TUHH
Hamburg
University of
Technology

Module Manual

Bachelor of Science (B.Sc.)

Data Science
Dual study program

Cohort: Winter Term 2022

Updated: 21st June 2022

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 Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Orientation Studies: Core Qualification: Elective Compulsory

Course L0164: Discrete Algebraic Structures

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

Course L0165: Discrete Algebraic Structures

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

Module M1436: Procedural Programming for Computer Engineers

Courses

Title	Typ	Hrs/wk	CP
Procedural Programming for Computer Engineers (L2163)	Lecture	1	2
Procedular Programming for Computer Engineers (L2164)	Recitation Section (large)	1	1
Procedural Programming for Computer Engineers (L2165)	Practical Course	2	3

Module Responsible	Prof. Bernd-Christian Renner
Admission Requirements	None
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students will know - the essential features of a procedural programming language - the steps during the compilation of procedural source code to machine code - all essential language constructs and data types of a procedural programming language - software design concepts for the implementation of procedural programs
Skills	- Mastery of typical development tools - Designing simple, structured programs based on a procedural programming language - Debugging by analyzing compiler warnings and error messages - Analysis and explanation of procedural programs
Personal Competence	
Social Competence	- After completing the module, students are able to work on subject-specific tasks alone or in a group and to present the results appropriately.
Autonomy	- After completion of the module, students are able to work independently on parts of the subject area using reference books, to summarize the acquired knowledge, to present and to link it with the contents of other courses.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Orientation Studies: Core Qualification: Elective Compulsory Technomathematics: Core Qualification: Compulsory

Course L2163: Procedural Programming for Computer Engineers

Typ	Lecture
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Bernd-Christian Renner
Language	DE/EN
Cycle	WiSe
Content	- Development tools: preprocessor, compiler, linker, assembler, IDE, version management (Git) - Procedural programming: fundamental data types, operators, control structures, functions, pointers and arrays, scopes and lifetime of variables, structures / unions, function pointers, Command line arguments - Programming techniques: Modularization, separation of interface and implementation, callback functions, structured data types.
Literature	- Greg Perry and Dean Miller. C Programming Absolute Beginner's Guide: No experience necessary! Que Publishing; 3. Auflage (7. August 2013). ISBN 978-0789751980. - Helmut Erlenkötter. C: Programmieren von Anfang an. Rowohlt Taschenbuch; 25. Auflage (1. Dezember 1999). ISBN 978-3499600746. - Markus Neumann. C Programmieren: für Einsteiger: Der leichte Weg zum C-Experten (Einfach Programmieren lernen, Band 8). BMU Verlag (30. Januar 2020). ISBN 978-3966450607. - Brian W. Kernighan, Dennis M. Ritchie: The C Programming Language. Prentice Hall; 2. Auflage (1988), ISBN 0-13-110362-8.

Course L2164: Procedular Programming for Computer Engineers	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Bernd-Christian Renner
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L2165: Procedural Programming for Computer Engineers	
Typ	Practical Course
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Bernd-Christian Renner
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1809: Introduction to Data Science

Courses

Title	Typ	Hrs/wk	CP
Introduction to Data Science (L2998)	Lecture	2	4
Introduction to Data Science (L2999)	Seminar	1	2

Module Responsible	Prof. Tobias Knopp
Admission Requirements	None
Recommended Previous Knowledge	none
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	In this course, students receive a broad overview of the scientific field known as Data Science. The basic terms and concepts are explained at a high level of abstraction and enable the students to classify the methods taught in the further course of study. In addition to a historical overview, current application examples of Data Science are presented.
Skills	Students are able to: • to define data science; • to understand that problem definition and problem solving include different perspectives, approaches, and motives; • to discuss the responsibility of data science and computer science for the design of technology in respect to societal change; • to list important methods and ideas of data science, and to critically discuss their relevance.
Personal Competence	
Social Competence	Students are able to discuss and collaborate in small groups to present a topic related to Data Science.
Autonomy	Students are able to independently prepare and review the lecture content.
Workload in Hours	Independent Study Time 138, Study Time in Lecture 42
Credit points	6
Course achievement	None
Examination	Presentation
Examination duration and scale	Preparation and presentation of a poster on a Data Science topic
Assignment for the Following Curricula	Data Science: Core Qualification: Compulsory

Course L2998: Introduction to Data Science

Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Tobias Knopp
Language	DE
Cycle	WiSe
Content	In this course, students receive a broad overview of the scientific field known as Data Science. The basic terms and concepts are explained at a high level of abstraction and enable the students to classify the methods taught in the further course of study. In addition to a historical overview, current application examples of Data Science are presented.
Literature	Christopher M. Bishop: Pattern Recognition and Machine Learning

Course L2999: Introduction to Data Science

Typ	Seminar
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Tobias Knopp
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1728: Mathematics I (EN)

Courses

Title	Typ	Hrs/wk	CP
Mathematics I (EN) (L2973)	Lecture	4	4
Mathematics I (EN) (L2974)	Recitation Section (large)	2	2
Mathematics I (EN) (L2975)	Recitation Section (small)	2	2

Module Responsible	Prof. Daniel Ruprecht
Admission Requirements	None
Recommended Previous Knowledge	School mathematics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can name the basic concepts in analysis and linear algebra. They are able to explain them using appropriate examples. • Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples. • They know proof strategies and can reproduce them.
Skills	• Students can model problems in analysis and linear algebra with the help of the concepts studied in this course. Moreover, they are capable of solving them by applying established methods. • Students are able to discover and verify further logical connections between the concepts studied in the course. • For a given problem, the students can develop and execute a suitable approach, and are able to critically evaluate the results.
Personal Competence	
Social Competence	• Students are able to work together in teams. They are capable to use mathematics as a common language. • In doing so, they can communicate new concepts according to the needs of their cooperating partners. Moreover, they can design examples to check and deepen the understanding of their peers.
Autonomy	• Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them. • Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.
Workload in Hours	Independent Study Time 128, Study Time in Lecture 112
Credit points	8
Course achievement	Compulsory: Yes; Bonus: 10 %; Form: Excercises; Description:
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Engineering Science: Core Qualification: Compulsory

Course L2973: Mathematics I (EN)	
Typ	Lecture
Hrs/wk	4
CP	4
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Lecturer	Prof. Anusch Taraz
Language	EN
Cycle	WiSe
Content	Mathematical Foundations: sets, statements, induction, mappings, trigonometry Analysis: Foundations of differential calculus in one variable • natural and real numbers • convergence of sequences and series • continuous and differentiable functions • mean value theorems • Taylor series
Literature	• T. Arens u.a. : Mathematik, Springer Spektrum, Heidelberg 2015 • W. Mackens, H. Voß: Mathematik I für Studierende der Ingenieurwissenschaften, HECO-Verlag, Alsdorf 1994 • W. Mackens, H. Voß: Aufgaben und Lösungen zur Mathematik I für Studierende der Ingenieurwissenschaften, HECO-Verlag, Alsdorf 1994 • G. Strang: Lineare Algebra, Springer-Verlag, 2003 • G. und S. Teschl: Mathematik für Informatiker, Band 1, Springer-Verlag, 2013

Course L2974: Mathematics I (EN)	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Anusch Taraz
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L2975: Mathematics I (EN)	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Anusch Taraz
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1750: Practical module 1 (dual study program, Bachelor's degree)

Courses

Title	Typ	Hrs/wk	CP
Practical term 1 (dual study program, Bachelor's degree) (L2879)		0	6

Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	A: Self-management, organising work and learning in engineering (for dual study program)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students... • ... describe their employer's organisation (company) and the associated regulations that relate to how tasks and competences are distributed, as well as how work processes are handled. • ... understand the structure and objectives of the dual study programme and the increasing requirements throughout the course of study.
Skills	Dual students... • ... use equipment and resources professionally in accordance with the assigned work areas and tasks, and describe operational processes and procedures with regard to the intended work results/objectives. • ... implement the university's application recommendations in relation to their current tasks.
Personal Competence	
Social Competence	Dual students... • ... have familiarised themselves with their new working environment (learning environment) and the associated tasks/processes/working relationships. • ... know their central points of contact and company colleagues, and exchange ideas with them constructively. • ... coordinate work tasks with their professional supervisor and ask for support as needed. • ... help shape the work in the assigned work area and offer their colleagues support to complete their work. • ... work together with others in smaller work teams in a result-oriented manner.
Autonomy	Dual students... • ... structure their work and learning processes within the company independently in line with their responsibilities and authorisations, and coordinate them with their professional supervisor. • ... complete work tasks/assignments with the support of colleagues. • ... coordinate the practical phase with any individual preparation required for the examination phase at TUHH. • ... document and reflect on how their foundational subjects link with their work as an engineer.
Workload in Hours	Independent Study Time 180, Study Time in Lecture 0
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Documentation accompanying studies and across semesters: Module credit points are earned by completing a digital learning and development report (e-portfolio). This documents and reflects individual learning experiences and skills development relating to interlinking theory and practice, as well as professional practice. In addition, the partner company provides proof to the dual@TUHH Coordination Office that the dual student has completed the practical phase.
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Core Qualification: Compulsory Civil- and Environmental Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Engineering Science: Core Qualification: Compulsory Green Technologies: Energy, Water, Climate: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Mechanical Engineering: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Naval Architecture: Core Qualification: Compulsory Technomathematics: Core Qualification: Compulsory Engineering and Management - Major in Logistics and Mobility: Core Qualification: Compulsory

Course L2879: Practical term 1 (dual study program, Bachelor's degree)	
Typ	
Hrs/wk	0
CP	6
Workload in Hours	Independent Study Time 180, Study Time in Lecture 0
Lecturer	Dr. Henning Haschke
Language	DE
Cycle	WiSe
Content	**Company onboarding process** • Assigning initial work areas (supervisor, colleagues) • Assigning a contact person within the company (usually the HR department) • Assigning a professional mentor in the work area (relating to practical application) • Responsibilities and authorisations of the dual student within the company • Supporting/working with colleagues • Scheduling the relevant practical modules with initial work tasks • Theory/practice transfer options • Scheduling the examination phase/subsequent study semester **Operational knowledge and skills** • Company-specific: organisational structure, corporate strategy, business and work areas, work procedures and processes, operational levels • Process and procedure options within the labour-market-relevant field of engineering • Operational equipment and resources • Implementing the university’s application recommendations (theory-practice transfer) in corresponding work and task areas across the company **Sharing/reflecting on learning** • Creating an e-portfolio • Relevance of foundational subjects when working as an engineer • Comparing the learning and working processes of different learning environments with regard to their results and effects
Literature	• Studierendenhandbuch • Betriebliche Dokumente • Hochschulseitige Anwendungsempfehlungen zum Theorie-Praxis-Transfer

Module M1755: Linking theory and practice (dual study program, Bachelor's degree)	
Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	none
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students... ... can describe and classify selected classic and modern theories, concepts and methods • related to self-management, and organising work and learning • self-competence and • social skills ... and apply them to specific situations, projects and plans in a personal and professional context.
Skills	Dual students... • ... anticipate typical difficulties, positive and negative effects, as well as success and failure factors in the engineering sector, evaluate them and consider promising strategies and courses of action.
Personal Competence	
Social Competence	Dual students... • ... work together in a problem-oriented and interdisciplinary manner as part of expert and work teams. • ... are able to assemble and lead working groups. • ... present complex, subject-related solutions to problems to experts and stakeholders and can develop these further together.
Autonomy	Dual students... • ... define, reflect and evaluate goals for learning and work processes. • ... design their learning and work processes independently and sustainably at the university and company. • ... take responsibility for their learning and work processes. • ... are able to consciously think through their ideas or actions and relate them to their self-image to develop conclusions for future action based on this.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Studienbegleitende und semesterübergreifende Dokumentation: Die Leistungspunkte für das Modul werden durch die Anfertigung eines digitalen Lern- und Entwicklungsberichtes (E-Portfolio) erworben. Dabei handelt es sich um eine fortlaufende Dokumentation und Reflexion der Lernerfahrungen und der Kompetenzentwicklung im Bereich der Personalen Kompetenz.

