

UNIVERSITÄT
BAYREUTH

Book of Modules for the Bachelor Program

Data, Science and AI

Faculty for Mathematics, Physics and Computer Science, University of Bayreuth, Germany

February 10, 2025

Preface

This Book of Modules describes all currently admissible modules for the Bachelor program 'Data, Science and AI' and their use in the examination regulations "Studien- und Prüfungsordnung".

Contents

1 Module Section A: Foundations of Mathematics **3**
1.1 Obligatory Modules A1 . . . 3

2 Module Section B: Foundations of Computer Science **6**
2.1 Obligatory Modules B1 . . . 6

3 Module Section C: Introduction to Applications **11**
3.1 Obligatory Modules C1 . . . 11
3.2 Optional Compulsory Modules C2 . . . 13

4 Module Section D: Specialisation Mathematics **20**
4.1 Obligatory Modules D1 . . . 20
4.2 Optional Compulsory Modules D2 . . . 23
4.3 Optional Compulsory Modules D3 . . . 25

5 Module Section E: Specialisation Computer Science **31**
5.1 Obligatory Modules E1 . . . 31
5.2 Optional Compulsory Modules E2 . . . 35

6 Module Section F: Specialisation Applications **42**
6.1 Obligatory Modules for Specialisation Natural and Life Sciences F1 . . . 42
6.2 Obligatory Modules for Specialisation Applied AI and Data Science F2 . . . 46
6.3 Obligatory Modules for Specialisation Human-Centered Data Science F3 . . . 52

7 Module Section G: Additional Topics **61**
7.1 Elective Modules for Specialisation Natural and Life Sciences G3 . . . 61
7.2 Elective Modules for Specialisation Applied AI and Data Science G4 . . . 73
7.3 Elective Modules for Specialisation Human-Centered Data Science G5 . . . 74

8 Module Section H: Bachelor Thesis **80**

1 Module Section A: Foundations of Mathematics

1.1 Obligatory Modules A1

Title	Foundations of Higher Mathematics
Module Label	A1.1
Module Type	Lecture
Area of Research	Mathematics
Responsible	Prof. Dr. Lars Grüne
Learning Outcomes	• Understanding and mastery of important basic concepts of Mathematical Analysis and Linear Algebra • Ability to use standard methods to compute bases, eigenvalues and eigenvectors, limits, derivatives, and to solve linear systems • Understanding of basic proof methods in Mathematical Analysis and Linear Algebra • Ability to communicate precisely and effectively about mathematics
Content	• Basics (logic, sets, maps) • Algebraic structures: groups and fields, real and complex numbers • Convergence of real sequences and series • Cauchy sequences and completeness, power series and convergence radius • Vector spaces, linear subspaces • Linear independence, generating systems, bases, dimension • Continuity and differentiability of real functions • Extreme values, mean value theorem • Taylor polynomials and L'Hospital's rule • Linear maps • Matrices and systems of linear equations • Determinant, eigenvalues and eigenvectors, diagonalizability
Duration	1 semester
Language	English
Teaching Method	Lectures (6 h/week) and tutorials (4 h/week)
Credit Points	14
Work Load	420 h total (150 h contact, 270 h self-study)
Recommended Prerequisites	
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every year in the Winter semester

Title	Mathematical Analysis
Module Label	A1.2
Module Type	Lecture
Area of Research	Mathematics
Responsible	Prof. Dr. Thomas Kriecherbauer
Learning Outcomes	• Understanding and mastery of advanced concepts of Mathematical Analysis • Ability to compute integrals in $\mathbb{R}$ and $\mathbb{R}^n$ and derivatives in $\mathbb{R}^n$ • Understanding of advanced proof methods in Mathematical Analysis • Ability to communicate precisely and effectively about mathematics
Content	• Riemann integral in $\mathbb{R}$ • Sequences of functions • Topology of sets in $\mathbb{R}^n$ • Differentiability in $\mathbb{R}^n$ • Integration in $\mathbb{R}^n$ • Vector calculus
Duration	1 semester
Language	English
Teaching Method	Lectures (4 h/week) and tutorials (2 h/week)
Credit Points	9
Work Load	270 h total (90 h contact, 180 h self-study)
Recommended Prerequisites	Foundations of Higher Mathematics
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every year in the Summer semester

Title	Linear Algebra
Module Label	A1.3
Module Type	Lecture
Area of Research	Mathematics
Responsible	Prof. Dr. Michael Stoll
Learning Outcomes	• Understanding and mastery of advanced concepts of Linear Algebra • Ability to compute orthonormal bases, normal forms, and singular values • Understanding of advanced proof methods in Linear Algebra • Ability to communicate precisely and effectively about mathematics
Content	• Sums of linear subspaces, complements, codimension • Real and complex inner product spaces, Gram-Schmidt algorithm • Equivalence relations, quotient spaces • Jordan normal form • Spectral theorem • Singular Value Decomposition • Euclidean normal form of quadrics
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (1 h/week)
Credit Points	5
Work Load	150 h total (45 h contact, 105 h self-study)
Recommended Prerequisites	Foundations of Higher Mathematics
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every year in the Summer semester

2 Module Section B: Foundations of Computer Science

2.1 Obligatory Modules B1

Title	Introduction to Programming
Module Label	B1.1
Module Type	Lecture
Area of Research	Computer Science
Responsible	Prof. Dr. Heike Leutheuser
Learning Outcomes	The aim of the course is to provide students with a sound understanding of programming, which will serve as a foundation for their further studies in computer science. Java is used as an example language.
Content	The focus is on the acquisition of methodological skills: By understanding fundamental concepts such as control and data structures, methods, object orientation, syntax, type concept, etc., students should be able to use these concepts when implementing algorithms in programs and furthermore familiarize themselves with other programming languages. Initial algorithmic skills are also acquired. They lay the foundation for further courses. There is also a preparatory course. The preparatory course is aimed in particular at students with no previous knowledge of programming, whereas is recommended for all students. The course is designed to bring all students up to the same level of knowledge. Java is used as the introductory language.
Duration	1 semester
Language	English
Teaching Method	Lectures (4 h/week) and tutorials (2 h/week)
Credit Points	8
Work Load	240 h total (90 h contact, 150 h self-study)
Recommended Prerequisites	
Grading	Coursework: Active participation in the courses and self-study Examination: written or oral examination
Frequency	Every year in the Winter semester

Title	Data Analysis and Deep Learning in Python
Module Label	B1.2, Fak119817
Module Type	Lecture
Area of Research	Computer Science
Responsible	Prof. Dr. Jörg Müller
Learning Outcomes	Students learn to quickly prototype and implement numerical programs in Python. They learn Python as a scientific computing environment. They acquire knowledge of the basic programming language, as well as of important libraries for scientific computing, such as Jupyter Notebooks, NumPy, SciPy, Matplotlib, Seaborn, and Pandas. They develop practical and applied skills in exploratory computing, rapid prototyping, and implementation of numerical methods.
Content	Linear Algebra with NumPy Vectors, Matrices, Dot product, Inverses, Pseudoinverse Data analysis with Pandas Systems of linear equations Least Squares Linear Regression Gradient Descent Newton's Method Logistic Regression Deep Learning Overfitting
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (2 h/week)
Credit Points	5
Work Load	150 h total (60 h contact, 90 h self-study)
Recommended Prerequisites	Foundations of Higher Mathematics, Introduction to Programming
Grading	Coursework: Active participation in the courses and self-study Examination: Portfolio examination, consisting of a written or oral examination and homework assignments
Frequency	Every year in the Winter semester

