 5 min. |
| **Assignment for the Following Curricula** | Computer Science: Core Qualification: Compulsory |

### Course L1781: Seminar Computer Science/Engineering Mathematics

| | |
|---|---|
| **Typ** | Seminar |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Karl-Heinz Zimmermann, Dr. Jens-Peter Zemke |
| **Language** | DE/EN |
| **Cycle** | WiSe/SoSe |
| **Content** | • Seminar presentations by enrolled students. Seminar topics from the field of computer science or engineering mathematics are proposed by the organizer<br>• Active participation in discussions. |
| **Literature** | Wird vom Seminarveranstalter bekanntgegeben. |

| Course L0796: Seminar Computational Engineering Science | |
|---|---|
| **Typ** | Seminar |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Karl-Heinz Zimmermann |
| **Language** | DE/EN |
| **Cycle** | WiSe/SoSe |
| **Content** | • Seminar presentations by enrolled students. Seminar topics from the field of computer science or engineering science are proposed by the organizer<br>• Active participation in discussions. |
| **Literature** | Wird vom Seminarveranstalter bekanntgegeben. |

| Course L0797: Seminar Computer Science/Mathematics | |
|---|---|
| **Typ** | Seminar |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Karl-Heinz Zimmermann, Dr. Jens-Peter Zemke, Dr. Mehwish Saleemi, Dr. Simon Campese |
| **Language** | DE/EN |
| **Cycle** | WiSe/SoSe |
| **Content** | • Seminar presentations by enrolled students. Seminar topics from the field of computer-oriented mathematics or computer science are proposed by the organizer<br>• Active participation in discussions. |
| **Literature** | Wird vom Seminarveranstalter bekanntgegeben. |

## 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<br><br>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<br>Computer Science: Core Qualification: Compulsory<br>Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory<br>Data Science: Core Qualification: Compulsory<br>Electrical Engineering: Core Qualification: Compulsory<br>Computational Science and Engineering: Core Qualification: Compulsory<br>Mechanical Engineering: Specialisation Mechatronics: Elective Compulsory<br>Mechatronics: Core Qualification: Compulsory<br>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** | • Introduction to signal and system theory<br>• Signals<br>  ◦ Classification of signals<br>  ▪ Continuous-time and discrete-time signals<br>  ▪ Analog and digital signals<br>  ▪ Deterministic and random signals<br>  ◦ Description of LTI systems by differential equations or difference equations, respectively<br>  ◦ Basic properties of signals and operations on signals<br>  ◦ Elementary signals<br>  ◦ Distributions (Generalized Functions)<br>  ◦ Power and energy of signals<br>  ◦ Correlation functions of deterministic signals<br>  ▪ Autocorrelation function<br>  ▪ Crosscorrelation function<br>  ▪ Orthogonal signals<br>  ▪ Applications of correlation<br>• Linear time-invariant (LTI) systems<br>  ◦ Linearity<br>  ◦ Time-invariance |

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

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| **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 |

## Specialization Computer and Software Engineering

### Module M0625: Databases

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Databases (L0337) | Lecture | 3 | 5 |
| Databases (L1150) | Project-/problem-based Learning | 1 | 1 |

| | |
|---|---|
| **Module Responsible** | Prof. Stefan Schulte |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Students should have basic knowledge in the following areas:<br>• Discrete Algebraic Structures<br>• Procedural Programming<br>• Automata Theory and Formal Languages<br>• 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:<br>• Design instruments for relational databases<br>• The relational model<br>• Relational query languages, especially SQL<br>• Requirements on data integrity<br>• Possibilities for query optimization<br>• Aspects of transaction handling, fault handling and concurrency/synchronization in database systems<br>• Specific attributes and differences of object-oriented and object-relational databases<br>• 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** | 90 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory<br>Data Science: Core Qualification: Compulsory<br>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<br>• Database design, especially entity-relationship<br>• The relational model<br>• Relational query languages<br>• Data integrity and temporal data<br>• Query processing<br>• Transaction management<br>• Fault tolerance<br>• Concurrency control<br>• Object-oriented databases<br>• Object-relational databases<br>• XML data modelling<br>• NoSQL databases<br>• Big data (Overview) |
| **Literature** | • R. Ramakrishnan, J. Gehrke, Database Management Systems, McGraw Hill, 2003<br>• A. Kemper, A. Eickler, Datenbanksysteme, 10. Auflage, De Gruyter, Oldenbourg, 2015 |

| Course L1150: Databases | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Stefan Schulte |
| **Language** | EN |
| **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<br>• 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. |
| *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<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computer Science: Specialisation Computational Mathematics: Elective Compulsory<br>Data Science: Core Qualification: Elective Compulsory<br>Electrical Engineering: Core Qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Electrical Engineering: Compulsory<br>Computational Science and Engineering: Core Qualification: Compulsory<br>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** | • Fundamentals of random processes<br>• Introduction to communications engineering<br>• Quadrature amplitude modulation<br>• Description of radio frequency transmission in the equivalent complex baseband<br>• Transmission channels, channel models<br>• Analog digital conversion: Sampling, quantization, pulsecode modulation (PCM)<br>• Fundamentals of information theory, source coding, channel coding<br>• Digital baseband transmission: Pulse shaping, eye diagramm, 1. and 2. Nyquist condition, matched filter, detection, error probability<br>• Fundamentals of digital modulation |
| **Literature** | K. Kammeyer: Nachrichtenübertragung, Teubner<br>P.A. Höher: Grundlagen der digitalen Informationsübertragung, Teubner.<br>M. Bossert: Einführung in die Nachrichtentechnik, Oldenbourg.<br>J.G. Proakis, M. Salehi: Grundlagen der Kommunikationstechnik. Pearson Studium.<br>J.G. Proakis, M. Salehi: Digital Communications. McGraw-Hill.<br>S. Haykin: Communication Systems. Wiley<br>J.G. Proakis, M. Salehi: Communication Systems Engineering. Prentice-Hall.<br>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 |