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

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

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

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

Module M0727: Stochastics

Courses

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

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

Course L0777: Stochastics	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Matthias Schulte
Language	DE/EN
Cycle	SoSe
Content	• Definitions of probability, conditional probability • Random variables • Independence • Distributions and density functions • Characteristics: expectation, variance, standard deviation, moments • Multivariate distributions • Law of large numbers and central limit theorem • Basic notions of stochastic processes • Basic concepts of statistics (point estimators, confidence intervals, hypothesis testing)
Literature	• L. Dümbgen (2003): Stochastik für Informatiker, Springer. • H.-O. Georgii (2012): Stochastics: Introduction to Probability and Statistics, 2nd edition, De Gruyter. • N. Henze (2018): Stochastik für Einsteiger, 12th edition, Springer. • A. Klenke (2014): Probability Theory: A Comprehensive Course, 2nd edition, Springer. • U. Krengel (2005): Einführung in die Wahrscheinlichkeitstheorie und Statistik, 8th edition, Vieweg. • A.N. Shiryaev (2012): Problems in probability, Springer.

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

Module M1432: Programming Paradigms

Courses

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

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

Course L2169: Programming Paradigms

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

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

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

Module M1729: Mathematics II (EN)

Courses

Title	Typ	Hrs/wk	CP
Mathematics II (EN) (L2979)	Lecture	4	4
Mathematics II (EN) (L2980)	Recitation Section (large)	2	2
Mathematics II (EN) (L2981)	Recitation Section (small)	2	2

Module Responsible	Prof. Daniel Ruprecht
Admission Requirements	None
Recommended Previous Knowledge	School mathematics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can name the basic concepts in analysis and linear algebra. They are able to explain them using appropriate examples. • Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples. • They know proof strategies and can reproduce them.
Skills	• Students can model problems in analysis and linear algebra with the help of the concepts studied in this course. Moreover, they are capable of solving them by applying established methods. • Students are able to discover and verify further logical connections between the concepts studied in the course. • For a given problem, the students can develop and execute a suitable approach, and are able to critically evaluate the results.
Personal Competence	
Social Competence	• Students are able to work together in teams. They are capable to use mathematics as a common language. • In doing so, they can communicate new concepts according to the needs of their cooperating partners. Moreover, they can design examples to check and deepen the understanding of their peers.
Autonomy	• Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them. • Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.
Workload in Hours	Independent Study Time 128, Study Time in Lecture 112
Credit points	8
Course achievement	Compulsory: Yes; Bonus: 10 %; Form: Excercises; Description:
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Engineering Science: Core Qualification: Compulsory

Course L2979: Mathematics II (EN)

Typ	Lecture
Hrs/wk	4
CP	4
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Lecturer	Prof. Anusch Taraz
Language	EN
Cycle	SoSe
Content	
Literature	

Course L2980: Mathematics II (EN)

Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Anusch Taraz
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L2981: Mathematics II (EN)	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Anusch Taraz
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0829: Foundations of Management

Courses

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

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

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

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

Module M1751: Practical module 2 (dual study program, Bachelor's degree)

Courses

Title	Typ	Hrs/wk	CP
Practical term 2 (dual study program, Bachelor's degree) (L2880)		0	6

Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	• Successful completion of practical module 1 as part of the dual Bachelor’s course • course A from the module on interlinking theory and practice as part of the dual Bachelor’s course
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... • ... describe their employer’s organisational structure (company) and differentiate between associated regulations that relate to how tasks and competences are distributed, as well as how work processes are handled. • ... understand the structure and objectives of the dual study programme and the increasing requirements throughout the course of study.
Skills	Dual students ... • ... use equipment and resources professionally in accordance with the assigned work areas and tasks, and assess operational processes and procedures with regard to the intended work results/objectives. • ... implement the university’s application recommendations in relation to their current tasks.
Personal Competence	
Social Competence	Dual students ... • ... have familiarised themselves with their new working environment (learning environment) and the associated tasks/processes/working relationships. • ... know their central points of contact and colleagues, and are integrated into the designated tasks and work areas. • ... coordinate work tasks with their professional supervisor and justify procedures and intended results. • ... help shape the work in the assigned work area and offer their colleagues support to complete their work or ask for support based on their needs. • ... work together with others in interdisciplinary work teams in a result-oriented manner.
Autonomy	Dual students ... • ... structure their work and learning processes within the company independently in line with their responsibilities and authorisations, and coordinate them with their professional supervisor. • ... complete work tasks/assignments independently and/or with the support of colleagues. • ... coordinate the practical phase with any individual preparation required for the examination phase at TUHH. • ... document and reflect on how their foundational subjects link with their work as an engineer.
Workload in Hours	Independent Study Time 180, Study Time in Lecture 0
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Documentation accompanying studies and across semesters: Module credit points are earned by completing a digital learning and development report (e-portfolio). This documents and reflects individual learning experiences and skills development relating to interlinking theory and practice, as well as professional practice. In addition, the partner company provides proof to the dual@TUHH Coordination Office that the dual student has completed the practical phase.
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Core Qualification: Compulsory Civil- and Environmental Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Engineering Science: Core Qualification: Compulsory Green Technologies: Energy, Water, Climate: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Mechanical Engineering: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Naval Architecture: Core Qualification: Compulsory Technomathematics: Core Qualification: Compulsory Engineering and Management - Major in Logistics and Mobility: Core Qualification: Compulsory

Course L2880: Practical term 2 (dual study program, Bachelor's degree)	
Typ	
Hrs/wk	0
CP	6
Workload in Hours	Independent Study Time 180, Study Time in Lecture 0
Lecturer	Dr. Henning Haschke
Language	DE
Cycle	SoSe
Content	**Company onboarding process** • Assigning work areas (supervisor, colleagues) • Assigning a contact person within the company (usually the HR department) • Assigning a professional mentor in the work area (relating to practical application) • Responsibilities and authorisations of the dual student within the company • Supporting/working with colleagues • Scheduling the relevant practical modules with work tasks • Theory/practice transfer options • Scheduling the examination phase/subsequent study semester **Operational knowledge and skills** • Company-specific: organisational structure, corporate strategy, business and work areas, work procedures and processes, operational levels • Process and procedure options within the labour-market-relevant field of engineering • Operational equipment and resources • Implementing the university’s application recommendations (theory-practice transfer) in corresponding work and task areas across the company **Sharing/reflecting on learning** • Creating an e-portfolio • Relevance of foundational subjects when working as an engineer • Comparing the learning and working processes of different learning environments with regard to their results and effects
Literature	• Studierendenhandbuch • Betriebliche Dokumente • Hochschulseitige Anwendungsempfehlungen zum Theorie-Praxis-Transfer

Module M0625: Databases

Courses

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

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

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

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

Module M1592: Statistics

Courses

Title	Typ	Hrs/wk	CP
Statistics (L2430)	Lecture	3	4
Statistics (L2431)	Recitation Section (small)	1	2

Module Responsible	Prof. Matthias Schulte
Admission Requirements	None
Recommended Previous Knowledge	Stochastics (or a comparable class)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can name the basic concepts in Statistics. They are able to explain them using appropriate examples. • Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples.
Skills	• Students can model statistical problems with the help of the concepts studied in this course. Moreover, they are capable of solving them by applying established methods. They are able to use the statistical software R. • Students are able to discover and verify further logical connections between the concepts studied in the course. • For a given problem, the students can develop and execute a suitable approach, and are able to critically evaluate the results.
Personal Competence	
Social Competence	• Students are able to work together (e.g. on their regular home work) in heterogeneously composed teams and to present their results appropriately (e.g. during exercise class). • In doing so, they can communicate new concepts according to the needs of their cooperating partners. Moreover, they can design examples to check and deepen the understanding of their peers.
Autonomy	• Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them. • Students can put their knowledge in relation to the contents of other lectures. • Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Advanced Materials: Elective Compulsory General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory Data Science: Core Qualification: Compulsory Engineering Science: Specialisation Advanced Materials: Elective Compulsory Logistics and Mobility: Specialisation Information Technology: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Engineering and Management - Major in Logistics and Mobility: Specialisation Information Technology: Elective Compulsory

Course L2430: Statistics	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Matthias Schulte
Language	DE/EN
Cycle	WiSe
Content	• Multivariate distributions and stochastic convergence • Point estimators • Confidence intervals • Hypothesis testing • Nonparametric statistics • Linear Regression • Time series analysis • Statistical software (R)
Literature	• L. Dümbgen (2016): Einführung in die Statistik, Birkhäuser. • L. Dümbgen (2003): Stochastik für Informatiker, Springer. • H.-O. Georgii (2012): Stochastics: Introduction to Probability and Statistics, 2nd edition, De Gruyter. • N. Henze (2018): Stochastik für Einsteiger, 12th edition, Springer. • A. Klenke (2014): Probability Theory: A Comprehensive Course, 2nd edition, Springer. • U. Krengel (2005): Einführung in die Wahrscheinlichkeitstheorie und Statistik, 8th edition, Vieweg.