Title	Theoretical Computer Science I
Module Label	B1.3, Fak117267
Module Type	Lecture
Area of Research	Computer Science
Responsible	Prof. Dr. Wim Martens
Learning Outcomes	Students should understand and be able to explain the foundations of regular, context-free, computable, and efficiently computable formal languages. They should be able to categorize certain languages into these classes and explain why or why not they are members of a class. Students should be able to explain the methods from the lecture and apply them to examples. Students should be able to understand and apply the results of the lecture, and be able to understand and explain their proofs. Furthermore, they should understand the connections between regular, context-free, computable, and efficiently computable formal languages.
Content	Formal languages Automata, grammars and the Chomsky hierarchy Formal models of computation Decidability Complexity theory
Duration	1 semester
Language	English
Teaching Method	Lectures (4 h/week) and tutorials (2 h/week)
Credit Points	8
Work Load	240 h total (90 h contact, 150 h self-study)
Recommended Prerequisites	Mathematical Analysis or both Introduction to Programming and Logic
Grading	Coursework: Active participation in the courses and self-study Examination: Portfolio examination, consisting of a written or oral examination and homework assignments
Frequency	Every year in the Summer semester

Title	Algorithms and Data Structures
Module Label	B1.4
Module Type	Lecture
Area of Research	Computer Science
Responsible	Prof. Dr. Ruben Mayer
Learning Outcomes	Students should learn how to structure and dynamically represent data. The close link between these data structures and the algorithms applied to them is important here. A further aim is to acquire skills in analyzing the complexity of algorithms (methodological competence).
Content	Lists, basements, search and sorting methods, binary trees, search trees (AVL), graphs, hash methods, complexity of algorithms, algorithm theory.
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (1 h/week)
Credit Points	5
Work Load	150 h total (45 h attendance, 75 h preparation and follow-up, 30 h exam preparation)
Recommended Prerequisites	Introduction to Programming
Grading	Coursework: Active participation in the courses and self-study Examination: written or oral examination
Frequency	Every year in the Summer semester

Title	Graph Processing and Machine Learning
Module Label	B1.5, Fak125291
Module Type	Lecture
Area of Research	Computer Science
Responsible	Prof. Dr. Ruben Mayer, Prof. Dr. Wim Martens
Learning Outcomes	The module conveys a systematic and deep understanding of methods for the processing and analytics of graph-structured data. The course topics consist of theoretical foundations of graph-structured data as well as system- and implementation-oriented aspects of graph data management. A special focus is put on methods for machine learning on graph-structured data, such as graph embeddings and graph neural networks. The course topics find many applications in numerous areas, such as social network analysis, fraud detection, medicine, and biology.
Content	Fundamentals; Graph problems; Graph algorithms; Graph analytics; Pattern matching; Knowledge graphs; Graph databases; Graph learning; Graph neural networks; Graph processing frameworks
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (1 h/week)
Credit Points	5
Work Load	150 h total (45 h contact, 105 h self-study)
Recommended Prerequisites	Introduction to Programming
Grading	Coursework: Active participation in the courses and self-study Examination: written or oral examination
Frequency	Every year in the Winter semester

3 Module Section C: Introduction to Applications

3.1 Obligatory Modules C1

Title	Logic and Argumentation Theory
Module Label	C1.1, Fak510010
Module Type	Lecture
Area of Research	Philosophy
Responsible	Prof. Dr. Olivier Roy
Learning Outcomes	Being able to recognize valid and invalid inferences, both in natural language and in abstract, mathematical form.
Content	• Common biases and fallacies in reasoning (Argumentation Theory) • Logical forms and validity of arguments that use propositional connectives such as “and,” “or,” “if... then”, or “not” (propositional logic) • Logical forms and validity of arguments that use quantifiers such as “all” and “some” (Predicate logic) • Relation between logic and computability.
Duration	1 semester
Language	English
Teaching Method	Lectures (4 h/week) and tutorials (2 h/week)
Credit Points	5
Work Load	150 h total (84 h attendance, 28 h preparation and follow-up, 38 h exam preparation)
Recommended Prerequisites	
Grading	Graded assessment. Three 40-minute written exams at the end of the parts of the lecture on argumentation theory, propositional logic, and predicate logic. Each exam counts for a third of the final grade.
Frequency	Every year in the Winter semester

Title	Introduction to Specialisations
Module Label	C1.2
Module Type	Lecture
Area of Research	Mathematics, Computer Science, Natural and Life Sciences, Business Informatics, Humanities
Responsible	Prof. Dr. Vadym Aizinger
Learning Outcomes	First contact with basic problems and methods of participating disciplines.
Content	Course parts: • Mathematics • Computer Science • Natural and Life Sciences • Applied AI and Data Science • Philosophy and Humanities
Duration	2 semesters
Language	English
Teaching Method	Lectures, tutorials, seminars (3 h/week)
Credit Points	8
Work Load	240 h total (90 h attendance, 150 h preparation and follow-up)
Recommended Prerequisites	
Grading	Coursework: Active participation in the courses and self-study Examination: Successful completion of each course part
Frequency	Every year in the Winter and Summer semesters

3.2 Optional Compulsory Modules C2

Title	General Physics I
Module Label	C2.1
Module Type	Lecture
Area of Research	Physics
Responsible	Prof. Dr. Harald Oberhofer
Learning Outcomes	• Understanding of the basic concepts of classical mechanics and electrostatics and their applications • Ability to solve problems with the methods developed in the framework of classical mechanics and electrostatics • Development of an interdisciplinary connection to applied mathematics
Content	• Mechanics of point masses, Newtonian equations of motion, central potentials, constraints, Lagrange equations, rigid bodies, inertial tensors, Hamiltonian mechanics, Hamiltonian principle, symmetries and conserved properties • Electrostatics, magnetostatics, Maxwell's equations, electrostatics in matter
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (2 h/week)
Credit Points	5
Work Load	150 h total (60 h attendance, 60 h preparation and follow-up, 30 h exam preparation)
Recommended Prerequisites	Foundations of Higher Mathematics, Mathematical Analysis, Linear Algebra
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every year in the Winter semester

Title	General Physics II
Module Label	C2.2
Module Type	Lecture
Area of Research	Physics
Responsible	Prof. Dr. Harald Oberhofer
Learning Outcomes	• Understanding of the basic concepts of quantum mechanics, statistical mechanics, thermodynamics, and their applications • Ability to solve problems with the methods, developed in the frameworks of quantum mechanics and statistical mechanics • Intensification of the interdisciplinary connection to applied mathematics
Content	• Wavefunctions, Schrödinger's equation, Heisenberg uncertainty, probabilities, stationary solutions of Schrödinger's equation, operators, expectation values, simple problems of quantum mechanics • Statistical mechanics, thermodynamic potentials and states, statistical ensembles, laws of thermodynamics, equilibrium conditions
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (2 h/week)
Credit Points	5
Work Load	150 h total (60 h attendance, 60 h preparation and follow-up, 30 h exam preparation)
Recommended Prerequisites	Foundations of Higher Mathematics, Mathematical Analysis, Linear Algebra, General Physics I
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every year in the Summer semester