## 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<br>• Discrete Algebraic Structures<br>• 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.<br>• Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples.<br>• 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.<br>• Students are able to discover and verify further logical connections between the concepts studied in the course.<br>• 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.<br>• 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.<br>• 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 Computer and Software Engineering: Elective Compulsory<br>Computer Science: Specialisation Computational Mathematics: Elective Compulsory<br>Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory<br>Data Science: Core Qualification: Elective Compulsory<br>Computational Science and Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory<br>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<br>• Structural Graph Theory<br>• Analysis of Algorithms<br>• Extremal Combinatorics<br>• Random discrete structures |
| **Literature** | • M. Aigner: Diskrete Mathematik, Vieweg, 6. Aufl., 2006<br>• J. Matoušek & J. Nešetřil: Diskrete Mathematik - Eine Entdeckungsreise, Springer, 2007<br>• A. Steger: Diskrete Strukturen - Band 1: Kombinatorik, Graphentheorie, Algebra, Springer, 2. Aufl. 2007<br>• 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 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<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory<br>Aircraft Systems Engineering: Core Qualification: Elective Compulsory<br>Aircraft Systems Engineering: Specialisation Avionic Systems: Elective Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory<br>Computational Science and Engineering: Specialisation I. Computer Science: Elective Compulsory<br>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<br>• VHDL Basics<br>• Programming Models<br>• Realization of Elementary Data Types<br>• Dynamic Scheduling<br>• Branch Prediction<br>• Superscalar Machines<br>• Memory Hierarchies<br><br>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.<br>• 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 M0651: Computational Geometry

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Computational Geoemetry (L0393) | Lecture | 2 | 4 |
| Computational Geoemetry (L0394) | Recitation Section (small) | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Dr. Prashant Batra |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Linear algebra and analytic geometry as taught in higher secondary school<br><br>(Computing with vectors a. determinants, Interpretation of scalar product, cross-product, Representation of lines/planes, Satz d. Pythagoras' theorem, cosine theorem, Thales' theorem, projections/embeddings)<br><br>Basic data structures (trees, binary trees, search trees, balanced binary trees, linked lists)<br><br>Definition of a graph |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can name the basic concepts of computer-assisted geometry, describe them with mathematical precision, and explain them by means of examples.<br><br>Students are conversant with the computational description of geometrical (combinational/topological) facts, including determinant formulas and complexity assessments and proofs for all algorithms, especially output-sensitive algorithms.<br><br>Students are able to discuss logical connections between these concepts and to explain them by means of examples. |
| *Skills* | Students can model tasks from computer-assisted geometry with the aid of the concepts about which they have learnt and can solve them by means of the methods they have learnt. |
| **Personal Competence** | |
| *Social Competence* | Students are able to discuss with other attendees their own algorithmic suggestions for solving the problems presented. They are also able to work in teams and are conversant with mathematics as a common language. |
| *Autonomy* | Students are capable of accessing independently further logical connections between the concepts about which they have learnt and are able to verify them. |
| **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** | Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computer Science: Specialisation Computational Mathematics: Elective Compulsory |

| Course L0393: Computational Geoemetry | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 92, Study Time in Lecture 28 |
| **Lecturer** | Dr. Prashant Batra |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | Construction of the convex hull of n points, triangulation of a simple polygon<br><br>Construction of Delaunay-triangulation and Voronoi-diagram<br><br>Algorithms and data structures for the construction of arrangements, and Ham-Sandwich-Cuts.<br><br>the intersection of half-planes, the optimization of a linear functional over the latter.<br><br>Efficiente determination of all intersection of (orthogonal) lines (line segments)<br><br>Approximative computation of the diameter of a point set<br><br>Randomised incremental algorithms<br><br>Basics of lattice point theory , LLL-algorithm and application in integer-valued optimization.<br><br>Basics of motion planning |
| **Literature** | Computational Geometry Algorithms and Applications Authors:<br>• Prof. Dr. Mark de Berg,<br>• Dr. Otfried Cheong,<br>• Dr. Marc van Kreveld,<br>• Prof. Dr. Mark Overmars<br><br>Springer e-Book: http://dx.doi.org/10.1007/978-3-540-77974-2<br><br>Algorithmische Geometrie : Grundlagen, Methoden, Anwendungen / Rolf Klein<br>**Verfasser:** Klein, Rolf<br>**Ausgabe:** 2., vollst. überarb. Aufl.<br>**Erschienen:** Berlin [u.a.] : Springer, 2005<br>**Umfang:** XI, 392 S. : graph. Darst.<br>Springer e-Book: http://dx.doi.org/10.1007/3-540-27619-X<br><br>O'Rourke, Joseph<br>Computational geometry in C. (English) Zbl 0816.68124<br>Cambridge: Univ. Press. ix, 346 p. $ 24.95; £16.95 /sc; $ 59.95; £35.00 /hc (1994).<br><br>**ISBN:** 0-521-44034-3 ; 0-521-44592-2<br><br>**Computational geometry** : an introduction / Franco P. Preparata; Michael Ian Shamos<br>**Verfasser:** Preparata, Franco P. ; Shamos, Michael Ian<br>**Ausgabe:** Corr. and expanded 2. printing.<br>**Erschienen:** New York [u.a.] : Springer, 1988<br>**Umfang:** XIV, 398 S. : graph. Darst.<br>**Schriftenreihe:** Texts and monographs in computer science<br>**ISBN:** 3-540-96131-3<br>0-387-96131-3<br><br>Devadoss, Satyan L.; O'Rourke, Joseph<br>Discrete and computational geometry. (English) Zbl 1232.52001<br>Princeton, NJ: Princeton University Press (ISBN 978-0-691-14553-2/hbk; 978-1-400-83898-1/ebook). xi, 255 p.<br><br>ISBN: 978-3-540-77973-5 (Print) 978-3-540-77974-2 (Online) |