Course L2431: Statistics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Matthias Schulte
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 • basic MATLAB/Python knowledge
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to • name numerical methods for interpolation, integration, least squares problems, eigenvalue problems, nonlinear root finding problems and to explain their core ideas, • repeat convergence statements for the numerical methods, • explain aspects for the practical execution of numerical methods with respect to computational and storage complexitx.
Skills	Students are able to • implement, apply and compare numerical methods using MATLAB/Python, • justify the convergence behaviour of numerical methods with respect to the problem and solution algorithm, • select and execute a suitable solution approach for a given problem.
Personal Competence	
Social Competence	Students are able to • work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge), explain theoretical foundations and support each other with practical aspects regarding the implementation of algorithms.
Autonomy	Students are capable • to assess whether the supporting theoretical and practical excercises are better solved individually or in a team, • to assess their individual progess and, if necessary, to ask questions and seek help.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Compulsory General Engineering Science (German program, 7 semester): Specialisation Biomedical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Theoretical Mechanical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Aircraft Systems Engineering: Elective Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Mechatronics: Elective Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Energy Systems: Elective Compulsory General Engineering Science (German program, 7 semester): Specialisation Advanced Materials: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Materials in Engineering Sciences: Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory Data Science: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Elective Compulsory Engineering Science: Core Qualification: Compulsory Engineering Science: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Mechanical Engineering: Specialisation Theoretical Mechanical Engineering: Compulsory Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course Core Studies: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

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

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

Module M1423: Algorithms and Data Structures

Courses

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

Module Responsible	Prof. Matthias Mnich
Admission Requirements	None
Recommended Previous Knowledge	• Discrete Algebraic Structures • Mathematics I • Mathematics II • Procedual Programming • Objectoriented Programming
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can name the basic concepts in algorithm design, algorithm analysis and problem reductions. They are able to explain them using appropriate examples. • Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples. • They know proof strategies and can reproduce them.
Skills	• Students can model discrete decision, search and optimization problems with the help of the concepts studied in this course. Moreover, they are capable of solving them, and reducing them to each other, by applying established methods. • Students are able to discover and verify further logical connections between the concepts studied in the course. • For a given problem, the students can develop and execute a suitable approach, and are able to critically evaluate the results.
Personal Competence	
Social Competence	• Students are able to work together in teams. They are capable to use mathematics as a common language. • In doing so, they can communicate new concepts according to the needs of their cooperating partners. Moreover, they can design examples to check and deepen the understanding of their peers.
Autonomy	• Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them. • Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Logistics and Mobility: Specialisation Information Technology: Elective Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory Engineering and Management - Major in Logistics and Mobility: Specialisation Information Technology: Elective Compulsory

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

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

Module M1732: Mathematics III (EN)

Courses

Title	Typ	Hrs/wk	CP
Analysis III (EN) (L2790)	Lecture	2	2
Analysis III (EN) (L2791)	Recitation Section (large)	1	1
Analysis III (EN) (L2792)	Recitation Section (small)	1	1
Differential Equations 1 (Ordinary Differential Equations) (EN) (L2793)	Lecture	2	2
Differential Equations 1 (Ordinary Differential Equations) (EN) (L2794)	Recitation Section (large)	1	1
Differential Equations 1 (Ordinary Differential Equations) (EN) (L2795)	Recitation Section (small)	1	1

Module Responsible	Prof. Anusch Taraz
Admission Requirements	None
Recommended Previous Knowledge	Mathematik I and II (EN or DE)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can name the basic concepts in the area of analysis and differential equations. They are able to explain them using appropriate examples. • Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples. • They know proof strategies and can reproduce them.
Skills	• Students can model problems in the area of analysis and differential equations with the help of the concepts studied in this course. Moreover, they are capable of solving them by applying established methods. • Students are able to discover and verify further logical connections between the concepts studied in the course. • For a given problem, the students can develop and execute a suitable approach, and are able to critically evaluate the results.
Personal Competence	
Social Competence	• Students are able to work together in teams. They are capable to use mathematics as a common language. • In doing so, they can communicate new concepts according to the needs of their cooperating partners. Moreover, they can design examples to check and deepen the understanding of their peers.
Autonomy	• Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them. • Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.
Workload in Hours	Independent Study Time 128, Study Time in Lecture 112
Credit points	8
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Engineering Science: Core Qualification: Compulsory

Course L2790: Analysis III (EN)

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	EN
Cycle	WiSe
Content	Main features of differential and integrational calculus of several variables • Differential calculus for several variables • Mean value theorems and Taylor's theorem • Maximum and minimum values • Implicit functions • Minimization under equality constraints • Newton's method for multiple variables • Double integrals over general regions • Line and surface integrals • Theorems of Gauß and Stokes
Literature	http://www.math.uni-hamburg.de/teaching/export/tuhh/index.html

Course L2791: Analysis III (EN)	
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	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L2792: Analysis III (EN)	
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	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L2793: Differential Equations 1 (Ordinary Differential Equations) (EN)	
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	EN
Cycle	WiSe
Content	Main features of the theory and numerical treatment of ordinary differential equations • Introduction and elementary methods • Exsitence and uniqueness of initial value problems • Linear differential equations • Stability and qualitative behaviour of the solution • Boundary value problems and basic concepts of calculus of variations • Eigenvalue problems • Numerical methods for the integration of initial and boundary value problems • Classification of partial differential equations
Literature	• http://www.math.uni-hamburg.de/teaching/export/tuhh/index.html

Course L2794: Differential Equations 1 (Ordinary Differential Equations) (EN)	
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	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L2795: Differential Equations 1 (Ordinary Differential Equations) (EN)	
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	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1752: Practical module 3 (dual study program, Bachelor's degree)

Courses

Title	Typ	Hrs/wk	CP
Practical term 3 (dual study program, Bachelor's degree) (L2881)		0	6

Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	• Successful completion of practical module 2 as part of the dual Bachelor’s course • course B from the module on interlinking theory and practice as part of the dual Bachelor’s course
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... • ... understand the company’s strategic orientation, as well as the functions and organisation of central departments with their decision-making structures, network relationships. • ... understand the requirements of the engineering profession and correctly estimate the resulting responsibility. • ... combine their knowledge of facts, principles, theories and methods gained from previous study content with acquired practical knowledge - in particular their knowledge of practical professional procedures and approaches, in the current field of activity.
Skills	Dual students ... • ... apply technical theoretical knowledge to current problems in their own area of work, and evaluate work processes and results. • ... use technology, equipment and resources in accordance with the assigned work areas and tasks, and assess operational processes and procedures with regard to the intended work results/objectives. • ... implement the university’s application recommendations in relation to their current tasks.
Personal Competence	
Social Competence	Dual students ... • ... plan work processes cooperatively, including across work areas. • ... communicate professionally with operational stakeholders and present complex issues in a structured, targeted and convincing manner.
Autonomy	Dual students ... • ... assume responsibility for work assignments and areas. • ... document and reflect on the relevance of subject modules and specialisations for work as an engineer, as well as the implementation of the university’s application recommendations and the associated challenges of a positive transfer of knowledge between theory and practice.
Workload in Hours	Independent Study Time 180, Study Time in Lecture 0
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Documentation accompanying studies and across semesters: Module credit points are earned by completing a digital learning and development report (e-portfolio). This documents and reflects individual learning experiences and skills development relating to interlinking theory and practice, as well as professional practice. In addition, the partner company provides proof to the dual@TUHH Coordination Office that the dual student has completed the practical phase.
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Core Qualification: Compulsory Civil- and Environmental Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Engineering Science: Core Qualification: Compulsory Green Technologies: Energy, Water, Climate: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Mechanical Engineering: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Naval Architecture: Core Qualification: Compulsory Technomathematics: Core Qualification: Compulsory Engineering and Management - Major in Logistics and Mobility: Core Qualification: Compulsory

Course L2881: Practical term 3 (dual study program, Bachelor's degree)	
Typ	
Hrs/wk	0
CP	6
Workload in Hours	Independent Study Time 180, Study Time in Lecture 0
Lecturer	Dr. Henning Haschke
Language	DE
Cycle	WiSe
Content	**Company onboarding process** • Assigning work area(s) • Extending responsibilities and authorisations of the dual student within the company • Independent work tasks and areas • Participating in project teams • Scheduling the relevant practical modules with work tasks • Theory/practice transfer options • Scheduling the examination phase/subsequent study semester **Operational knowledge and skills** • Company-specific: strategic direction, organisation of central business and work areas, departments, decision-making structures, network relationships and internal communication • Linking facts, principles and theories with practical knowledge • Process and procedure options within the labour-market-relevant field of engineering • Operational technology, equipment and resources • Implementing the university’s application recommendations (theory-practice transfer) in corresponding work and task areas across the company **Sharing/reflecting on learning** • E-portfolio • Relevance of subject modules and specialisations when working as an engineer • University application recommendations for transferring knowledge between theory and practice
Literature	• Studierendenhandbuch • Betriebliche Dokumente • Hochschulseitige Anwendungsempfehlungen zum Theorie-Praxis-Transfer

Module M1595: Machine Learning I

Courses

Title	Typ	Hrs/wk	CP
Machine Learning I (L2432)	Lecture	2	3
Machine Learning I (L2433)	Recitation Section (small)	2	3

Module Responsible	Prof. Nihat Ay
Admission Requirements	None
Recommended Previous Knowledge	Linear Algebra, Analysis, Basic Programming Course
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know • general principles of machine learning learning: supervised/unsupervised learning, generative/descriptive learning, parametric/non-parametric learning • different learning methods: neural networks, support vector machines, clustering, dimensionality reduction, kernel methods • fundamentals of statistical learning theory • advanced techniques such as transfer learning, reinforcement learning, generative adversarial networks and adaptive control
Skills	The students can • apply machine learning methods to concrete problems • select and evaluate suitable methods for specific problems • evaluate the quality of a trained data-driven model • work with known software frameworks for machine learning • adapt the architecture and cost function of neural networks to specific problems • show the limits of machine learning methods
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	Compulsory: No; Bonus: 20 %; 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 Mechanical Engineering, Focus Theoretical Mechanical Engineering: Elective Compulsory Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Data Science: Core Qualification: Compulsory Engineering Science: Specialisation Advanced Materials: Elective Compulsory Engineering Science: Specialisation Mechanical Engineering: Elective Compulsory Engineering Science: Specialisation Mechatronics: Elective Compulsory Logistics and Mobility: Specialisation Information Technology: Elective Compulsory Mechanical Engineering: Specialisation Theoretical Mechanical Engineering: Elective Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory Engineering and Management - Major in Logistics and Mobility: Specialisation Information Technology: Elective Compulsory

Course L2432: Machine Learning I	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Nihat Ay
Language	DE/EN
Cycle	SoSe
Content	• History of neuroscience and machine learning (in particular, the age of deep learning) • McCulloch-Pitts neurons and binary Artificial Neural Networks • Boolean and threshold functions • Universality of McCulloch-Pitts neural networks • Learning and the perceptron convergence theorem • Support vector machines • Harmonic analysis of Boolean functions • Continuous Artificial Neural Networks • Kolmogorov's superposition theorem • Universal approximation with continuous neural networks • Approximation error and the gradient decent method: the general idea • The stochastic gradient decent method (Robbins-Monro and Kiefer-Wolfowitz cases) • Multilayer networks and the backpropagation algorithm • Statistical Learning Theory
Literature	• Martin Anthony and Peter L. Bartlett. Neural Network Learning: Theoretical Foundations. Cambridge University Press, 1999. • Martin Anthony. Discrete Mathematics of Neural Networks: Selected Topics. SIAM Monographs on Discrete Mathematics & Applications, 1987. • Mehryar Mohri, Afshin Rostamizadeh and Ameet Talwalkar. Foundations of Machine Learning, Second Edition. MIT Press, 2018. • Christopher M. Bishop. Pattern Recognition and Machine Learning. Information Science and Statistics. Springer-Verlag, 2008. • Bernhard Schölkopf, Alexander Smola. Learning with Kernels: Support Vector Machines, Regularization, Optimization, and Beyond. Adaptive Computation and Machine Learning series. MIT Press, Cambridge, MA, 2002. • Luc Devroye, László Györfi, Gábor Lugosi. A Probabilistic Theory of Pattern Recognition. Springer, 1996. • Vladimir Vapnik. The Nature of Statistical Learning Theory. Springer-Verlag: New York, Berlin, Heidelberg, 1995.