Title	General Chemistry I
Module Label	C2.3
Module Type	Lecture
Area of Research	Chemistry
Responsible	Prof. Dr. Johannes Margraf
Learning Outcomes	• Acquire basic concepts of general and inorganic chemistry • Ability to apply these concepts to solve problems in chemistry, biochemistry and materials science • Tutorials compensate for the students' different prior knowledge from school and deepen the content of the lectures.
Content	The lecture General Chemistry I provides an introduction to the basic principles of general and inorganic chemistry. The focus is on the fundamentals of chemical bonding and chemical reactivity: • Atomic structure and the structure of the electron shell; ionic bonding and atomic bonding (incl. Lewis formulas, dative, sigma and pi bonding, hybridization and mesomerism, electronegativity and oxidation number) • Reaction and formation enthalpy; chemical equilibrium (incl. mass action law and Le Chatelier's principle, reaction rates) • Salts, acids and bases (incl. electrolytes, solubility and ionic product, pH and pKs value, buffers); redox processes (incl. electrolysis); selected aspects of non-metals and metals; brief introduction to molecular complex compounds.
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (2 h/week)
Credit Points	5
Work Load	150 h total (60 h attendance, 60 h preparation and follow-up, 30 h exam preparation)
Recommended Prerequisites	
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every year in the Winter semester

Title	General Chemistry II
Module Label	C2.4
Module Type	Lecture
Area of Research	Chemistry
Responsible	Prof. Dr. Johannes Margraf
Learning Outcomes	• Acquire basic concepts of organic chemistry • Ability to apply these concepts to solve problems in chemistry, biochemistry and materials science • Tutorials compensate for the students' different prior knowledge from school and deepen the content of the lectures.
Content	The lecture General Chemistry II provides a brief introduction to organic chemistry: • Hydrocarbons, halogenated hydrocarbons, alkenes, alkynes, alcohols, aromatics, carbonyl compounds, amines, polymers. When discussing the individual substance classes, overarching principles such as the chirality of organic compounds and molecular orbital theory are discussed. • Important analytical methods such as infrared and NMR spectroscopy, and computational methods such as structure optimization and molecular dynamics are demonstrated using case studies.
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (2 h/week)
Credit Points	5
Work Load	150 h total (60 h attendance, 60 h preparation and follow-up, 30 h exam preparation)
Recommended Prerequisites	General Chemistry I
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every year in the Summer semester

Title	Process Mining I
Module Label	C2.5
Module Type	Lecture
Area of Research	Business Informatics
Responsible	Prof. Dr. Agnes Koschmider
Learning Outcomes	With the help of process mining, processes can be analyzed and reconstructed on the basis of digital traces (so-called event logs). Numerous process mining algorithms exist for this purpose, which reconstruct the process model depending on the event log. In addition to the construction of a model from the event log in order to answer the question ”What is really happening?”, there are other areas of application such as conformity validation and process prediction. This lecture provides an introduction to process mining. First of all the basics of modelling and analysing Petri nets are introduced. Subsequently algorithms for the construction of processes from event logs and procedures for conformity validation are discussed.
Content	• Introducing areas of application for process mining • Understanding the construction of process models from log files • Depending on the characteristics of the log file, select and apply the appropriate algorithms for process mining • Fundamentals of process modeling • Analyzing business process models (soundness) • Introduction to process mining • Introduction to conformance checking • Process Mining Enhancement • Process Mining tools
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (1 h/week)
Credit Points	5
Work Load	150 h total (45 h attendance, 75 h preparation and follow-up, 30 h exam preparation)
Recommended Prerequisites	
Grading	Coursework: Active participation in the courses and tutorials Examination: Written exam
Frequency	Every year in the Winter semester

Title	Applied Artificial Intelligence
Module Label	C2.6, Fak324808
Module Type	Lecture
Area of Research	Business Informatics
Responsible	Prof. Dr. Niklas Kühl
Learning Outcomes	Students of this course will be able to understand and implement the complete lifecycle of a typical Artificial Intelligence use case with supervised machine learning — from problem statement until productive, scalable deployment. This includes examples from the field of Generative AI and Large Language Models. Furthermore, they understand the importance and the means of applying Machine Learning within systems, which allows multiple, independent entities to collaborate and derive insights. Besides technical aspects, they will gain an understanding of the broader challenges and aspects when dealing with AI. Students will be proficient with typical Python code for AI challenges.
Content	AI and the application of machine learning is becoming more and more popular to solve relevant business challenges. However, it is not only essential to be familiar with precise algorithms but rather a general understanding of the necessary steps with a holistic view—from real-world challenges to the successful, scalable deployment of an AI-based solution. As part of this course, we teach the complete lifecycle of an AI project focusing on supervised machine learning challenges with excursions into Generative AI as well as Large Language Models. Apart from the technical aspects necessary when developing AI within complex systems, we also shed light on the collaboration of humans and AI in such systems (e.g., with the support of explainable AI), topics of ethics and bias in AI, as well as AI's capabilities on being generative and creative.
Duration	One semester
Language	English
Teaching Method	The course is designed so that students can demonstrate the best possible learning outcomes through a combination of lectures, discussions, and optionally active programming. In general, it features the following core concepts of teaching: • A weekly lecture • A weekly discussion round • A weekly shared programming exercise • A weekly homework submission • A final project work
Credit Points	12
Work Load	360 h total (30 h x 2 Attendance time for exercise, 10 h x 2 Attendance time for practical lectures, 20 x 2 h Flipped classroom videos, 60 x 2 h Preparation and follow-up, literature study, 60 x 2 h Preparation and follow-up, Exam preparation)
Recommended Prerequisites	
Grading	Written exam
Frequency	Every year in the Winter semester

Title	Basics of Data Analysis
Module Label	C2.7
Module Type	Seminar or Lecture
Area of Research	Data Science
Responsible	Prof. Dr. Karolina Milewicz
Learning Outcomes	After successful participation in this module, students have acquired a solid understanding of data analysis and are able to carry out independent data analyzes in diverse application scenarios.
Content	The module covers basics in data analysis which includes data preprocessing, introduction and application of statistical and stochastic methods, and critical evaluation of results.
Duration	1 semester
Language	English
Teaching Method	2 h/week
Credit Points	5
Work Load	150 h total (30 h contact, 120 h self-study)
Recommended Prerequisites	
Grading	Oral or written exam
Frequency	Every year in the Winter semester

4 Module Section D: Specialisation Mathematics

4.1 Obligatory Modules D1

Title	Introduction to Numerical Mathematics
Module Label	D1.1, Fak111273
Module Type	Lecture
Area of Research	Mathematics
Responsible	Prof. Dr. Holger Wendland
Learning Outcomes	• Understanding the concepts of condition and stability of numerical algorithms • Ability to analyze convergence and computational overhead of numerical algorithms • Ability to choose a suitable numerical method for standard problem classes • Ability to implement numerical algorithms in a higher level programming language
Content	• Error analysis, condition, and stability of numerical methods • Direct methods for linear equation systems • Numerical approximation, least squares method • Interpolation and extrapolation • Numerical integration • Numerical solution of nonlinear algebraic equations and systems
Duration	1 semester
Language	English
Teaching Method	Lectures (3 h/week) and tutorials (2 h/week)
Credit Points	8
Work Load	240 h total (75 h contact, 165 h self-study)
Recommended Prerequisites	Foundations of Higher Mathematics, Mathematical Analysis, Linear Algebra
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every year in the Winter semester