| Course L0394: Computational Geoemetry | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Prashant Batra |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0972: Distributed Systems

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Distributed Systems (L1155) | Lecture | 2 | 3 |
| Distributed Systems (L1156) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Volker Turau |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Procedural programming<br>• Object-oriented programming with Java<br>• Networks<br>• Socket programming |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students explain the main abstractions of Distributed Systems (Marshalling, proxy, service, address, Remote procedure call, synchron/asynchron system). They describe the pros and cons of different types of interprocess communication. They give examples of existing middleware solutions. The participants of the course know the main architectural variants of distributed systems, including their pros and cons. Students can describe at least three different synchronization mechanisms. |
| *Skills* | Students can realize distributed systems using at least three different techniques:<br>• Proprietary protocol realized with TCP<br>• HTTP as a remote procedure call<br>• RMI as a middleware |
| **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** | 120 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation I. Computer Science: Elective Compulsory<br>Technomathematics: Specialisation II. Informatics: Elective Compulsory |

### Course L1155: Distributed 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** | WiSe |
| **Content** | • Architectures for distributed systems<br>• HTTP: Simple remote procedure call<br>• Client-Server Architectures<br>• Remote procedure call<br>• Remote Method Invocation (RMI)<br>• Synchronization<br>• Distributed Caching<br>• Name servers<br>• Distributed File systems |
| **Literature** | • Verteilte Systeme – Prinzipien und Paradigmen, Andrew S. Tanenbaum, Maarten van Steen, Pearson Studium<br>• Verteilte Systeme, G. Coulouris, J. Dollimore, T. Kindberg, 2005, Pearson Studium |

### Course L1156: Distributed 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** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M1242: Quantum Mechanics for Engineers

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Quantum Mechanics for Engineers (L1686) | Lecture | 2 | 3 |
| Quantum Mechanics for Engineers (L1688) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Wolfgang Hansen |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Knowledge in physics, particularly in optics and wave phenomena;<br>• knowledge in mathematics, particularly linear algebra, vector calculus, complex numbers and Fourier expansion |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students are able to describe and explain basic terms and principles of quantum mechanics. They can distinguish commons and differences to classical physics and know, in which situations quantum mechanical phenomena may be expected. |
| *Skills* | The students get the ability to apply concepts and methods of quantum mechanics to simple problems and systems. Vice versa, they are also able to comprehend requirements and principles of quantum mechanical devices. |
| **Personal Competence** | |
| *Social Competence* | The students discuss contents of the lectures and present solutions to simple quantum mechanical problems in small groups during the exercises. |
| *Autonomy* | The students are able to independently find answers to simple questions on quantum mechanical systems. The students are able to independently comprehend literature to more complex subjects with quantum mechanical background. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | Compulsory: No; Bonus: None; Form: Written elaboration; Description: optionale Vorlage von selbst ausgearbeiteten Lösungen zu den Übungen |
| **Examination** | Oral exam |
| **Examination duration and scale** | 90 Minuten |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computational Mathematics: Elective Compulsory<br>Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Electrical Engineering: Core Qualification: Elective Compulsory |

### Course L1686: Quantum Mechanics for Engineers

| | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Wolfgang Hansen |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | This lecture introduces into fundamental concepts, methods, and definitions in quantum mechanics, which are needed in modern material and device science. Applications will be discussed using examples in the field of electronic and optical devices.<br><br>Central topics are:<br><br>Schrödinger equation, wave function, operators, eigenstates, eigenvalues, quantum wells, harmonic oscillator, tunnel processes, resonant tunnel diode, band structure, density of states, quantum statistics, Zener-diode, stationary perturbation calculation with the quantum-confined Stark effect as an example, Fermi's golden rule and transition matrix elements, heterostructure laser, quantum cascade laser, many-particle physics, molecules and exchange interaction, quantum bits and quantum cryptography. |
| **Literature** | • David J. Griffiths: "Quantenmechanik, eine Einführung", Pearson (2012), ISBN 978-3-8632-6514-4.<br>• David K. Ferry: "Quantum Mechanics", IOP Publishing (1995), ISBN 0-7503-0327-1 (hbk) bzw. 0-7503-0328-X (pbk).<br>• M. Jaros: " Physics and Applications of Semiconductor Microstructures ", Clarendon Press (1989), ISBN: 0-19-851994-X bzw. 0-19-853927-4 (Pbk).<br>• Randy Harris, "Modernes Physik Lehr- und Übungsbuch", 2. aktualisierte Auflage, Kapitel 3-10, Pearson (2013), ISBN 978-3-86894-115-9.<br>• Michael A Nielsen and Isaac L. Chuang: "Quantum Computation and Quantum Informatioin", 10. Auflage, Cambridge University Press (2011), ISBN: 1107002176 9781107002173.<br>• Hiroyuki Sagawa and Nobuaki Yoshida: "Fundamentals of Quantum Information", World Scientific Publishing (2010), ISBN-13: 978-9814324236. |