Course L2433: Machine Learning I	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Nihat Ay
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0672: Signals and Systems

Courses

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

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

Course L0432: Signals and Systems

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

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

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

	• Oppenheim, R. W. Schafer: Discrete-time signal processing. Pearson.

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

Module 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 • 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. • Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples. • They know proof strategies and can reproduce them.
Skills	• Students can model problems in 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. • Students are able to discover and verify further logical connections between the concepts studied in the course. • For a given problem, the students can develop and execute a suitable approach, and are able to critically evaluate the results.
Personal Competence	
Social Competence	• Students are able to work together in teams. They are capable to use mathematics as a common language. • In doing so, they can communicate new concepts according to the needs of their cooperating partners. Moreover, they can design examples to check and deepen the understanding of their peers.
Autonomy	• Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them. • Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Logistics and Mobility: Specialisation Engineering Science: Elective Compulsory Logistics and Mobility: Specialisation Traffic Planning and Systems: Elective Compulsory Logistics and Mobility: Specialisation Information Technology: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Engineering and Management - Major in Logistics and Mobility: Specialisation Traffic Planning and Systems: Elective Compulsory Engineering and Management - Major in Logistics and Mobility: Specialisation Information Technology: 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 • planar graphs • shortest paths • minimum spanning trees • maximum flow and minimum cut • theorems of Menger, König-Egervary, Hall • NP-complete problems • backtracking and heuristics • linear programming • duality • integer linear programming
Literature	• M. Aigner: Diskrete Mathematik, Vieweg, 2004 • T. Cormen, Ch. Leiserson, R. Rivest, C. Stein: Algorithmen - Eine Einführung, Oldenbourg, 2013 • J. Matousek und J. Nesetril: Diskrete Mathematik, Springer, 2007 • A. Steger: Diskrete Strukturen (Band 1), Springer, 2001 • A. Taraz: Diskrete Mathematik, Birkhäuser, 2012 • V. Turau: Algorithmische Graphentheorie, Oldenbourg, 2009 • 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 M1586: Scientific Programming

Courses

Title	Typ	Hrs/wk	CP
Scientific Programming (L2405)	Lecture	3	4
Scientific Programming (L2406)	Recitation Section (small)	2	2

Module Responsible	Prof. Tobias Knopp
Admission Requirements	None
Recommended Previous Knowledge	procedural programming, linear algebra
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students • can efficiently solve scientific problems in a modern programming language. • are familiar with the concept of reproducible science. • can handle multidimensional arrays, sparse arrays, data frames and missing data. They know the advantages and disadvantages of specific data structures. • know various ways of presenting data, data relationships and error measures in a suitable way. They are familiar with known data formats for storing scientific data and can select a suitable format for specific data.
Skills	Students are able • to translate complex problems from a mathematical formulation into a suitable program. • to divide a complex problem into subproblems which can be implemented modularly. • to identify numerical standard problems and to use suitable standard algorithms which are available in libraries. • to write maintainable program code, the correctness of which is verified by suitable tests. • to measure the runtime of programs, to identify bottlenecks and to apply suitable acceleration techniques.
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 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	exercise task, group project with presentation, and written test
Assignment for the Following Curricula	Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Data Science: Core Qualification: Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory

Course L2405: Scientific Programming

Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Tobias Knopp
Language	DE/EN
Cycle	SoSe
Content	• Elementary Data Types and the Relationship to Mathematics • Scientific data types: Multidimensional Arrays, sparse Arrays, Data Frames, Missing Data • Multiple Dispatch as an Efficient Paradigm for Scientific Programming • Literate Programming • Profiling and benchmarks • Acceleration techniques: caching, multi-threading, SIMD, GPGPU • Scientific data formats: CSV, TOML, HDF5, and selected examples • Data visualization • Standard numerical techniques and efficient program libraries (BLAS, LAPACK, FFTW, ...) • Tests, code management, documentation • Reproducible science
Literature	Ben Lauwens, Allen Downey: Think Julia: How to Think Like a Computer Scientist

Course L2406: Scientific Programming	
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	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1578: Seminars Computer Science

Courses

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

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

Course L2362: Introductory Seminar Computer Science I

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dozenten des SD E
Language	DE/EN
Cycle	WiSe/SoSe
Content	
Literature	

Course L2361: Introductory Seminar Computer Science II

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dozenten des SD E
Language	DE/EN
Cycle	WiSe/SoSe
Content	
Literature	

Module M1753: Practical module 4 (dual study program, Bachelor's degree)

Courses

Title	Typ	Hrs/wk	CP
Practical term 4 (dual study program, Bachelor's degree) (L2882)		0	6

Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	• Successful completion of practical module 3 as part of the dual Bachelor's course • course B from the module on interlinking theory and practice as part of the dual Bachelor's course
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... • ... understand the company's strategic orientation, as well as the functions and organisation of central departments with their decision-making structures, network relationships, and relevant company communication. • ... have developed an understanding of the requirements and responsibilities of the engineering profession, know the scope and limits of the professional field of activity. • ... can combine their knowledge of facts, principles, theories and methods gained from previous study content with acquired practical knowledge - in particular their knowledge of practical professional procedures and approaches, in the current field of activity.
Skills	Dual students ... • ... apply technical theoretical knowledge to current problems in their own field of work, and evaluate work processes and results, taking into account different possible courses of action. • ... use technology, equipment and resources in accordance with the assigned work areas and tasks, and can assess operational processes and procedures with regard to the intended work results/objectives. • ... implement the university's application recommendations in relation to their current tasks.
Personal Competence	
Social Competence	Dual students ... • ... are able to plan work processes cooperatively, across work areas and in heterogeneous groups. • ... communicate professionally with operational stakeholders and present complex issues in a structured, targeted and convincing manner.
Autonomy	Dual students ... • ... assume responsibility for work assignments and areas, and coordinate the associated work processes. • ... document and reflect on the relevance of subject modules and specialisations for work as an engineer, as well as the implementation of the university's application recommendations and the associated challenges of a positive transfer of knowledge between theory and practice.
Workload in Hours	Independent Study Time 180, Study Time in Lecture 0
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Documentation accompanying studies and across semesters: Module credit points are earned by completing a digital learning and development report (e-portfolio). This documents and reflects individual learning experiences and skills development relating to interlinking theory and practice, as well as professional practice. In addition, the partner company provides proof to the dual@TUHH Coordination Office that the dual student has completed the practical phase.
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Core Qualification: Compulsory Civil- and Environmental Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Engineering Science: Core Qualification: Compulsory Green Technologies: Energy, Water, Climate: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Mechanical Engineering: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Naval Architecture: Core Qualification: Compulsory Technomathematics: Core Qualification: Compulsory Engineering and Management - Major in Logistics and Mobility: Core Qualification: Compulsory

Course L2882: Practical term 4 (dual study program, Bachelor's degree)	
Typ	
Hrs/wk	0
CP	6
Workload in Hours	Independent Study Time 180, Study Time in Lecture 0
Lecturer	Dr. Henning Haschke
Language	DE
Cycle	SoSe
Content	**Company onboarding process** • Assigning work area(s) • Extending responsibilities and authorisations of the dual student within the company • Independent work tasks and areas • Participating in project teams • Scheduling the relevant practical module • Theory/practice transfer options • Scheduling the examination phase/subsequent study semester **Operational knowledge and skills** • Company-specific: strategic direction, organisation of central business and work areas, departments, decision-making structures, network relationships and internal communication • Linking facts, principles and theories with practical knowledge • Process and procedure options within the labour-market-relevant field of engineering • Operational technology, equipment and resources • Implementing the university’s application recommendations (theory-practice transfer) in corresponding work and task areas across the company **Sharing/reflecting on learning** • E-portfolio • Relevance of subject modules and specialisations when working as an engineer • University application recommendations for transferring knowledge between theory and practice
Literature	• Studierendenhandbuch • Betriebliche Dokumente • Hochschulseitige Anwendungsempfehlungen zum Theorie-Praxis-Transfer

Module M0953: Introduction to Information Security

Courses

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

Module Responsible	Prof. Riccardo Scandariato
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 • name the main security risks when using Information and Communication Systems and name the fundamental security mechanisms, • describe commonly used methods for risk and security analysis, • name the fundamental principles of data protection.
Skills	Students can • evaluate the strenghts and weaknesses of the fundamental security mechanisms and of the commonly used methods for risk and security analysis, • 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 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 minutes
Assignment for the Following Curricula	Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Data Science: Core Qualification: Compulsory

Course L1114: Introduction to Information Security

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Riccardo Scandariato
Language	EN
Cycle	WiSe
Content	• Fundamental concepts • Passwords & biometrics • Introduction to cryptography • Sessions, SSL/TLS • Certificates, electronic signatures • Public key infrastructures • Side-channel analysis • Access control • Privacy • Software security basics • Security management & risk analysis • Security evaluation: Common Criteria
Literature	D. Gollmann: Computer Security, Wiley & Sons, third edition, 2011 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. Riccardo Scandariato
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1594: Machine Learning II

Courses

Title	Typ	Hrs/wk	CP
Machine Learning II (L2436)	Lecture	2	3
Machine Learning II (L2941)	Recitation Section (small)	2	3

Module Responsible	Prof. Nihat Ay
Admission Requirements	None
Recommended Previous Knowledge	Successful participation in the modules: • Scientific Programming • Algorithms and Data Structures • Machine Learning
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students get to know tools used by development teams to • plan development flows, • mine, process and analyze data • train and validate data-orientated models • follow good practice in software engineering
Skills	Students work in teams on a larger data project. The required competences are learned and practically applied. These are for example: • project specification based on user requirements • creating a data-orientated software architecture • mining, preprocessing and analyzing larger datasets • implementing a learning platform in a team • comparison of different learning methods • performing statistical tests
Personal Competence	
Social Competence	Team work has its own challenges with respect to interaction of team members as well as finding the necessary agreement during joint software development. During the project students learn the required competences and experience the practical needs.
Autonomy	During team work it is mandatory to take and explain a certain position, to independently complete assigned tasks, and to present results to the team. Open issues must be identified and returned into the team to find an agreed resolution.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** No / 20 % / Excercises
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Data Science: Core Qualification: Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory

Course L2436: Machine Learning II	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Nihat Ay
Language	DE/EN
Cycle	WiSe
Content	• Supervised statistical learning and generalisation • The empirical risk minimisation principle • The law of large numbers and the Glivenko-Cantellit heorem • Shatter coefficients, VC dimension, and Rademacher complexity • Fast convergence theorem of Vapnik and Chervonenkis • VC dimensions of discrete neural networks • The structural risk minimisation principle • Learning from samples as an inverse problem • Reproducing kernel Hilbert space • Moore-Penrose inverse • Ill-posed inverse problems and regularisation • Tikhonov regularisation • Regularised empirical risk minimisation • covering numbers • The bias variance problem
Literature	• Martin Anthony and Peter L. Bartlett. Neural Network Learning: Theoretical Foundations. Cambridge University Press, 1999. • Martin Anthony. Discrete Mathematics of Neural Networks: Selected Topics. SIAM Monographs on Discrete Mathematics & Applications, 1987. • Mehryar Mohri, Afshin Rostamizadeh and Ameet Talwalkar. Foundations of Machine Learning, Second Edition. MIT Press, 2018. • Christopher M. Bishop. Pattern Recognition and Machine Learning. Information Science and Statistics. Springer-Verlag, 2008. • Bernhard Schölkopf, Alexander Smola. Learning with Kernels: Support Vector Machines, Regularization, Optimization, and Beyond. Adaptive Computation and Machine Learning series. MIT Press, Cambridge, MA, 2002. • Luc Devroye, László Györfi, Gábor Lugosi. A Probabilistic Theory of Pattern Recognition. Springer, 1996. • Vladimir Vapnik. The Nature of Statistical Learning Theory. Springer-Verlag: New York, Berlin, Heidelberg, 1995.