Title	Probability Theory and Statistics
Module Label	D1.2
Module Type	Lecture
Area of Research	Mathematics
Responsible	Prof. Dr. Melanie Birke
Learning Outcomes	• Understanding mathematical arguments behind probabilistic and statistical methods • Ability to prove small results on his/her own • Knowledge of standard statistical methods to analyze data sets • Ability to statistically analyze data sets
Content	• Basic probability theory (probability space, probability measure, measurability, random variables) • Advanced concepts (independence and conditional probability, distribution function, density, standard distributions, expectation, variance and covariance) • Convergence of random sequences: Definitions and limit theorems (LLN, CLT) • Markov chains (basics, stationary distribution, irreducibility, convergence, optionally basic potential theory) • Algorithms for data generation (e.g., generate samples from general analytically known distributions, Markov chain Monte Carlo) • Descriptive statistics (primarily visualization) • Maximum-likelihood estimation and confidence intervals (uncertainty quantification); optionally concentration inequalities (Hoeffding) • Hypothesis testing (statistical test, applied aspects) • Bayesian statistics (prior / posterior distribution, Bayes estimator / risk) • Optionally linear models: regression
Duration	1 semester
Language	English
Teaching Method	Lectures (4 h/week) and tutorials (2 h/week)
Credit Points	10
Work Load	4 h lectures plus 5 h post-processing per week = 135 h; 2 h discussion sections plus 7 h preparation/post-processing = 135 h; 30 h preparation for exam, in total: 300 h
Recommended Prerequisites	Foundations of Higher Mathematics, Mathematical Analysis, Linear Algebra
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every year in the Summer semester

Title	Mathematical Seminar
Module Label	D1.4
Module Type	Seminar
Area of Research	Mathematics
Responsible	Prof. Dr. Vadym Aizinger
Learning Outcomes	The students acquire methodological skills in scientific research methods (in particular, literature review, presentation, and writing techniques), as well as communication skills in the oral and written presentation of scientific content.
Content	Students present a selected topic from mathematics (30-45 min followed by discussion) and submit a written report.
Duration	1 semester
Language	English
Teaching Method	Seminar (2 h/week)
Credit Points	5
Work Load	150 h total (30 h contact, 120 h self-study)
Recommended Prerequisites	-
Grading	Coursework: Active participation in the sessions and self-study. Examination: Tasks to be completed throughout and at the end of the semester in the form of written reports, oral contributions, presentations, or practical work (e.g., programming assignments, literature overview).
Frequency	Every year in the Summer semester

4.2 Optional Compulsory Modules D2

Title	Introduction to Iterative Numerical Methods
Module Label	D2.1, Fak127251
Module Type	Lecture
Area of Research	Numerical Mathematics
Responsible	Prof. Dr. Mario Bebendorf
Learning Outcomes	• understanding the principal necessity of iterative methods • acquisition of knowledge on approximate solution of linear equation systems and eigenvalue problems • ability to implement the introduced numerical algorithms in a higher programming language
Content	• iterative methods for solution of large linear equation systems (classical iterative methods, CG and GMRES methods, preconditioners) • numerical methods for eigenvalue problems (QR, Lanczos methods, etc.), singular value decomposition and further topics such as • nonlinear equations and optimization • approximation theory
Duration	1 semester
Language	English
Teaching Method	Lectures (3 h/week) and tutorials (2 h/week)
Credit Points	8
Work Load	4 h lectures plus 3 h post-processing per week = 105 h; 2 h discussion sections plus 5 h preparation/post-processing = 105 h; 30 h preparation for exam, in total: 240 h
Recommended Prerequisites	Linear Algebra, Mathematical Analysis
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every year in the Summer semester

Title	Linear Optimization
Module Label	D2.2
Module Type	Lecture
Area of Research	Optimization
Responsible	Prof. Dr. Jörg Rambau
Learning Outcomes	• Ability to explain in precise mathematical terms the optimality, duality, and sensitivity theory of linear optimization • Ability to explain in precise mathematical terms the foundations of polyhedral theory • Ability to explain in precise mathematical terms some of the most important numerical solution methods for linear optimization • Ability to implement linear optimization algorithms in a higher programming language • Ability to identify, model, and solve application problems that can be tackled by linear optimization • Ability to use standard software for modeling and solving application problems by linear optimization
Content	• Examples for linear optimization problems • Context and distinction of linear optimization • The idea of the simplex algorithm • Introduction to polyhedral theory • Optimality, duality, and sensitivity theory of linear optimization • The simplex algorithm and its variations in detail • The foundations of the path-following interior point method
Duration	1 semester
Language	Bilingual English/German with video support
Teaching Method	Lectures (3 h/week) and tutorials (2 h/week)
Credit Points	8
Work Load	3 h lectures plus 2 h post-processing per week = 75 h; 2 h tutorials plus 5 h preparation/post-processing = 105 h; 40 h preparation for exam, 20 h preparation/post-processing in break, in total: 240 h.
Recommended Prerequisites	Mathematical Analysis, Linear Algebra
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every year in the Summer semester

4.3 Optional Compulsory Modules D3

Title	Mathematical Control Theory
Module Label	D3.3, Fak118960
Module Type	Lecture
Area of Research	Optimization, Advanced Analysis and Applications
Responsible	Prof. Dr. Lars Grüne
Learning Outcomes	• knowledge of methods and concepts of mathematical control theory • ability to solve selected problems from mathematical control theory • ability to apply these solution strategies to practical problem formulations
Content	• definition and classification of control systems • qualitative analysis of control systems • methods for controller design, e.g. – methods from linear algebra – methods from optimal control – methods based on Lyapunov functions
Duration	1 semester
Language	English
Teaching Method	Lectures (4 h/week) and tutorials (2 h/week)
Credit Points	10
Work Load	300 h total (90 h contact, 210 h self-study)
Recommended Prerequisites	Introduction to Numerical Mathematics, Numerical Methods for Differential Equations
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every two years

Title	Nonlinear Optimization
Module Label	D3.4, Fak118961
Module Type	Lecture
Area of Research	Optimization
Responsible	Prof. Dr. Anton Schiela
Learning Outcomes	• understanding of optimality conditions for nonlinear optimization • understanding of the most important algorithms for the numerical solution of nonlinear optimization problems • ability to model and solve given practical problems in nonlinear optimization • ability to use and develop software for nonlinear optimization
Content	• modeling of nonlinear optimization problems • advanced algorithms for unconstrained optimization • optimality conditions for nonlinear optimization problems • algorithms for constrained optimization • outlook on further problem classes
Duration	1 semester
Language	English
Teaching Method	Lectures (4 h/week) and tutorials (2 h/week)
Credit Points	10
Work Load	4 h lectures plus 4 h post-processing per week = 120 h; 2 h discussion sections plus 6 h preparation/post-processing = 120 h; 60 h preparation for exam, in total: 300 h
Recommended Prerequisites	Introduction to Numerical Mathematics, Introduction to Iterative Numerical Methods
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every two years