| Course L1688: Quantum Mechanics for Engineers | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Wolfgang Hansen |
| **Language** | DE |
| **Cycle** | WiSe |
| **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<br>• Automata theory and formal languages<br>• Functional programming or procedural programming<br>• Object-oriented programming, algorithms, and data structures<br>• 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 Computer and Software Engineering: Elective Compulsory<br>Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation I. Computer Science: Elective Compulsory<br>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<br>• Semantic analysis<br>• High-level optimization<br>• Intermediate languages and code generation<br>• Compilation pipeline |
| **Literature** | Alfred Aho, Jeffrey Ullman, Ravi Sethi, and Monica S. Lam, Compilers: Principles, Techniques, and Tools, 2nd edition<br><br>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 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)<br>principles of stochastics<br>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. |
| *Autonomy* | The students can reflect their knowledge and document the results of their work. They can present the results in an appropriate manner. |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Credit points** | 6 |
| **Course achievement** | Compulsory: Yes; Bonus: 10 %; Form: Written elaboration<br>Compulsory: Yes; Bonus: 10 %; Form: Presentation |
| **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<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory<br>Data Science: Core Qualification: Elective Compulsory<br>Electrical Engineering: Core Qualification: Elective Compulsory<br>Engineering Science: Specialisation Biomedical Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: Compulsory<br>Computational Science and Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory<br>Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory<br>Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory<br>Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory<br>Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory<br>Technomathematics: Specialisation III. Engineering Science: Elective Compulsory |

### 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<br>- computer aided surgery<br>- medical sensor systems<br>- medical information systems<br>- regulatory affairs<br>- standard in medical technology<br>The students will work in groups to apply the methods introduced during the lecture using problem based learning. |
| **Literature** | Wird in der Veranstaltung bekannt gegeben. |

| 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** | - imaging systems<br>- computer aided surgery<br>- medical sensor systems<br>- medical information systems<br>- regulatory affairs<br>- standard in medical technology<br>The students will work in groups to apply the methods introduced during the lecture using problem based learning. |
| **Literature** | Wird in der Veranstaltung bekannt gegeben. |

## 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<br>• Programming Skills<br>• 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<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computational Science and 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<br>• Test-Driven Development and Unit Testing<br>• Continuous Integration<br>• Web Services<br>• Scalability<br>• From Defects to Failure |
| **Literature** | Duvall, Paul M. Continuous Integration. Pearson Education India, 2007.<br>Humble, Jez, and David Farley. Continuous delivery: reliable software releases through build, test, and deployment automation. Pearson Education, 2010.<br>Martin, Robert Cecil. Agile software development: principles, patterns, and practices. Prentice Hall PTR, 2003.<br>http://scrum-kompakt.de/<br>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<br>• Test-Driven Development and Unit Testing<br>• Continuous Integration<br>• Web Services<br>• Scalability<br>• From Defects to Failure |
| **Literature** | Duvall, Paul M. Continuous Integration. Pearson Education India, 2007.<br>Humble, Jez, and David Farley. Continuous delivery: reliable software releases through build, test, and deployment automation. Pearson Education, 2010.<br>Martin, Robert Cecil. Agile software development: principles, patterns, and practices. Prentice Hall PTR, 2003.<br>http://scrum-kompakt.de/<br>Myers, Glenford J., Corey Sandler, and Tom Badgett. The art of software testing. John Wiley & Sons, 2011. |

## 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).<br><br>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** **Bonus** **Form** **Description**<br>Yes 10 % Subject theoretical and practical work |
| **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<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory<br>Electrical Engineering: Core Qualification: Elective Compulsory<br>Engineering Science: Specialisation Mechatronics: Elective Compulsory<br>Aircraft Systems Engineering: Core Qualification: Elective Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechatronics: Elective Compulsory<br>Computational Science and Engineering: Core Qualification: Compulsory<br>Mechatronics: Specialisation System Design: Elective Compulsory<br>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory<br>Mechatronics: Core Qualification: Elective Compulsory<br>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<br>• Specifications and Modeling<br>• Embedded/Cyber-Physical Systems Hardware<br>• System Software<br>• Evaluation and Validation<br>• Mapping of Applications to Execution Platforms<br>• 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 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.<br><br>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<br>Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory<br>Computational Science and Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory<br>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory<br>Mechatronics: Specialisation System Design: Elective Compulsory<br>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<br>• Experiment 2: Programming the Robot in Matlab/Simulink<br>• 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.<br>• Begleitende Foliensätze |

## Specialization Computational Mathematics

### 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<br>• 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. |
| *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<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computer Science: Specialisation Computational Mathematics: Elective Compulsory<br>Data Science: Core Qualification: Elective Compulsory<br>Electrical Engineering: Core Qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Electrical Engineering: Compulsory<br>Computational Science and Engineering: Core Qualification: Compulsory<br>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** | • Fundamentals of random processes<br>• Introduction to communications engineering<br>• Quadrature amplitude modulation<br>• Description of radio frequency transmission in the equivalent complex baseband<br>• Transmission channels, channel models<br>• Analog digital conversion: Sampling, quantization, pulsecode modulation (PCM)<br>• Fundamentals of information theory, source coding, channel coding<br>• Digital baseband transmission: Pulse shaping, eye diagramm, 1. and 2. Nyquist condition, matched filter, detection, error probability<br>• Fundamentals of digital modulation |
| **Literature** | K. Kammeyer: Nachrichtenübertragung, Teubner<br>P.A. Höher: Grundlagen der digitalen Informationsübertragung, Teubner.<br>M. Bossert: Einführung in die Nachrichtentechnik, Oldenbourg.<br>J.G. Proakis, M. Salehi: Grundlagen der Kommunikationstechnik. Pearson Studium.<br>J.G. Proakis, M. Salehi: Digital Communications. McGraw-Hill.<br>S. Haykin: Communication Systems. Wiley<br>J.G. Proakis, M. Salehi: Communication Systems Engineering. Prentice-Hall.<br>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 |