Course L2941: Machine Learning II	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Nihat Ay
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1593: Data Mining

Courses

Title	Typ	Hrs/wk	CP
Data Mining (L2434)	Lecture	2	3
Data Mining (L2435)	Project-/problem-based Learning	2	3

Module Responsible	Prof. Stefan Schulte
Admission Requirements	None
Recommended Previous Knowledge	• Databases • Machine learning
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After successful completion of the course, students know: • Basic concepts for data preparation • Similarity and distance measures • Methods to mine data patterns • Procedures to analyse clusters • Approaches to identify outliers • Data mining for different types of data, e.g., data streams, text data, time series data
Skills	Students are able to analyze large, heterogeneous volumes of data. They know methods and their application to recognize patterns in data sets and data clusters. The students are able to apply the studied methods in different domains, e.g., for data streams, text data, or time series data.
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	**Compulsory** Yes; **Bonus** 20 %; **Form** Subject theoretical and practical work; **Description** Praktische Arbeiten zu bestimmten Themen aus dem Bereich Data Mining
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Data Science: Core Qualification: Compulsory Logistics and Mobility: Specialisation Information Technology: Elective Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory Engineering and Management - Major in Logistics and Mobility: Specialisation Information Technology: Elective Compulsory

Course L2434: Data Mining

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Stefan Schulte
Language	EN
Cycle	WiSe
Content	• Data preparation • Similarity and distance measures • Pattern mining • Cluster analysis • Outliers detection • Data mining for different types of data, e.g., data streams, text data, time series data
Literature	Charu C. Aggarwal: Text Mining - The Textbook, Springer, 2015. Available at https://link.springer.com/book/10.1007/978-3-319-14142-8

Course L2435: Data Mining	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Stefan Schulte
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1754: Practical module 5 (dual study program, Bachelor's degree)

Courses

Title	Typ	Hrs/wk	CP
Practical term 5 (dual study program, Bachelor's degree) (L2883)		0	6

Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	• Successful completion of practical module 4 as part of the dual Bachelor’s course • course C from the module on interlinking theory and practice as part of the dual Bachelor’s course
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... • ... combine their knowledge of facts, principles, theories and methods gained from previous study content with acquired practical knowledge - in particular their knowledge of practical professional procedures and approaches, in the current field of activity. • ... have a critical understanding of the practical applications of their engineering subject.
Skills	Dual students ... • ... apply technical theoretical knowledge to complex, interdisciplinary problems within the company, and evaluate the associated work processes and results, taking into account different possible courses of action. • ... implement the university’s application recommendations with regard to their current tasks. • ... develop new solutions as well as procedures and approaches in their field of activity and area of responsibility - including in the case of frequently changing requirements (systemic skills). • ... are able to analyse and evaluate operational issues using academic methods.
Personal Competence	
Social Competence	Dual students ... • ... work responsibly in operational project teams and proactively deal with problems within their team. • ... represent complex engineering viewpoints, facts, problems and solution approaches in discussions with internal and external stakeholders and develop these further together.
Autonomy	Dual students ... • ... define goals for their own learning and working processes as engineers. • ... document and reflect on learning and work processes in their area of responsibility. • ... document and reflect on the relevance of subject modules, specialisations and research for work as an engineer, as well as the implementation of the university’s application recommendations and the associated challenges of a positive transfer of knowledge between theory and practice.
Workload in Hours	Independent Study Time 180, Study Time in Lecture 0
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Documentation accompanying studies and across semesters: Module credit points are earned by completing a digital learning and development report (e-portfolio). This documents and reflects individual learning experiences and skills development relating to interlinking theory and practice, as well as professional practice. In addition, the partner company provides proof to the dual@TUHH Coordination Office that the dual student has completed the practical phase.
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Core Qualification: Compulsory Civil- and Environmental Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Engineering Science: Core Qualification: Compulsory Green Technologies: Energy, Water, Climate: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Mechanical Engineering: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Naval Architecture: Core Qualification: Compulsory Technomathematics: Core Qualification: Compulsory Engineering and Management - Major in Logistics and Mobility: Core Qualification: Compulsory

Course L2883: Practical term 5 (dual study program, Bachelor's degree)	
Typ	
Hrs/wk	0
CP	6
Workload in Hours	Independent Study Time 180, Study Time in Lecture 0
Lecturer	Dr. Henning Haschke
Language	DE
Cycle	WiSe
Content	**Company onboarding process** • Assigning a future professional field of activity as an engineer (B.Sc.) and associated areas of work • Extending responsibilities and authorisations of the dual student within the company up to the intended first assignment after completing their studies or to the assignment completed during the subsequent dual Master's course • Taking personal responsibility within a team - in their own area of responsibility and across departments • Scheduling the final practical module with a clear correlation to work structures • Internal agreement on a potential topic for the Bachelor's dissertation • Planning the Bachelor's dissertation within the company in cooperation with TU Hamburg • Scheduling the examination phase/sixth study semester **Operational knowledge and skills** • Company-specific: dealing with change, team development, responsibility as an engineer in their own future field of work (B.Sc.), dealing with complex contexts and unresolved problems, developing and implementing innovative solutions • Specialising in one field of work (final dissertation) • Systemic skills • Implementing the university's application recommendations (theory-practice transfer) in corresponding work and task areas across the company **Sharing/reflecting on learning** • E-portfolio • Relevance of subject modules and specialisations when working as an engineer • Importance of research and innovation when working as an engineer • University application recommendations for transferring knowledge between theory and practice
Literature	• Studierendenhandbuch • Betriebliche Dokumente • Hochschulseitige Anwendungsempfehlungen zum Theorie-Praxis-Transfer

Module M1620: Ethics in Information Technology

Courses

Title	Typ	Hrs/wk	CP
Ethics in Information Technology (L2450)	Lecture	2	3
Ethics in Information Technology (L2451)	Seminar	2	3

Module Responsible	NN
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence *Knowledge* *Skills* **Personal Competence** *Social Competence* *Autonomy*	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	-
Assignment for the Following Curricula	Data Science: Core Qualification: Compulsory

Course L2450: Ethics in Information Technology

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	NN
Language	DE/EN
Cycle	SoSe
Content	
Literature	Wird zu Beginn der Lehrveranstaltung bekannt gegeben.

Course L2451: Ethics in Information Technology

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	NN
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Specialization I. Mathematics/Computer Science

Module M0834: Computernetworks and Internet Security

Courses

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

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

Course L1098: Computer Networks and Internet Security	
Typ	Lecture
Hrs/wk	3
CP	5
Workload in Hours	Independent Study Time 108, Study Time in Lecture 42
Lecturer	Prof. Andreas Timm-Giel, Prof. Dieter Gollmann, Dr.-Ing. Koojana Kuladinithi
Language	EN
Cycle	WiSe
Content	In this class an introduction to computer networks with focus on the Internet and its security is given. Basic functionality of complex protocols are introduced. Students learn to understand these and identify common principles. In the exercises these basic principles and an introduction to performance modelling are addressed using computing tasks and (virtual) labs. In the second part of the lecture an introduction to Internet security is given. This class comprises: • Application layer protocols (HTTP, FTP, DNS) • Transport layer protocols (TCP, UDP) • Network Layer (Internet Protocol, routing in the Internet) • Data link layer with media access at the example of Ethernet • Multimedia applications in the Internet • Network management • Internet security: IPSec • Internet security: Firewalls
Literature	• Kurose, Ross, Computer Networking - A Top-Down Approach, 6th Edition, Addison-Wesley • Kurose, Ross, Computernetzwerke - Der Top-Down-Ansatz, Pearson Studium; Auflage: 6. Auflage • W. Stallings: Cryptography and Network Security: Principles and Practice, 6th edition Further literature is announced at the beginning of the lecture.

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

Module 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 Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Elective Compulsory Data Science: Specialisation I. Mathematics/Computer Science: Elective Compulsory Engineering Science: Specialisation Mechatronics: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechatronics: Elective Compulsory Computer Science in Engineering: Specialisation I. Computer Science: Elective Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory

Course L0624: Functional Programming

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

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

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

Module M0941: Combinatorial Structures and Algorithms

Courses

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

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

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

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

Module M0675: Introduction to Communications and Random Processes

Courses

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

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

Course L0442: Introduction to Communications and Random Processes

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

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

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

	▪ Delta modulation • Fundamentals of information theory and coding ◦ Definitions of information: Self-information, entropy ◦ Binary entropy function ◦ Source coding theorem ◦ Source coding: Huffman code ◦ Mutual information and channel capacity ◦ Channel capacity of the AWGN channel and the binary input AWGN channel ◦ Channel coding theorem ◦ Principles of channel coding: Code rate and data rate, Hamming distance, minimum Hamming distance, error detection and error correction ◦ Examples for channel codes: Block codes and convolutional codes, repetition code, single parity check code, Hamming code, Turbo codes • Combinatorics ◦ Variation with and without repetition ◦ Combination with and without repetition ◦ Permutation, Permutation of multisets ◦ Word error probabilities of linear block codes • Baseband transmission ◦ Pulse shaping: Non-return to zero (NRZ) rectangular pulses, Manchester pulses, raised-cosine pulses, square-root raised-cosine pulses, Gaussian pulses ◦ Transmit signal energy, average energy per symbol ◦ Power spectral density (psd) of baseband signals ◦ Definitions of signal bandwidth ◦ Bandwidth efficiency ◦ Intersymbol interference (ISI) ◦ First and second Nyquist criterion ◦ Eye patterns ◦ Receive filter design: Matched filter ◦ Matched-filter receiver and correlation receiver ◦ Square-root Nyquist pulse shaping ◦ Discrete-time AWGN channel model • Maximum a posteriori probability (MAP) and maximum likelihood (ML) detection • Bit error probability in AWGN channels for binary antipodal and on-off signaling • Band-pass transmission via carrier modulation ◦ Amplitude modulation, frequency modulation, phase modulation ◦ Linear digital modulation methods: On-off keying (OOK), phase-shift keying (PSK), amplitude shift keying (ASK), quadrature amplitude shift keying (QAM) •
Literature	K. Kammeyer: Nachrichtenübertragung, Teubner P.A. Höher: Grundlagen der digitalen Informationsübertragung, Teubner. M. Bossert: Einführung in die Nachrichtentechnik, Oldenbourg. J.G. Proakis, M. Salehi: Grundlagen der Kommunikationstechnik. Pearson Studium. J.G. Proakis, M. Salehi: Digital Communications. McGraw-Hill. S. Haykin: Communication Systems. Wiley J.G. Proakis, M. Salehi: Communication Systems Engineering. Prentice-Hall. J.G. Proakis, M. Salehi, G. Bauch, Contemporary Communication Systems. Cengage Learning.