Title	Modeling, Simulation, and Optimization with Ordinary Differential Equations

Module Label	D3.5
Module Type	Lecture
Area of Research	Numerical Mathematics, Optimization
Responsible	Prof. Dr. Lars Grüne

Learning Outcomes	• ability to model application problems with the help of ordinary differential equations • understanding of operating principles numerical algorithms for the solution of ordinary differential equations • understanding of the connection between mathematical modeling, numerical simulation, and optimization when solving a problem • ability to implement the introduced numerical algorithms in a higher programming language
Content	• mathematical modeling of application problems using ordinary differential equations (e.g. celestial mechanics, epidemiology, reaction kinetics) • numerical methods for the initial value problems for ordinary differential equations (convergence theory, one-step methods, step size control, stiff differential equations) • optimization and boundary value problems for ordinary differential equations (formulation, shooting method, collocation method) • further topics from the area of modeling, simulation, and optimization with ordinary differential equations
Duration	1 semester
Language	English
Teaching Method	Lectures (4 h/week) and tutorials (2 h/week)
Credit Points	10
Work Load	300 h total (90 h contact, 210 h self-study)
Recommended Prerequisites	Linear Algebra, Mathematical Analysis, Introduction to Numerical Mathematics
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every year in the Summer semester

Title	Numerical Methods for Partial Differential Equations
Module Label	D3.6, Fak114149
Module Type	Lecture
Area of Research	Numerical Mathematics
Responsible	Prof. Dr. Vadym Aizinger
Learning Outcomes	• Understanding the theory and application of numerical methods for the solution of partial differential equations (PDEs) • ability to choose a suitable numerical method a given class of PDEs • ability to adapt standard numerical algorithms to new problems • ability to implement the introduced numerical methods in a higher programming language
Content	• finite difference method for PDEs, including the transport, Poisson, and heat equations • conforming finite element methods for elliptic PDEs (Galerkin method, convergence) • finite element methods for parabolic PDEs
Duration	1 semester
Language	English
Teaching Method	Lectures (4 h/week) and tutorials (2 h/week)
Credit Points	10
Work Load	4 h lectures plus 3 h post-processing per week = 105 h; 2 h practical sections plus 9 h preparation/post-processing = 165 h; 30 h preparation for exam, in total: 300 h
Recommended Prerequisites	Introduction to Numerical Mathematics
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every year in the Winter semester

Title	Foundations of Mathematical Data Science
Module Label	D3.7
Module Type	Lecture
Area of Research	Data Science, Various fields in applied mathematics
Responsible	Prof. Dr. Péter Koltai
Learning Outcomes	• Ability to formalize problems from mathematical data science (MDS) • Ability to make an informed choice of methods for the solution of MDS problems • Ability to analyze approaches from MDS on their applicability and performance in given scenarios, and interpret their results • Ability to read research papers
Content	The mathematical foundations of different learning methods. The focus is to understand why (and in what sense) these methods work. An integral part of the course is to deepen our understanding by means of many numerical examples. Focal points include: • dimension reduction • (spectral) clustering • learning of manifolds • kernel methods • support vector machines • Probably Approximately Correct (PAC) framework
Duration	1 semester
Language	English
Teaching Method	Lectures (4 h/week) and tutorials (2 h/week)
Credit Points	10
Work Load	4 h lectures plus 5 h post-processing per week = 135 h; 2 h discussion sections plus 7 h preparation/post-processing = 135 h; 30 h preparation for exam, in total: 300 h
Recommended Prerequisites	Linear Algebra, Mathematical Analysis, Probability Theory and Statistics, Basic programming skills (e.g., Matlab, Python, or Julia)
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every two years

Title	Integer Linear Optimization
Module Label	D3.8, Fak111272
Module Type	Lecture
Area of Research	Optimization
Responsible	Prof. Dr. Jörg Rambau
Learning Outcomes	• Ability to motivate and explain the core standard problem types for integer linear optimization • Ability to explain in precise mathematical terms the polyhedral method to generate dual bounds for integer linear optimization problems • Ability to explain in precise mathematical terms the most important numerical solution methods for integer linear optimization, in particular, branch-and bound • Ability to implement integer linear optimization algorithms in a higher programming language • Ability to identify, model, and solve application problems that can be tackled by integer linear optimization • Ability to use standard software for modeling and solving application problems by integer linear optimization
Content	• Examples for integer linear optimization problems • Context and distinction of integer linear optimization • Branch-and-bound • Theoretical complexity of integer linear optimization • Integral polyhedra • Valid inequalities and cutting planes • Duality, relaxations, decompositions
Duration	1 semester
Language	Bilingual English/German with video support
Teaching Method	Lectures (4 h/week) and tutorials (2 h/week)
Credit Points	10
Work Load	4 h lectures plus 4 h post-processing per week = 120 h; 2 h tutorials plus 6 h preparation/post-processing = 120 h; 40 h preparation for exam, 20 h preparation/post-processing in break, in total: 300 h.
Recommended Prerequisites	Mathematical Analysis, Linear Algebra, and Linear Optimization
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every year in the Winter semester

5 Module Section E: Specialisation Computer Science

5.1 Obligatory Modules E1

Title	Software Engineering
Module Label	E1.1
Module Type	Lecture
Area of Research	Computer Science
Responsible	Prof. Dr. Sebastian Baltes
Learning Outcomes	The aim of the course is to provide a systematic and in-depth understanding of fundamental concepts as well as selected procedures, methods, and tools of modern software engineering. Students are expected to apply a selection of these procedures, methods, and tools in the context of assignments and case studies. In particular, analysis and design skills, which are crucial for the development of software systems, are taught. Additionally, methodical skills in areas such as project management and quality assurance are also covered.
Content	**Introduction to Software Engineering** (history, terms, etc.); **Software Development Processes** (SDLC, historical process models, V-model, agile process models, DevOps); **Software Development Tools** (version control systems, collaborative software development, integrated development environments, build automation, static code analysis, continuous integration and delivery, AI coding assistants); **Requirements Engineering** (requirements elicitation, analysis, specification, validation, management, stakeholder groups, use cases, user stories, acceptance criteria); **Software Architecture** (top-down vs. bottom-up architecture, modules, components, decomposition, architectural patterns); **Requirements to Code** (BDD, TDD); **Software Documentation and Visualization** (documentation as code, architectural decision records); **Object-Oriented Modeling** (Unified Modeling Language, design patterns); **Software Quality** (antipatterns, clean code, functional vs. non-functional quality, performance, security, usability); **Code Comprehension and Code Reviews** (mental models, cognitive complexity, code comments, pull request reviews, code review best practices); **Software Testing** (regression testing, black box vs. glass box testing, risk-based testing, testability of requirements, testing pyramid, exploratory vs. structured testing, unit vs. integration vs. system testing, code coverage, test doubles, writing testable code); **Managing Software Projects** (people management, risk management, project management, effort estimation, definition of ready/done, Gantt charts, Critical Path Method); **Open Source and Inner Source** (definition, copyright, software licenses, open-source ecosystems, software supply chains, open-source by and within companies); **Software Evolution and Maintenance** (evolution vs. maintenance, technical debt, debugging, reverse-engineering, reengineering, refactoring, writing good bug reports, Lehman's laws, migrations); **Software Measurement and Metrics** (software metrics, business metrics, Goodhart's law); Cloud-native Software Development (scalability, elasticity, virtualization, containerization); **Introduction to Software Analytics**
Duration	1 semester
Language	English
Teaching Method	Lectures (4 h/week) and tutorials (2 h/week)
Credit Points	8
Work Load	240 h total (90 h contact, 150 h self-study)
Recommended Prerequisites	Introduction to Programming
Grading	Coursework: Active participation in the courses and self-study Examination: Portfolio examination, consisting of a written or oral examination and homework assignments
Frequency	Every year in the Summer semester