## 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<br>• They can explain the dynamics of simple control loops and interpret dynamic properties in terms of frequency response and root locus<br>• They can explain the Nyquist stability criterion and the stability margins derived from it.<br>• They can explain the role of the phase margin in analysis and synthesis of control loops<br>• They can explain the way a PID controller affects a control loop in terms of its frequency response<br>• 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<br>• They can simulate and assess the behavior of systems and control loops<br>• They can design PID controllers with the help of heuristic (Ziegler-Nichols) tuning rules<br>• They can analyze and synthesize simple control loops with the help of root locus and frequency response techniques<br>• They can calculate discrete-time approximations of controllers designed in continuous-time and use it for digital implementation<br>• 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.<br><br>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<br>Bioprocess Engineering: Core Qualification: Compulsory<br>Computer Science: Specialisation Computational Mathematics: Elective Compulsory<br>Data Science: Core Qualification: Elective Compulsory<br>Electrical Engineering: Core Qualification: Compulsory<br>Energy and Environmental Engineering: Core Qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Electrical Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Civil Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Bioprocess Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Energy and Enviromental Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Computer Science: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Energy Systems: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Aircraft Systems Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Product Development and Production: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Naval Architecture: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Process Engineering: Compulsory |

| | |
|---|---|
| | General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: Compulsory<br>Green Technologies: Energy, Water, Climate: Core Qualification: Compulsory<br>Computational Science and Engineering: Core Qualification: Compulsory<br>Logistics and Mobility: Specialisation Engineering Science: Elective Compulsory<br>Logistics and Mobility: Specialisation Information Technology: Elective Compulsory<br>Logistics and Mobility: Specialisation Traffic Planning and Systems: Elective Compulsory<br>Logistics and Mobility: Specialisation Production Management and Processes: Elective Compulsory<br>Mechanical Engineering: Core Qualification: Compulsory<br>Mechatronics: Core Qualification: Compulsory<br>Technomathematics: Specialisation III. Engineering Science: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course Core Studies: Elective Compulsory<br>Process Engineering: Core Qualification: Compulsory<br>Engineering and Management - Major in Logistics and Mobility: Specialisation Information Technology: Elective Compulsory<br>Engineering and Management - Major in Logistics and Mobility: Specialisation Traffic Planning and Systems: Elective Compulsory<br>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<br>• Linear systems, differential equations and transfer functions<br>• First and second order systems, poles and zeros, impulse and step response<br>• Stability<br>Feedback systems<br>• Principle of feedback, open-loop versus closed-loop control<br>• Reference tracking and disturbance rejection<br>• Types of feedback, PID control<br>• System type and steady-state error, error constants<br>• Internal model principle<br>Root locus techniques<br>• Root locus plots<br>• Root locus design of PID controllers<br>Frequency response techniques<br>• Bode diagram<br>• Minimum and non-minimum phase systems<br>• Nyquist plot, Nyquist stability criterion, phase and gain margin<br>• Loop shaping, lead lag compensation<br>• Frequency response interpretation of PID control<br>Time delay systems<br>• Root locus and frequency response of time delay systems<br>• Smith predictor<br>Digital control<br>• Sampled-data systems, difference equations<br>• Tustin approximation, digital implementation of PID controllers<br>Software tools<br>• Introduction to Matlab, Simulink, Control toolbox<br>• Computer-based exercises throughout the course |
| **Literature** | • Werner, H., Lecture Notes „Introduction to Control Systems“<br>• G.F. Franklin, J.D. Powell and A. Emami-Naeini "Feedback Control of Dynamic Systems", Addison Wesley, Reading, MA, 2009<br>• K. Ogata "Modern Control Engineering", Fourth Edition, Prentice Hall, Upper Saddle River, NJ, 2010<br>• 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 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<br>• Discrete Algebraic Structures<br>• 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.<br>• Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples.<br>• 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.<br>• Students are able to discover and verify further logical connections between the concepts studied in the course.<br>• 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.<br>• 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.<br>• 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 Computer and Software Engineering: Elective Compulsory<br>Computer Science: Specialisation Computational Mathematics: Elective Compulsory<br>Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory<br>Data Science: Core Qualification: Elective Compulsory<br>Computational Science and Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory<br>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<br>• Structural Graph Theory<br>• Analysis of Algorithms<br>• Extremal Combinatorics<br>• Random discrete structures |
| **Literature** | • M. Aigner: Diskrete Mathematik, Vieweg, 6. Aufl., 2006<br>• J. Matoušek & J. Nešetřil: Diskrete Mathematik - Eine Entdeckungsreise, Springer, 2007<br>• A. Steger: Diskrete Strukturen - Band 1: Kombinatorik, Graphentheorie, Algebra, Springer, 2. Aufl. 2007<br>• 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 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<br>• basic MATLAB/Python knowledge |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to<br>• name numerical methods for interpolation, integration, least squares problems, eigenvalue problems, nonlinear root finding problems and to explain their core ideas,<br>• repeat convergence statements for the numerical methods,<br>• explain aspects for the practical execution of numerical methods with respect to computational and storage complexitx. |
| *Skills* | Students are able to<br>• implement, apply and compare numerical methods using MATLAB/Python,<br>• justify the convergence behaviour of numerical methods with respect to the problem and solution algorithm,<br>• select and execute a suitable solution approach for a given problem. |
| **Personal Competence** | |
| *Social Competence* | Students are able to<br>• 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<br>• to assess whether the supporting theoretical and practical excercises are better solved individually or in a team,<br>• 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<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Biomedical Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Aircraft Systems Engineering: Elective Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Elective Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Energy Systems: Elective Compulsory<br>Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Computer Science: Specialisation Computational Mathematics: Elective Compulsory<br>Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory<br>Data Science: Core Qualification: Compulsory<br>Electrical Engineering: Core Qualification: Elective Compulsory<br>Engineering Science: Core Qualification: Compulsory<br>Engineering Science: Core Qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Core Qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Computer Science: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Elective Compulsory |