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

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

Module M0730: Computer Engineering

Courses

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

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

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

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

Module M1615: Introduction to Data Acquisition and Processing

Courses

Title	Typ	Hrs/wk	CP
Data Acquisition and Data Processing (L2445)	Project Seminar	2	2
Measurements: Methods and Data Processing (L0779)	Lecture	2	3
Measurements: Methods and Data Processing (L0780)	Recitation Section (small)	1	1

Module Responsible	Prof. Alexander Schlaefer
Admission Requirements	None
Recommended Previous Knowledge	principles of mathematics sound programming skills basic principles of electrical engineering / physics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to explain the purpose of metrology and the acquisition and processing of measurements. They can detail aspects of probability theory and errors, and explain the processing of stochastic signals. Students know methods to digitalize and describe measured signals. Data processing from acquisition to regression and classification can be described in context.
Skills	The students are able to evaluate problems of metrology and to apply methods for describing and processing of measurements.
Personal Competence	
Social Competence	The students solve problems in small groups. An actual problem including data acquisition and data processing is solved in groups.
Autonomy	The students can reflect their knowledge and discuss and evaluate their results.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / None / Presentation Yes / 10 % / Excercises
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Data Science: Core Qualification: Elective Compulsory Data Science: Specialisation I. Mathematics/Computer Science: Elective Compulsory

Course L2445: Data Acquisition and Data Processing

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	WiSe
Content	Within an actual project setting, relevant tasks in data acquisition and data processing willbe discussed, including - data acquisition (e.g., image data, sensor data) - data pre-processing (e.g., filtering) - data analysis (e.g., solving regressing and classification tasks using machine learning methods) - evaluation and interpretation of the results
Literature	Puente León, Kiencke: Messtechnik, Springer 2012 Lerch: Elektrische Messtechnik, Springer 2012 Weitere Literatur wird in der Veranstaltung bekanntgegeben.

Course L0779: Measurements: Methods and Data Processing	
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	WiSe
Content	introduction, systems and errors in metrology, probability theory, measuring stochastic signals, describing measurements, acquisition of analog signals, applied metrology
Literature	Puente León, Kiencke: Messtechnik, Springer 2012 Lerch: Elektrische Messtechnik, Springer 2012 Weitere Literatur wird in der Veranstaltung bekanntgegeben.

Course L0780: Measurements: Methods and Data Processing	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Alexander Schlaefer
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1598: Image Processing

Courses

Title	Typ	Hrs/wk	CP
Image Processing (L2443)	Lecture	2	4
Image Processing (L2444)	Recitation Section (small)	2	2

Module Responsible	Prof. Tobias Knopp
Admission Requirements	None
Recommended Previous Knowledge	Signal and Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know about • visual perception • multidimensional signal processing • sampling and sampling theorem • filtering • image enhancement • edge detection • multi-resolution procedures: Gauss and Laplace pyramid, wavelets • image compression • image segmentation • morphological image processing
Skills	The students can • analyze, process, and improve multidimensional image data • implement simple compression algorithms • design custom filters for specific applications
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	Data Science: Core Qualification: Elective Compulsory Data Science: Specialisation I. Mathematics/Computer Science: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L2443: Image Processing	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Tobias Knopp
Language	DE/EN
Cycle	WiSe
Content	• Visual perception • Multidimensional signal processing • Sampling and sampling theorem • Filtering • Image enhancement • Edge detection • Multi-resolution procedures: Gauss and Laplace pyramid, wavelets • Image Compression • Segmentation • Morphological image processing
Literature	Bredies/Lorenz, Mathematische Bildverarbeitung, Vieweg, 2011 Pratt, Digital Image Processing, Wiley, 2001 Bernd Jähne: Digitale Bildverarbeitung - Springer, Berlin 2005

Course L2444: Image Processing	
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	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0562: Computability and Complexity Theory

Courses

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

Module Responsible	NN
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 Computer Science: Core Qualification: Compulsory Data Science: Core Qualification: Elective Compulsory Data Science: Specialisation I. Mathematics/Computer Science: Elective Compulsory Computer Science in Engineering: Specialisation I. Computer Science: Elective Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory

Course L0166: Computability and Complexity Theory

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	NN
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	NN
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 • Programming experience in C
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can • list classical and modern iteration methods and their interrelationships, • repeat convergence statements for iterative methods, • explain aspects regarding the efficient implementation of iteration methods.
Skills	Students are able to • analyse, implement, test, and compare iterative methods, • analyse the convergence behaviour of iterative methods and, if applicable, compute congergence rates.
Personal Competence	
Social Competence	Students are able to • work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge), explain theoretical foundations and support each other with practical aspects regarding the implementation of algorithms.
Autonomy	Students are capable • to assess whether the supporting theoretical and practical excercises are better solved individually or in a team, • to work on complex problems over an extended period of time, • to assess their individual progess and, if necessary, to ask questions and seek help.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory Data Science: Core Qualification: Elective Compulsory Data Science: Specialisation I. Mathematics/Computer Science: Elective Compulsory Computer Science in Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory

Course L0583: Solvers for Sparse Linear Systems

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

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

Module M1730: Mathematics IV (EN)

Courses

Title	Typ	Hrs/wk	CP
Differential Equations 2 (Partial Differential Equations) (EN) (L2783)	Lecture	2	1
Differential Equations 2 (Partial Differential Equations) (EN) (L2784)	Recitation Section (large)	1	1
Differential Equations 2 (Partial Differential Equations) (EN) (L2785)	Recitation Section (small)	1	1
Complex Functions (EN) (L2786)	Lecture	2	1
Complex Functions (EN) (L2787)	Recitation Section (large)	1	1
Complex Functions (EN) (L2788)	Recitation Section (small)	1	1

Module Responsible	Prof. Anusch Taraz
Admission Requirements	None
Recommended Previous Knowledge	Mathematics I - III (EN or DE)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can name the basic concepts in Mathematics IV. They are able to explain them using appropriate examples. • Students can discuss logical connections between these concepts. They are capable of illustrating these connections with the help of examples. • They know proof strategies and can reproduce them.
Skills	• Students can model problems in Mathematics IV with the help of the concepts studied in this course. Moreover, they are capable of solving them by applying established methods. • Students are able to discover and verify further logical connections between the concepts studied in the course. • For a given problem, the students can develop and execute a suitable approach, and are able to critically evaluate the results.
Personal Competence	
Social Competence	• Students are able to work together in teams. They are capable to use mathematics as a common language. • In doing so, they can communicate new concepts according to the needs of their cooperating partners. Moreover, they can design examples to check and deepen the understanding of their peers.
Autonomy	• Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them. • Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.
Workload in Hours	Independent Study Time 68, Study Time in Lecture 112
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Advanced Materials: Compulsory Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory Data Science: Core Qualification: Elective Compulsory Data Science: Specialisation I. Mathematics/Computer Science: Elective Compulsory Engineering Science: Specialisation Electrical Engineering: Compulsory Engineering Science: Core Qualification: Compulsory Engineering Science: Core Qualification: Compulsory Engineering Science: Specialisation Mechatronics: Elective Compulsory

Course L2783: Differential Equations 2 (Partial Differential Equations) (EN)	
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	EN
Cycle	SoSe
Content	Main features of the theory and numerical treatment of partial differential equations • Examples of partial differential equations • First order quasilinear differential equations • Normal forms of second order differential equations • Harmonic functions and maximum principle • Maximum principle for the heat equation • Wave equation • Liouville's formula • Special functions • Difference methods • Finite elements
Literature	http://www.math.uni-hamburg.de/teaching/export/tuhh/index.html

Course L2784: Differential Equations 2 (Partial Differential Equations) (EN)	
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	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L2785: Differential Equations 2 (Partial Differential Equations) (EN)	
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	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L2786: Complex Functions (EN)	
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	EN
Cycle	SoSe
Content	Main features of complex analysis • Functions of one complex variable • Complex differentiation • Conformal mappings • Complex integration • Cauchy's integral theorem • Cauchy's integral formula • Taylor and Laurent series expansion • Singularities and residuals • Integral transformations: Fourier and Laplace transformation
Literature	http://www.math.uni-hamburg.de/teaching/export/tuhh/index.html

Course L2787: Complex Functions (EN)	
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	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L2788: Complex Functions (EN)	
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	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0732: Software Engineering

Courses

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

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

Course L0627: Software Engineering

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

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

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

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

Specialization II. Application

Module M0933: Fundamentals of Materials Science

Courses

Title	Typ	Hrs/wk	CP
Fundamentals of Materials Science I (L1085)	Lecture	2	2
Fundamentals of Materials Science II (Advanced Ceramic Materials, Polymers and Composites) (L0506)	Lecture	2	2
Physical and Chemical Basics of Materials Science (L1095)	Lecture	2	2

Module Responsible	Prof. Jörg Weißmüller
Admission Requirements	None
Recommended Previous Knowledge	Highschool-level physics, chemistry und mathematics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students have acquired a fundamental knowledge on metals, ceramics and polymers and can describe this knowledge comprehensively. Fundamental knowledge here means specifically the issues of atomic structure, microstructure, phase diagrams, phase transformations, corrosion and mechanical properties. The students know about the key aspects of characterization methods for materials and can identify relevant approaches for characterizing specific properties. They are able to trace materials phenomena back to the underlying physical and chemical laws of nature.
Skills	The students are able to trace materials phenomena back to the underlying physical and chemical laws of nature. Materials phenomena here refers to mechanical properties such as strength, ductility, and stiffness, chemical properties such as corrosion resistance, and to phase transformations such as solidification, precipitation, or melting. The students can explain the relation between processing conditions and the materials microstructure, and they can account for the impact of microstructure on the material's behavior.
Personal Competence	
Social Competence	-
Autonomy	-
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	180 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Biomedical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Naval Architecture: Compulsory General Engineering Science (German program, 7 semester): Specialisation Advanced Materials: Compulsory Data Science: Specialisation II. Application: Elective Compulsory Digital Mechanical Engineering: Core Qualification: Compulsory Green Technologies: Energy, Water, Climate: Specialisation Energy Technology: Elective Compulsory Logistics and Mobility: Specialisation Engineering Science: Elective Compulsory Logistics and Mobility: Specialisation Production Management and Processes: Elective Compulsory Mechanical Engineering: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Naval Architecture: Core Qualification: Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Engineering and Management - Major in Logistics and Mobility: Specialisation Production Management and Processes: Elective Compulsory