Title	CS Individual Project
Module Label	E1.2
Module Type	Practical course
Area of Research	Computer Science
Responsible	Prof. Dr. Daniel Buschek
Learning Outcomes	The focus is on the acquisition of individual skills in algorithms, design, and implementation. Students should be enabled to systematically develop software of limited scope and complexity (methodological competence) and to present the solution they have developed (communication competence).
Content	Students individually develop smaller software systems under guidance. Problems are analyzed, requirements defined, a system design is created, and the design components are implemented and tested. Additionally, the solution concepts are presented.
Duration	1 semester
Language	English
Teaching Method	Practical course (4 h/week)
Credit Points	6
Work Load	180 h total (60 h contact, 120 h self-study)
Recommended Prerequisites	Programming skills, Algorithms and Data Structures
Grading	Tasks to be completed throughout and/or until the end of the semester in the form of written, oral, and/or practical work (e.g., programming, writing a documentation, discussing the work).
Frequency	Every year in the Summer semester

Title	CS Team Project
Module Label	E1.3
Module Type	Practical course
Area of Research	Computer Science
Responsible	Prof. Dr. Daniel Buschek
Learning Outcomes	Students should be able to work in a team to solve a comprehensive project task. This project may have an interdisciplinary nature. Specifically, the following tasks are to be completed by the participants: structuring the problem (e.g., in the form of a requirements specification), defining a solution (e.g., in the form of a functional specification), organizing the implementation in subprojects, testing the implementation, and presenting and delivering the solution. Interdisciplinary skills are acquired through cross-disciplinary collaboration. Another focus is on the development of project management skills and communication skills (team cooperation).
Content	The task is solved within a project, ideally involving 6 to 12 members. The work is planned, coordinated, and monitored using project management methods. The project work also includes presenting the developed solution.
Duration	1 semester
Language	English
Teaching Method	Practical course (4 h/week)
Credit Points	6
Work Load	180 h total (60 h contact, 120 h self-study)
Recommended Prerequisites	Programming skills, CS individual project, Software Engineering
Grading	Tasks to be completed throughout and/or until the end of the semester in the form of written, oral, and/or practical work (e.g., programming, writing a documentation, discussing the work).
Frequency	Every year in the Winter semester

Title	Foundations of Data Management
Module Label	E1.4, Fak118969
Module Type	Lecture
Area of Research	Computer Science
Responsible	Prof. Dr. Wim Martens
Learning Outcomes	Students will learn the mathematical foundations of data management (which includes databases and data science). They will understand the connections between logic, expressivity, computational complexity, and efficient algorithms in this area. They will learn the formal tools to be able to understand and interpret recent scientific developments in the area.
Content	The lecture starts with a formal definition of databases and database query languages. After establishing the connection between first-order logic and SQL on relational databases, we investigate the complexity and efficient algorithms for SQL and first-order queries more closely. Then we consider the practically highly relevant “conjunctive queries”, their evaluation and optimization algorithms, and establish connections with graph theory. (Knowledge about SQL is helpful for this lecture, but not required.)
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (1 h/week)
Credit Points	5
Work Load	150 h total (45 h contact, 105 h self-study)
Recommended Prerequisites	Algorithms and Data Structures, Theoretical Computer Science I
Grading	Coursework: Active participation in the courses and self-study Examination: written or oral examination
Frequency	Every year in the Winter semester

5.2 Optional Compulsory Modules E2

Title	Theoretical Computer Science II
Module Label	E2.1, Fak110696
Module Type	Lecture
Area of Research	Computer Science
Responsible	Prof. Dr. Wim Martens
Learning Outcomes	The students should obtain deeper knowledge in the areas of logic and computational complexity; and should understand the treated connections between these areas. They should be able to reproduce and explain the course material. They should be able to apply their knowledge from the lecture in exercises.
Content	Computational Complexity Logic
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (1 h/week)
Credit Points	5
Work Load	150 h total (45 h contact, 105 h self-study)
Recommended Prerequisites	Theoretical Computer Science I
Grading	Coursework: Active participation in the courses and self-study Examination: written or oral examination
Frequency	Every year in the Winter semester

Title	Information Visualization
Module Label	E2.2
Module Type	Lecture
Area of Research	Computer Science
Responsible	Prof. Dr. Daniel Buschek
Learning Outcomes	This module provides a systematic overview of information visualization and an advanced understanding of their fundamental concepts and of selected technical approaches and methods for their design, implementation and evaluation, as well as related data analyzes. The learning goals are: (1) Understanding of fundamental concepts, application areas and related data analyzes of information visualization. (2) Ability to design and implement useful information visualizations for concrete datasets, analyzes and research questions. (3) Ability to analyze existing information visualizations
Content	Introduction to Information Visualization (e.g. motivation, examples, core concepts); Specific visualization types and data types (e.g. multi-dimensional, graphs, hierarchies and trees, time series, text-related, etc.); Interaction with information visualizations; Presentation, integration and evaluation of information visualizations; Practical implementation of information visualizations (e.g. Python, web-based and other frameworks)
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (1 h/week)
Credit Points	5
Work Load	150 h total (45 h contact, 105 h self-study)
Recommended Prerequisites	Programming skills in Python
Grading	Coursework: Active participation in the courses and self-study Examination: Portfolio examination, consisting of a written or oral examination and homework assignments
Frequency	Every year in the Summer semester

Title	Intelligent User Interfaces
Module Label	E2.3
Module Type	Lecture
Area of Research	Computer Science
Responsible	Prof. Dr. Daniel Buschek
Learning Outcomes	This module provides a systematic overview of intelligent user interfaces and an advanced understanding of their fundamental concepts and of selected technical approaches and methods for their design, implementation and evaluation. The learning goals are: (1) Understanding of fundamental concepts, application areas, and benefits and challenges of intelligent user interfaces (2) Ability to apply specific approaches and methods in the design, implementation and evaluation of intelligent user interfaces (3) Ability to analyze existing intelligent user interfaces
Content	Introduction to Intelligent User Interfaces (e.g. motivation, examples, core concepts); HCI + AI recap/preparations (e.g. basic concepts; practical prototyping with Python (backend, AI, algorithms) and JS/HTML/CSS (user interface, interaction)); Recommender systems (e.g. movie recommendations); Conversational user interfaces (e.g. chatbots, voice assistants); Interaction with text (e.g. personalised keyboards, text suggestions, language modelling); User/input modelling and adaptive UIs (e.g. touch, pointing, typing, menus); Computational UI design and evaluation (e.g. layout optimisation); Broader perspective (e.g. explainable AI, ethics)
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (1 h/week)
Credit Points	5
Work Load	150 h total (45 h contact, 105 h self-study)
Recommended Prerequisites	Programming skills in Python
Grading	Coursework: Active participation in the courses and self-study Examination: Portfolio examination, consisting of a written or oral examination and homework assignments
Frequency	Every year in the Summer semester