| | |
|---|---|
| | Computational Science and Engineering: Core Qualification: Compulsory<br>Mechanical Engineering: Specialisation Theoretical Mechanical Engineering: Compulsory<br>Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory<br>Mechanical Engineering: Specialisation Mechatronics: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course Core Studies: Elective Compulsory<br>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<br>2. Linear systems of equations: LU and Cholesky factorization, condition<br>3. Interpolation: polynomial, spline and trigonometric interpolation<br>4. Nonlinear equations: fixed point iteration, root finding algorithms, Newton's method<br>5. Linear and nonlinear least squares problems: normal equations, Gram Schmidt and Householder orthogonalization, singular value decomposition, regularizatio, Gauss-Newton and Levenberg-Marquardt methods<br>6. Eigenvalue problems: power iteration, inverse iteration, QR algorithm<br>7. Numerical differentiation<br>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)<br>• Stoer/Bulirsch: Numerische Mathematik 1, Springer<br>• 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 M1242: Quantum Mechanics for Engineers

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Quantum Mechanics for Engineers (L1686) | Lecture | 2 | 3 |
| Quantum Mechanics for Engineers (L1688) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Wolfgang Hansen |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Knowledge in physics, particularly in optics and wave phenomena;<br>• knowledge in mathematics, particularly linear algebra, vector calculus, complex numbers and Fourier expansion |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students are able to describe and explain basic terms and principles of quantum mechanics. They can distinguish commons and differences to classical physics and know, in which situations quantum mechanical phenomena may be expected. |
| *Skills* | The students get the ability to apply concepts and methods of quantum mechanics to simple problems and systems. Vice versa, they are also able to comprehend requirements and principles of quantum mechanical devices. |
| **Personal Competence** | |
| *Social Competence* | The students discuss contents of the lectures and present solutions to simple quantum mechanical problems in small groups during the exercises. |
| *Autonomy* | The students are able to independently find answers to simple questions on quantum mechanical systems. The students are able to independently comprehend literature to more complex subjects with quantum mechanical background. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Course achievement** | Compulsory: No; Bonus: None; Form: Written elaboration; Description: optionale Vorlage von selbst ausgearbeiteten Lösungen zu den Übungen |
| **Examination** | Oral exam |
| **Examination duration and scale** | 90 Minuten |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computational Mathematics: Elective Compulsory<br>Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Electrical Engineering: Core Qualification: Elective Compulsory |

### Course L1686: Quantum Mechanics for Engineers

| | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Wolfgang Hansen |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | This lecture introduces into fundamental concepts, methods, and definitions in quantum mechanics, which are needed in modern material and device science. Applications will be discussed using examples in the field of electronic and optical devices.<br><br>Central topics are:<br><br>Schrödinger equation, wave function, operators, eigenstates, eigenvalues, quantum wells, harmonic oscillator, tunnel processes, resonant tunnel diode, band structure, density of states, quantum statistics, Zener-diode, stationary perturbation calculation with the quantum-confined Stark effect as an example, Fermi's golden rule and transition matrix elements, heterostructure laser, quantum cascade laser, many-particle physics, molecules and exchange interaction, quantum bits and quantum cryptography. |
| **Literature** | • David J. Griffiths: "Quantenmechanik, eine Einführung", Pearson (2012), ISBN 978-3-8632-6514-4.<br>• David K. Ferry: "Quantum Mechanics", IOP Publishing (1995), ISBN 0-7503-0327-1 (hbk) bzw. 0-7503-0328-X (pbk).<br>• M. Jaros: " Physics and Applications of Semiconductor Microstructures ", Clarendon Press (1989), ISBN: 0-19-851994-X bzw. 0-19-853927-4 (Pbk).<br>• Randy Harris, "Modernes Physik Lehr- und Übungsbuch", 2. aktualisierte Auflage, Kapitel 3-10, Pearson (2013), ISBN 978-3-86894-115-9.<br>• Michael A Nielsen and Isaac L. Chuang: "Quantum Computation and Quantum Informatioin", 10. Auflage, Cambridge University Press (2011), ISBN: 1107002176 9781107002173.<br>• Hiroyuki Sagawa and Nobuaki Yoshida: "Fundamentals of Quantum Information", World Scientific Publishing (2010), ISBN-13: 978-9814324236. |

| Course L1688: Quantum Mechanics for Engineers | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Wolfgang Hansen |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0651: Computational Geometry