Course L1085: Fundamentals of Materials Science I	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Jörg Weißmüller
Language	DE
Cycle	WiSe
Content	
Literature	Vorlesungsskript W.D. Callister: Materials Science and Engineering - An Introduction. 5th ed., John Wiley & Sons, Inc., New York, 2000, ISBN 0-471-32013-7 P. Haasen: Physikalische Metallkunde. Springer 1994

Course L0506: Fundamentals of Materials Science II (Advanced Ceramic Materials, Polymers and Composites)	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Bodo Fiedler, Prof. Gerold Schneider
Language	DE
Cycle	SoSe
Content	Chemische Bindungen und Aufbau von Festkörpern; Kristallaufbau; Werkstoffprüfung; Schweißbarkeit; Herstellung von Keramiken; Aufbau und Eigenschaften der Keramik; Herstellung, Aufbau und Eigenschaften von Gläsern; Polymerwerkstoffe, Makromolekularer Aufbau; Struktur und Eigenschaften der Polymere; Polymerverarbeitung; Verbundwerkstoffe
Literature	Vorlesungsskript W.D. Callister: Materials Science and Engineering -An Introduction-5th ed., John Wiley & Sons, Inc., New York, 2000, ISBN 0-471-32013-7

Course L1095: Physical and Chemical Basics of Materials Science	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Gregor Vonbun-Feldbauer
Language	DE
Cycle	WiSe
Content	• Motivation: „Atoms in Mechanical Engineering?“ • Basics: Force and Energy • The electromagnetic Interaction • „Detour“: Mathematics (complex e-funktion etc.) • The atom: Bohr's model of the atom • Chemical bounds • The multi part problem: Solutions and strategies • Descriptions of using statistical thermodynamics • Elastic theory of atoms • Consequences of atomar properties on makroskopic Properties: Discussion of examples (metals, semiconductors, hybrid systems)
Literature	Für den **Elektromagnetismus:** • Bergmann-Schäfer: „Lehrbuch der Experimentalphysik“, Band 2: „Elektromagnetismus“, de Gruyter Für die **Atomphysik:** • Haken, Wolf: „Atom- und Quantenphysik“, Springer Für die **Materialphysik und Elastizität:** • Hornbogen, Warlimont: „Metallkunde“, Springer

Module M1802: Engineering Mechanics I (Stereostatics)

Courses

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

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

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

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

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

Module M0833: Introduction to Control Systems

Courses

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

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

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

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

Module M0634: Introduction into Medical Technology and Systems

Courses

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

Module Responsible	Prof. Alexander Schlaefer
Admission Requirements	None
Recommended Previous Knowledge	principles of math (algebra, analysis/calculus) principles of stochastics principles of programming, R/Matlab
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can explain principles of medical technology, including imaging systems, computer aided surgery, and medical information systems. They are able to give an overview of regulatory affairs and standards in medical technology.
Skills	The students are able to evaluate systems and medical devices in the context of clinical applications.
Personal Competence	
Social Competence	The students describe a problem in medical technology as a project, and define tasks that are solved in a joint effort. The students can critically reflect on the results of other groups and make constructive suggestions for improvement.
Autonomy	The students can assess their level of knowledge and document their work results. They can critically evaluate the results achieved and present them in an appropriate manner.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / 10 % / Written elaboration Yes / 10 % / 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 Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory Data Science: Specialisation II. Application: Elective Compulsory Data Science: Core Qualification: Elective Compulsory Electrical Engineering: Core Qualification: Elective Compulsory Engineering Science: Specialisation Biomedical Engineering: Compulsory General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: Compulsory Computer Science in Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory

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

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

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

Module M1519: Introduction to Electrical Engineering (Technomathematics)

Courses

Title	Typ	Hrs/wk	CP
Introduction to Electrical Engineering (Technomathematics) (L2292)	Lecture	3	4
Introduction to Electrical Engineering (Technomathematics) (L2293)	Recitation Section (small)	2	2

Module Responsible	Prof. Christian Kautz
Admission Requirements	None
Recommended Previous Knowledge	Knowledge in Physics (upper-level secondary school)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students know and understand the basic concepts and relationships for electric circuits (DC and AC) and apply these to simple example systems. • Students know and understand the basic concepts and relationships for electric and magnetic interactions and apply these to simple example systems.
Skills	• Students use different representations for the description of electrical systems (circuits and fields) and explain their representation in mathematical form. They describe typical patterns and compare and contrast those. • Students calculate physical quantities on the basis of given data.
Personal Competence	
Social Competence	• Students work in teams, describe technical circumstances and carry out professional discussions.
Autonomy	• Students use recommended texts to study technical content on their own and critically examine their own understanding of the material
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	online exercises, short presentation, presence exercise, short oral exam
Assignment for the Following Curricula	Data Science: Specialisation II. Application: Elective Compulsory Technomathematics: Core Qualification: Compulsory

Course L2292: Introduction to Electrical Engineering (Technomathematics)

Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Christian Kautz
Language	DE
Cycle	SoSe
Content	• Electric charge, current, resistance, voltage, potential and power • Kirchhoff's laws and Ohm's law • Equivalent sources and load lines • Circuit elements in AC systems • complex-valued signals and phase relationships • Gauss' law of electrostatics and capacitance • Magnetic interactions and induction • Energy transport and electromagnetic waves
Literature	• **W. Nerreter**, Grundlagen der Elektrotechnik, 3. Auflage, 2020. (Online unter: https://www.hanser-elibrary.com/isbn/9783446465855 - aus dem Netz der TUHH oder über VPN) • **M. Albach**, Elektrotechnik, 2. Auflage, 2020. (Online unter: https://elibrary.pearson.de/book/view/99.150005/9783863268947? - aus dem Netz der TUHH oder über VPN)

Course L2293: Introduction to Electrical Engineering (Technomathematics)	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Christian Kautz
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1004: Logistics Management

Courses

Title	Typ	Hrs/wk	CP
Introduction into Production Logistics (L1222)	Lecture	2	2
Logistics Economics (L1221)	Project-/problem-based Learning	3	4

Module Responsible	Dr. Meike Schröder
Admission Requirements	None
Recommended Previous Knowledge	Introduction to Business and Management
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students will be able • to differentiate between production logistics and logistics services, • to describe internal and external areas of production and logistics management, • understand the difference between the different roles in a supply chain, • to describe and explain the actual challenges of production and Logistics management
Skills	Based on the acquired knowledge students are capable of • Analysing logistics problems and influence factors in companies, • Selecting appropriate methods for solving practical problems, • Applying methods and tools of logistics management for standardized problems.
Personal Competence	
Social Competence	Students can • actively participate in discussions and team sessions, • arrive at work results in groups and document them, • develop joint solutions in mixed teams and present them to others.
Autonomy	Students are able to - perform work steps for solving problems of business logistics independently with the aid of pointers - assess their own state of learning in specific terms and to define further work steps on this basis guided by teachers.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** **Bonus** **Form** **Description** No 20 % Subject theoretical and practical work
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Data Science: Specialisation II. Application: Elective Compulsory Logistics and Mobility: Core Qualification: Compulsory Orientation Studies: Core Qualification: Elective Compulsory Engineering and Management - Major in Logistics and Mobility: Core Qualification: Compulsory

Course L1222: Introduction into Production Logistics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Yong Lee
Language	DE
Cycle	SoSe
Content	In the era of time-competition production and logistics need to be considered as a combined strategic competitive advantage. "Introduction in to production logistics" gives an overview over the different disciplinces of production logistics: - Development from cost-, quality to time-competitiion, - fundamentals of production and logistics, - phase-oriented and functional subsystems of production logistics, - planning and steering, - analysis and optimization (focus: Lean Management), - production logistics controlling and supply-chain management in production network Theory is complented by case studies and guest presentations.
Literature	• Der Vorlesung zugrunde liegende Literatur (Auswahl): - Beer, Stafford (1988): Diagnosing the system for organizations. John Wiley & Sons. Chichester, New York, Brisbane, Toronto 1988. - Ferdows, Kasra; De Meyer, Arnoud (1990): Lasting Improvements in Manufacturing Performance In Search of a New Theory. In: Journal of Operations Management, Vol. 9 (2), 1990, S. 365-384. - Gudehus, Timm (2010): Logistik. Grundlagen - Strategien - Anwendungen. 4. aktual. Aufl. Springer Verlag. Heidelberg/Berlin 2010. - Günther, Hans-Otto/Tempelmeier, Horst (2012): Produktion und Logistik. 9., akt. u. erw. Aufl. Springer Verlag. Berlin/Heidelberg 2012. - Hayes, Robert H.; Schmenner, Roger (1978): How Should You Organize Ma-nufacturing?. In: Harvard Business Review, Vol. 56 (1), 1978, S. 105-118. - Krafcik, John F. (1988): Triumph of the lean production system. In: Sloan Management Review, Vol. 30 (1), S. 41-52. - Maskell, Brian H. (1989a): Performance Measurement for World Class Manufacturing. Part I. Manufacturing Systems, Vol. 7, 1989, S. 62-64. - Pawellek, Günther (2007): Produktionslogistik - Planung - Steuerung - Controlling. Carl Hanser Verlag. München 2007. - Nyhuis, Peter (2008): Beiträge zu einer Theorie der Logistik. Springer Verlag. Berlin/Heidelberg 2008. - Pfohl, Hans-Christian (2010): Logistiksysteme. Betriebswirtschaftliche Grundlagen. 8., neu bearb. u. aktual. Aufl. Springer Verlag. Berlin/Heidelberg 2010. - Schuh, Günther (1988): Gestaltung und Bewertung von Produktvarianten. Ein Beitrag zur systematischen Planung von Serienprodukten. Dissertation. RWTH Aachen 1988. - Takeda, Hitoshi (2012): Das synchrone Produktionssystem. Just-in-time für das ganze Unternehmen. 7. Aufl. Verlag Franz Vahlen. München 2012. - Ten Hompel, Michael/Sadowsky, Volker/Beck, Maria (2011): Kommissionierung. Materialflusssysteme 2 - Planung und Berechnung der Kommissionierung in der Logistik. Springer Verlag. Berlin/Heidelberg 2011. - Wannenwetsch, Helmut (2007): Integrierte Materialwirtschaft und Logistik. Beschaffung, Logistik, Materialwirtschaft und Produktion.3., akt. Aufl. Springer Verlag. Berlin/Heidelberg 2007. - Wiendahl, Hans-Peter/Reichardt, Jürgen/Nyhuis, Peter (2014): Handbuch Fabrikplanung. Konzept, Gestaltung und Umsetzung wandlungsfähiger Produktionsstätten. 2., überarb. u. erw. Aufl. Carl Hanser Verlag. München/Wien 2014. - Wildemann, Horst (1997): Fertigungsstrategien - Reorganisation für eine schlanke Produktion und Zulieferung. 3. Aufl. TCW Transfer-Centrum-Verlag. München 1997. - Wildemann, Horst (2008): Produktionssysteme. Leitfaden zur methoden-gestützten Reorganisation der Produktion. 6. Aufl. 2008, TCW München. - Wildemann, Horst (2009): Logistik Prozeßmanagement. 4. Aufl. TCW Transfer-Centrum-Verlag. München 2009. - Zäpfel, Günther (2001): Grundzüge des Produktions- und Logistikmanagement. 2., unwesentlich veränd. Aufl. R. Oldenbourg Verlag. München/Wien 2001.