Title	Knowledge-based Systems
Module Label	E2.4, Fak125452
Module Type	Lecture
Area of Research	Computer Science
Responsible	Prof. Dr. Michael Guthe
Learning Outcomes	The course teaches skills and knowledge of the most important AI methods and their application in practice. Among other things, students will learn how to programme knowledge-based inference systems in predicate logic using the Prolog programming language. Furthermore, knowledge representation forms as well as problem-solving, search and planning algorithms are taught. Students will be given an overview of common methods of probability-based reasoning, such as Bayesian inference and Dempster-Shafer theory.
Content	The course first deals with programming in Prolog, predicate logic and constraints. Then knowledge, knowledge representation and inference as well as the structure of knowledge-based systems are discussed. Finally, various methods for probability-based reasoning, such as Bayesian inference and Dempster-Shafer theory, are presented and analyzed.
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (1 h/week)
Credit Points	5
Work Load	150 h total (45 h contact, 105 h self-study)
Recommended Prerequisites	
Grading	Coursework: Active participation in the courses and self-study Examination: Portfolio examination, consisting of a written or oral examination and homework assignments
Frequency	Every year in the Winter semester

Title	Advanced Software Engineering
Module Label	E2.5, Fak126411
Module Type	Lecture
Area of Research	Computer Science
Responsible	Prof. Dr. Sebastian Baltes
Learning Outcomes	Building on the Software Engineering module, this module expands on the concepts, procedures, methods, and tools of modern software engineering and introduces new ones. Students should apply and deepen selected procedures, methods, and tools using examples and case studies. In particular, analysis and design skills are deepened, which are of central importance for developing software systems. In addition, methodological skills in project management, quality assurance, and other areas are deepened.
Content	**Software Development Tools:** Deepening of the previously introduced tools, especially the static code analysis tools. New: tools for large-scale refactoring and automated security analysis. **Software Architecture:** Focus on event-driven architectures and microservices, domain-driven design. **Software Testing:** Advanced procedures such as mutation testing, fuzzing, property-based testing, or symbolic execution. **APIs:** APIs as contracts, REST vs. GraphQL vs. gRPC, Java Bean Validation. **Java Virtual Machine:** Kotlin is used to demonstrate the interoperability of programming languages on the Java Virtual Machine and to highlight their differences and special features. **Software Supply Chains:** US Executive Order 14028, Software Bill of Material, integration in CI/CD pipelines. **Cloud-native Software Development:** Deepening the concept of containerization, introduction of Kubernetes and serverless functions, cost models in the cloud, authentication and authorization, multitenancy. **Frontend Development:** Overview of modern frameworks such as Angular, React or Vue.js, cross-platform apps.
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (2 h/week)
Credit Points	5
Work Load	150 h total (60 h contact, 90 h self-study)
Recommended Prerequisites	Introduction to Programming, Software Engineering, Individual Project
Grading	Coursework: Active participation in the courses and self-study Examination: Portfolio examination, consisting of a written or oral examination and homework assignments
Frequency	Every year in the Winter semester

Title	Biomedical Time Series Analysis
Module Label	E2.6, Fak127376
Module Type	Lecture
Area of Research	Computer Science
Responsible	Prof. Dr. Heike Leutheuser
Learning Outcomes	The course introduces analysis aspects for biomedical time series. The learning objectives are: 1) knowledge about the generation, measurement, and characteristics of important signals of the human body; 2) explain causes of artifacts in time series, explain filter operations for the reduction of artifacts, explain relations between the generation and the measured time series; 3) apply, implement, and compare algorithms for time series analysis in Python; and 4) evaluate classification results.
Content	The content of the lecture is divided in three parts: a) Basics for the generation of important time series of the human body, b) Measurement of these time series, c) Analysis of biomedical time series. Considered biomedical signals in this course include among others the action potential, the electrocardiogram (ECG), the electroencephalogram (EEG), the electromyogram (EMG) or movement (acceleration and gyroscope) signals. Apart from information about the generation and measurement of these time series, the main part of the lectures is the analysis part. There, concepts like filtering for artifact reduction, event detection, wavelet or waveform analysis are discussed. The course concludes with an insight into pattern recognition methods.
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (2 h/week)
Credit Points	5
Work Load	150 h total (60 h contact, 90 h self-study)
Recommended Prerequisites	-
Grading	Coursework: Active participation in the courses and self-study Examination: Portfolio examination, consisting of a written or oral examination and homework assignments
Frequency	Every year in the Winter semester

Title	CS Seminar
Module Label	E2.7
Module Type	Seminar
Area of Research	Computer Science
Responsible	Prof. Dr. Daniel Buschek
Learning Outcomes	The students acquire methodological skills in scientific research methods (in particular, literature review, presentation, and writing techniques), as well as communication skills in the oral and written presentation of scientific content.
Content	A selected topic from computer science will be presented in a written report and orally.
Duration	1 semester
Language	English
Teaching Method	Seminar (2 h/week)
Credit Points	5
Work Load	150 h total (30 h contact, 120 h self-study)
Recommended Prerequisites	-
Grading	Tasks to be completed throughout and/or until the end of the semester in the form of written, oral, and/or practical work (e.g., programming, writing a term paper, discussing a paper).
Frequency	Irregularly

6 Module Section F: Specialisation Applications

6.1 Obligatory Modules for Specialisation Natural and Life Sciences F1

Title	General Physics Lab
Module Label	F1.1
Module Type	Lab Course
Area of Research	Physics
Responsible	Dr. Frank-Julian Kahle, Chair of Experimental Physics II
Learning Outcomes	• Practical application of concepts from the lectures “General Physics I and II” and basic mathematical lectures to real measurements and data sets • Developing an understanding for measurement uncertainties • Comprehensible documentation and evaluation of a lab experiment
Content	Experiments covering topics from Newtonian Mechanics, error calculation and statistics, electrostatics, magnetostatics and thermodynamics: • Digital recording of data in mechanical experiments • Error calculation, statistics and tests • Coupled pendulums • Statistics of radioactive decay • Complex resistances • Behavior of real gases • Polarization of Light
Duration	1 semester
Language	English
Teaching Method	4 h/week (not weekly)
Credit Points	5
Work Load	150 h total (30 h attendance, 90 h preparation and follow-up, 30 h exam preparation)
Recommended Prerequisites	General Physics I & II, Linear Algebra, Probability Theory and Statistics, Ordinary Differential Equations
Grading	Oral presentations, written reports, and active participation in the lab courses
Frequency	Every year in the Winter semester