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Computational Geoemetry (L0393) | Lecture | 2 | 4 |
| Computational Geoemetry (L0394) | Recitation Section (small) | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Dr. Prashant Batra |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Linear algebra and analytic geometry as taught in higher secondary school<br><br>(Computing with vectors a. determinants, Interpretation of scalar product, cross-product, Representation of lines/planes, Satz d. Pythagoras' theorem, cosine theorem, Thales' theorem, projections/embeddings)<br><br>Basic data structures (trees, binary trees, search trees, balanced binary trees, linked lists)<br><br>Definition of a graph |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can name the basic concepts of computer-assisted geometry, describe them with mathematical precision, and explain them by means of examples.<br><br>Students are conversant with the computational description of geometrical (combinational/topological) facts, including determinant formulas and complexity assessments and proofs for all algorithms, especially output-sensitive algorithms.<br><br>Students are able to discuss logical connections between these concepts and to explain them by means of examples. |
| *Skills* | Students can model tasks from computer-assisted geometry with the aid of the concepts about which they have learnt and can solve them by means of the methods they have learnt. |
| **Personal Competence** | |
| *Social Competence* | Students are able to discuss with other attendees their own algorithmic suggestions for solving the problems presented. They are also able to work in teams and are conversant with mathematics as a common language. |
| *Autonomy* | Students are capable of accessing independently further logical connections between the concepts about which they have learnt and are able to verify them. |
| **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** | Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computer Science: Specialisation Computational Mathematics: Elective Compulsory |

| Course L0393: Computational Geoemetry | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 92, Study Time in Lecture 28 |
| **Lecturer** | Dr. Prashant Batra |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | Construction of the convex hull of n points, triangulation of a simple polygon<br><br>Construction of Delaunay-triangulation and Voronoi-diagram<br><br>Algorithms and data structures for the construction of arrangements, and Ham-Sandwich-Cuts.<br><br>the intersection of half-planes, the optimization of a linear functional over the latter.<br><br>Efficiente determination of all intersection of (orthogonal) lines (line segments)<br><br>Approximative computation of the diameter of a point set<br><br>Randomised incremental algorithms<br><br>Basics of lattice point theory , LLL-algorithm and application in integer-valued optimization.<br><br>Basics of motion planning |
| **Literature** | Computational Geometry Algorithms and Applications Authors:<br>• Prof. Dr. Mark de Berg,<br>• Dr. Otfried Cheong,<br>• Dr. Marc van Kreveld,<br>• Prof. Dr. Mark Overmars<br><br>Springer e-Book: http://dx.doi.org/10.1007/978-3-540-77974-2<br><br>Algorithmische Geometrie : Grundlagen, Methoden, Anwendungen / Rolf Klein<br>**Verfasser:** Klein, Rolf<br>**Ausgabe:** 2., vollst. überarb. Aufl.<br>**Erschienen:** Berlin [u.a.] : Springer, 2005<br>**Umfang:** XI, 392 S. : graph. Darst.<br>Springer e-Book: http://dx.doi.org/10.1007/3-540-27619-X<br><br>O'Rourke, Joseph<br>Computational geometry in C. (English) Zbl 0816.68124<br>Cambridge: Univ. Press. ix, 346 p. $ 24.95; £16.95 /sc; $ 59.95; £35.00 /hc (1994).<br><br>**ISBN:** 0-521-44034-3 ; 0-521-44592-2<br><br>**Computational geometry** : an introduction / Franco P. Preparata; Michael Ian Shamos<br>**Verfasser:** Preparata, Franco P. ; Shamos, Michael Ian<br>**Ausgabe:** Corr. and expanded 2. printing.<br>**Erschienen:** New York [u.a.] : Springer, 1988<br>**Umfang:** XIV, 398 S. : graph. Darst.<br>**Schriftenreihe:** Texts and monographs in computer science<br>**ISBN:** 3-540-96131-3<br>0-387-96131-3<br><br>Devadoss, Satyan L.; O'Rourke, Joseph<br>Discrete and computational geometry. (English) Zbl 1232.52001<br>Princeton, NJ: Princeton University Press (ISBN 978-0-691-14553-2/hbk; 978-1-400-83898-1/ebook). xi, 255 p.<br><br>ISBN: 978-3-540-77973-5 (Print) 978-3-540-77974-2 (Online) |

| Course L0394: Computational Geoemetry | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Prashant Batra |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

## Module M0668: Algebra and Control

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Algebra and Control (L0428) | Lecture | 2 | 4 |
| Algebra and Control (L0429) | Recitation Section (small) | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Dr. Prashant Batra |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basics of Real Analysis and Linear Algebra of Vector Spaces<br>and either of:<br>Introduction to Control Theory<br>or:<br>Discrete Mathematics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can<br>• Describe input-output systems polynomially<br>• Explain factorization approaches to transfer functions<br>• Name stabilization conditions for systems in coprime stable factorization. |
| *Skills* | Students are able to<br>• Undertake a synthesis of stable control loops<br>• Apply suitable methods of analysis and synthesis to describe all stable control loops<br>• Ensure the fulfillment of specified performance measurements. |
| **Personal Competence** | |
| *Social Competence* | After completing the module, students are able to solve subject-related tasks and to present the results. |
| *Autonomy* | Students are provided with tasks which are exam-related so that they can examine their learning progress and reflect on it. |
| **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 Computational Mathematics: Elective Compulsory<br>Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory<br>Technomathematics: Specialisation II. Informatics: Elective Compulsory |