Course L1221: Logistics Economics	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Dr. Meike Schröder
Language	DE
Cycle	SoSe
Content	• Explanation of basic concepts of logistics and outline of the scope of the logistics business, identification of global logistics networks and relationships • Stakeholder: Introduction to the different kinds of logistics service providers, characterization of services of consulting firms for logistics companies • Strategy: Influence of the business strategies on business logistics • Outsourcing: Decision processes, possibilities and risks of outsourcing of logistics services • Market: Logistics in Germany, relevance of logistics for the city of Hamburg • Research: Outlook on current issues in academic research, as well as an outline of supplementary management methods for logistics
Literature	• Arnold, D.; Isermann, H.; Kuhn, A.; Tempelmeier, H. (2008): Handbuch Logistik, Berlin: Springer, 2008, ISBN: 3-540-72928-3 • Ballou, R. H. (2004): Business logistics, supply chain management: planning, organizing, and controlling the supply chain, 5. ed., internat. ed., Upper Saddle River, NJ: Pearson Prentice Hall, 2004, ISBN: 0-13-123010-7 • Bretzke, W.-R. (2008): Logistische Netzwerke, Springer, Berlin, 2008 • Gleißner, H.; Femerling, C. (2008): Logistik - Grundlagen, Übungen, Fallbeispiele, Wiesbaden: Gabler, 2008, ISBN: 978-3-8349-0296-2 • Kersten, W.; Hohrath, P.; Koch, J. (2007): Innovative logistics services : Advantage and Disadvantages of Outsourcing Complex Service Bundles, in: Key Factors for Successful Logistics, Berlin: Erich Schmidt Verlag GmbH & Co. KG, 2007 • Kersten, W.; Koch, J. (2007): Motive für das Outsourcing komplexer Logistikdienstleistungen, in: Handbuch Kontraktlogistik : Management komplexer Logistikdienstleistungen, Weinheim • Schulte, C. (2009): Logistik: Wege zur Optimierung der Supply Chain, 5. überarb. und erw. Aufl., München: Vahlen, 2009, ISBN: 3-8006-3516-X • Wildemann, H. (1997): Logistik Prozessmanagement - Organisation und Methoden, München: TCW Transfer-Centrum Verlag, 1997, ISBN: 3-931511-17-0

Module M1277: MED I: Introduction to Anatomy

Courses

Title	Typ	Hrs/wk	CP
Introduction to Anatomy (L0384)	Lecture	2	3

Module Responsible	Prof. Udo Schumacher
Admission Requirements	None
Recommended Previous Knowledge	Students can listen to the lectures without any prior knowledge. Basic school knowledge of biology, chemistry / biochemistry, physics and Latin can be useful.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The lectures are about microscopic anatomy, describing the microscopic structure of tissues and organs, and about macroscopic anatomy which is about organs and organ systems. The lectures also contain an introduction to cell biology, human development and to the central nervous system. The fundamentals of radiologic imaging are described as well, using projectional x-ray and cross-sectional images. The Latin terms are introduced.
Skills	At the end of the lecture series the students are able to describe the microscopic as well as the macroscopic assembly and functions of the human body. The Latin terms are the prerequisite to understand medical literature. This knowledge is needed to understand und further develop medical devices. These insights in human anatomy are the fundamentals to explain the role of structure and function for the development of common diseases and their impact on the human body.
Personal Competence	
Social Competence	The students can participate in current discussions in biomedical research and medicine on a professional level. The Latin terms are prerequisite for communication with physicians on a professional level.
Autonomy	The lectures are an introduction to the basics of anatomy and should encourage students to improve their knowledge by themselves. Advice is given as to which further literature is suitable for this purpose. Likewise, the lecture series encourages students to recognize and think critically about biomedical problems.
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Credit points	3
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 Biomedical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory Data Science: Specialisation II. Application: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Engineering Science: Specialisation Biomedical Engineering: Compulsory General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: Compulsory Mechanical Engineering: Specialisation Biomechanics: Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory

Course L0384: Introduction to Anatomy	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Tobias Lange
Language	DE
Cycle	SoSe
Content	**General Anatomy** **1st week: The Eucaryote Cell** **2nd week: The Tissues** **3rd week: Cell Cycle, Basics in Development** **4th week: Musculoskeletal System** **5th week: Cardiovascular System** **6th week: Respiratory System** **7th week: Genito-urinary System** **8th week: Immune system** **9th week: Digestive System I** **10th week: Digestive System II** **11th week: Endocrine System** **12th week: Nervous System** **13th week: Exam**
Literature	Adolf Faller/Michael Schünke, Der Körper des Menschen, 17. Auflage, Thieme Verlag Stuttgart, 2016

Module M1278: MED I: Introduction to Radiology and Radiation Therapy

Courses

Title	Typ	Hrs/wk	CP
Introduction to Radiology and Radiation Therapy (L0383)	Lecture	2	3

Module Responsible	Prof. Ulrich Carl
Admission Requirements	None
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	**Therapy** The students can distinguish different types of currently used equipment with respect to its use in radiation therapy. The students can explain treatment plans used in radiation therapy in interdisciplinary contexts (e.g. surgery, internal medicine). **The students can describe the patients' passage from their initial admittance through to follow-up care.** **Diagnostics** The students can illustrate the technical base concepts of projection radiography, including angiography and mammography, as well as sectional imaging techniques (CT, MRT, US). The students can explain the diagnostic as well as therapeutic use of imaging techniques, as well as the technical basis for those techniques. The students can choose the right treatment method depending on the patient's clinical history and needs. The student can explain the influence of technical errors on the imaging techniques. The student can draw the right conclusions based on the images' diagnostic findings or the error protocol.
Skills	**Therapy** The students can distinguish curative and palliative situations and motivate why they came to that conclusion. The students can develop adequate therapy concepts and relate it to the radiation biological aspects. The students can use the therapeutic principle (effects vs adverse effects) The students can distinguish different kinds of radiation, can choose the best one depending on the situation (location of the tumor) and choose the energy needed in that situation (irradiation planning). The student can assess what an individual psychosocial service should look like (e.g. follow-up treatment, sports, social help groups, self-help groups, social services, psycho-oncology). **Diagnostics** The students can suggest solutions for repairs of imaging instrumentation after having done error analyses. The students can classify results of imaging techniques according to different groups of diseases based on their knowledge of anatomy, pathology and pathophysiology.
Personal Competence	
Social Competence	The students can assess the special social situation of tumor patients and interact with them in a professional way. The students are aware of the special, often fear-dominated behavior of sick people caused by diagnostic and therapeutic measures and can meet them appropriately.
Autonomy	The students can apply their new knowledge and skills to a concrete therapy case. The students can introduce younger students to the clinical daily routine. The students are able to access anatomical knowledge by themselves, can participate competently in conversations on the topic and acquire the relevant knowledge themselves.
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Credit points	3
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 Biomedical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory Data Science: Specialisation II. Application: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Engineering Science: Specialisation Biomedical Engineering: Compulsory General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: Compulsory Mechanical Engineering: Specialisation Biomechanics: Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory

	Technomathematics: Specialisation III. Engineering Science: Elective Compulsory

Course L0383: Introduction to Radiology and Radiation Therapy	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Ulrich Carl, Prof. Thomas Vestring
Language	DE
Cycle	SoSe
Content	The students will be given an understanding of the technological possibilities in the field of medical imaging, interventional radiology and radiation therapy/radiation oncology. It is assumed, that students in the beginning of the course have heard the word “X-ray” at best. It will be distinguished between the two arms of diagnostic (Prof. Dr. med. Thomas Vestring) and therapeutic (Prof. Dr. med. Ulrich Carl) use of X-rays. Both arms depend on special big units, which determine a predefined sequence in their respective departments
Literature	• "Technik der medizinischen Radiologie" von T. + J. Laubenberg – 7. Auflage – Deutscher Ärzteverlag – erschienen 1999 • "Klinische Strahlenbiologie" von Th. Herrmann, M. Baumann und W. Dörr – 4. Auflage - Verlag Urban & Fischer – erschienen 02.03.2006 ISBN: 978-3-437-23960-1 • "Strahlentherapie und Onkologie für MTA-R" von R. Sauer – 5. Auflage 2003 - Verlag Urban & Schwarzenberg – erschienen 08.12.2009 ISBN: 978-3-437-47501-6 • "Taschenatlas der Physiologie" von S. Silbernagel und A. Despopoulus- 8. Auflage – Georg Thieme Verlag - erschienen 19.09.2012 ISBN: 978-3-13-567708-8 • "Der Körper des Menschen " von A. Faller u. M. Schünke - 16. Auflage 2004 – Georg Thieme Verlag – erschienen 18.07.2012 ISBN: 978-3-13-329716-5 • „Praxismanual Strahlentherapie“ von Stöver / Feyer – 1. Auflage - Springer-Verlag GmbH – erschienen 02.06.2000

Thesis

Module M1800: Bachelor thesis (dual study program)

Courses

Title	Typ	Hrs/wk	CP

Module Responsible	Professoren der TUHH
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students... • ... choose central theoretical principles from their field of study (facts, theories, methods) in relation to problems and applications, present them and discuss them critically. • ... further develop their subject-related and practical knowledge as appropriate and link both areas of knowledge together. • ... present the current research available on a chosen topic or on a chosen operational issue linked to their subject.
Skills	Dual students... • ... evaluate both the basic knowledge linked to their field of study acquired at the university and professional knowledge gained through the company, then purposefully use it to solve technical and application-related problems. • ... analyse questions and problems using the methods learned throughout their studies (including practical phases), reach factually justifiable decisions and develop application-specific solutions. • ... critically analyse the results of their own research work from a subject-specific and professional perspective.
Personal Competence	
Social Competence	Dual students... • ... present a professional problem in the form of an academic question for a specialist audience in a structured, comprehensible and factually correct manner, both orally and in writing. • ... respond to questions as part of a specialist discussion and answer them appropriately. In doing so, they argue their own evaluations and points of view convincingly.
Autonomy	Dual students... • ... structure a comprehensive, chronological workflow and work independently on a question to a high academic level within a given period of time. • ... identify, develop and link necessary knowledge and material to handle an academic and application-related problem. • ... apply the essential techniques of academic work when conducting their own research on an operational issue.
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, 7 semester): Thesis: Compulsory Civil- and Environmental Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Engineering Science: Thesis: Compulsory Green Technologies: Energy, Water, Climate: Thesis: Compulsory Computer Science in Engineering: Thesis: Compulsory Mechanical Engineering: Thesis: Compulsory Mechatronics: Thesis: Compulsory Naval Architecture: Thesis: Compulsory Technomathematics: Thesis: Compulsory Engineering and Management - Major in Logistics and Mobility: Thesis: Compulsory