| Course L0428: Algebra and Control | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 92, Study Time in Lecture 28 |
| **Lecturer** | Dr. Prashant Batra |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | - Algebraic control methods, polynomial and fractional approach<br>-Single input - single output (SISO) control systems synthesis by algebraic methods,<br><br>- Simultaneous stabilization<br>- Parametrization of all stabilizing controllers<br>- Selected methods of pole assignment.<br>- Filtering and sensitivity minimization<br>- Polynomial matrices, left and right polynomial fractions.<br>- Euclidean algorithm, diophantine equations over rings<br>- Smith-McMillan normal form<br>- Multiple input - multiple output control system synthesis by polynomial methods, condition of stability. |
| **Literature** | • Vidyasagar, M.: Control system synthesis: a factorization approach. The MIT Press,Cambridge/Mass. - London, 1985.<br>• Vardulakis, A.I.G.: Linear multivariable control. Algebraic analysis and synthesis methods, John Wiley & Sons,Chichester,UK,1991.<br>• Chen, Chi-Tsong: Analog and digital control system design. Transfer-function, state-space, and algebraic methods. Oxford Univ. Press,1995.<br>• Kučera, V.: Analysis and Design of Discrete Linear Control Systems. Praha: Academia, 1991. |

| Course L0429: Algebra and Control | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Prashant Batra |
| **Language** | DE/EN |
| **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<br>• Programming experience in C |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can<br>• list classical and modern iteration methods and their interrelationships,<br>• repeat convergence statements for iterative methods,<br>• explain aspects regarding the efficient implementation of iteration methods. |
| *Skills* | Students are able to<br>• analyse, implement, test, and compare iterative methods,<br>• analyse the convergence behaviour of iterative methods and, if applicable, compute congergence rates. |
| **Personal Competence** | |
| *Social Competence* | Students are able to<br>• 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<br>• to assess whether the supporting theoretical and practical excercises are better solved individually or in a team,<br>• to work on complex problems over an extended period of time,<br>• 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 Computational Mathematics: Elective Compulsory<br>Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory<br>Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory<br>Data Science: Core Qualification: Elective Compulsory<br>Computational Science and Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory<br>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<br>2. Classical methods: basic notions, convergence<br>3. Projection methods<br>4. Krylov space methods<br>5. Preconditioning (e.g. ILU)<br>6. Multigrid methods<br>7. Domain Decomposition Methods |
| **Literature** | 1. Y. Saad. Iterative methods for sparse linear systems<br>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 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 1 - 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.<br>• Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples.<br>• 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.<br>• Students are able to discover and verify further logical connections between the concepts studied in the course.<br>• 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.<br>• 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.<br>• 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<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Naval Architecture: Compulsory<br>General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Elective Compulsory<br>Computer Science: Specialisation Computational Mathematics: Elective Compulsory<br>Electrical Engineering: Core Qualification: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Electrical Engineering: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Compulsory<br>General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory<br>Computational Science and Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory<br>Mechanical Engineering: Specialisation Mechatronics: Compulsory<br>Mechanical Engineering: Specialisation Theoretical Mechanical Engineering: Elective Compulsory<br>Mechatronics: Core Qualification: Compulsory<br>Naval Architecture: Core Qualification: Compulsory<br>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<br>• Examples of partial differential equations<br>• First order quasilinear differential equations<br>• Normal forms of second order differential equations<br>• Harmonic functions and maximum principle<br>• Maximum principle for the heat equation<br>• Wave equation<br>• Liouville's formula<br>• Special functions<br>• Difference methods<br>• 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<br>• Functions of one complex variable<br>• Complex differentiation<br>• Conformal mappings<br>• Complex integration<br>• Cauchy's integral theorem<br>• Cauchy's integral formula<br>• Taylor and Laurent series expansion<br>• Singularities and residuals<br>• 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 |

# Thesis

## Module M-001: Bachelor Thesis

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|

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| **Module Responsible** | Professoren der TUHH |
| **Admission Requirements** | • According to General Regulations §21 (1):<br>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).<br>• 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.<br>• 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.<br>• 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.<br>• 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.<br>• 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.<br>• The students are able to identify, open up, and connect knowledge and material necessary for working on a scientific problem.<br>• 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<br>General Engineering Science (German program, 7 semester): Thesis: Compulsory<br>Civil- and Environmental Engineering: Thesis: Compulsory<br>Bioprocess Engineering: Thesis: Compulsory<br>Computer Science: Thesis: Compulsory<br>Data Science: Thesis: Compulsory<br>Digital Mechanical Engineering: Thesis: Compulsory<br>Electrical Engineering: Thesis: Compulsory<br>Energy and Environmental Engineering: Thesis: Compulsory<br>Engineering Science: Thesis: Compulsory<br>General Engineering Science (English program): Thesis: Compulsory<br>General Engineering Science (English program, 7 semester): Thesis: Compulsory<br>Green Technologies: Energy, Water, Climate: Thesis: Compulsory<br>Computational Science and Engineering: Thesis: Compulsory<br>Logistics and Mobility: Thesis: Compulsory<br>Mechanical Engineering: Thesis: Compulsory<br>Mechatronics: Thesis: Compulsory<br>Naval Architecture: Thesis: Compulsory<br>Technomathematics: Thesis: Compulsory<br>Teilstudiengang Lehramt Elektrotechnik-Informationstechnik: Thesis: Compulsory<br>Teilstudiengang Lehramt Metalltechnik: Thesis: Compulsory<br>Process Engineering: Thesis: Compulsory<br>Engineering and Management - Major in Logistics and Mobility: Thesis: Compulsory |