Title	General Chemistry Lab
Module Label	F1.2
Module Type	Lab Course
Area of Research	Chemistry
Responsible	Prof. Dr. Johannes Margraf
Learning Outcomes	• Practical application of concepts from the lectures “General Chemistry I and II” to real measurements and data sets. • Developing an understanding for experimental and computational techniques in chemistry. • Data analytics and machine learning with experimental data from different domains of chemistry.
Content	In the laboratory course, the students are familiarized with measurement and simulation methods from physical chemistry on the basis of selected examples. The main focus of the projects will be on advanced data analysis methods. Under the supervision of experienced staff of the respective chairs, this includes in particular quantum chemistry, chemical machine learning, computer vision techniques and automation/optimization of chemical experiments.
Duration	1 semester
Language	English
Teaching Method	4 h/week (not weekly)
Credit Points	5
Work Load	150 h total (30 h attendance, 90 h preparation and follow-up, 30 h exam preparation)
Recommended Prerequisites	General Chemistry I & II, Linear Algebra, Probability Theory and Statistics
Grading	Oral presentations, written reports, and active participation in the lab courses
Frequency	Every year in the Winter semester

Title	General Life Sciences
Module Label	F1.3
Module Type	Lecture
Area of Research	Prof. Dr. Birte Höcker
Responsible	Biochemistry
Learning Outcomes	• Learn about structures & functions of biomolecules & cells • Gain a basic understanding of biochemical mechanisms & reactions • Acquire knowledge about information flow within biochemical systems
Content	• Amino acids, nucleotides and nucleic acids, structure and function of proteins, selected enzyme mechanisms, bioenergetics & metabolism • Molecular structure & functions of the cell from cellular level to integration into tissue associations
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (2 h/week)
Credit Points	5
Work Load	150 h total (60 h attendance, 60 h preparation and follow-up, 30 h exam preparation)
Recommended Prerequisites	General Chemistry I
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every year in the Summer semester

Title	Research Internship
Module Label	F1.4
Module Type	Project work
Area of Research	Natural and Life Sciences
Responsible	Prof. Dr. Harald Oberhofer
Learning Outcomes	Students should gain insight into the current best-practices of scientific research. In addition, they are to acquire scientific skills through independent research work under guidance, and they are to practice team skills and train in presentation techniques.
Content	The learning content relates to the current research projects of the Chair. The module includes experimental work, literary work, participation in work group seminars including their own presentation and the preparation of a protocol.
Duration	1 semester
Language	English
Teaching Method	Practical course (6 weeks)
Credit Points	10
Work Load	300 hours total. Practical work and evaluation: 200 hours; Preparation: 25 hours; writing: 50 hours; presentation: 25 hours
Recommended Prerequisites	General Chemistry I & II, General Physics I & II
Grading	Contribution (written report, 75%) and presentation (25%)
Frequency	Every semester

6.2 Obligatory Modules for Specialisation Applied AI and Data Science F2

Title	Human-AI-Collaboration
Module Label	F2.1, Fak324427
Module Type	Lecture
Area of Research	Business Informatics
Responsible	Prof. Dr. Niklas Kühl
Learning Outcomes	In this course, students will learn the fundamentals of human-AI collaboration. At the end of the course, students have a solid understanding of how to team up human and AI agents, ensure necessary aspects like transparency, fairness, and appropriate reliance and how meaningful collaboration can be facilitated while considering the individual strengths of both entities.
Content	In this lecture, we will dive into the most prominent topics when it comes to the effective collaboration between humans and AI. These topics include (among others): • General Introduction on how AI systems are trained • Transparency / Explainable AI • Fairness in AI • Complementarity Team Performance • Appropriate Reliance • Data-centric AI • Foundation Models, Generative AI, and Large Language Models • Requirements for effective Human AI teams
Duration	One semester (2 lecture hours per week)
Language	English
Teaching Method	Lecture, discussion rounds, and exercises.
Credit Points	6
Work Load	180 h total (30 h Active in-class participation, 30 h Flipped classroom videos, 60 h Scientific writing and presentation preparation, 60 h Exam preparation)
Recommended Prerequisites	Probability Theory and Statistics
Grading	The module examination consists of a written exam (60 min), the submission a scientific paper and the presentation and defense of the contents.
Frequency	Every year in the Summer semester

Title	Process Mining II
Module Label	F2.2
Module Type	Lecture
Area of Research	Business Informatics
Responsible	Prof. Dr. Agnes Koschmider
Learning Outcomes	In recent years many process mining algorithms have been developed and several process mining techniques have been successfully transferred into commercial applications. To fuel novel use cases based on event log analysis, several techniques require adoption. The intention of this course is to discuss scientific papers addressing solutions paving the way for novel use cases based on event log analysis.
Content	• Understand advanced process mining techniques and can apply them in practice • Understand shortcomings of process mining techniques • Capture future directions of process mining • Scalable process discovery • Event-activity correlation • Clustering techniques for event logs • Predictive performance monitoring • Noise and incompleteness in process mining • Quality of discovered models • Process mining for python
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (1 h/week)
Credit Points	5
Work Load	150 h total (45 h contact 75 h preparation and follow-up, 30 h exam preparation)
Recommended Prerequisites	Process Mining I
Grading	Coursework: Active participation in the courses and tutorials Examination: Written exam
Frequency	Every year in the Summer semester

Title	Foundations of Entrepreneurship I
Module Label	F2.3
Module Type	Lecture
Area of Research	Business
Responsible	Prof. Dr. Rebecca Preller
Learning Outcomes	In this course, students will learn the basics of entrepreneurship and develop their own ideas to solve technological, social, and/or ecological problems.
Content	Students will learn tools and practices to identify, evaluate, and select opportunities. They will learn creativity techniques and engage in feedback processes to refine their business opportunities. Students will learn how to apply these tools and practices in practice-oriented workshops and will be coached during their teamwork.
Duration	One semester (typically blocked format with workshop character)
Language	English
Teaching Method	Workshops, talks, coaching
Credit Points	5
Work Load	150 h total (45 h Contact hours in teaching units (approx.), 60 h Preparation and follow-up, literature study, 45 h Exam preparation)
Recommended Prerequisites	
Grading	The module examination typically consists of a presentation (opportunity development and reflection on learning)
Frequency	Every year in the Winter semester

Title	Foundations of Entrepreneurship II
Module Label	F2.4
Module Type	Lecture
Area of Research	Business
Responsible	Prof. Dr. Rebecca Preller
Learning Outcomes	In this course, students will deepen their knowledge and understanding of the concept of entrepreneurship.
Content	Students will learn tools and practices for developing and testing prototypes with stakeholders, working successfully in a founding team, and pitching their business ideas. They will also learn about funding options for their ventures. Students will learn how to apply these tools and practices in hands-on workshops and will be coached during their teamwork.
Duration	One semester (typically blocked format with workshop character)
Language	English
Teaching Method	Workshops, talks, coaching
Credit Points	5
Work Load	150 h total (45 h Contact hours in teaching units (approx.), 60 h Preparation and follow-up, literature study, 45 h Exam preparation)
Recommended Prerequisites	Foundations of Entrepreneurship I
Grading	The module examination typically consists of a presentation (opportunity development and reflection on learning)
Frequency	Every year in the Summer semester

Title	Data Science Project
Module Label	F2.5
Module Type	Project
Area of Research	Business Informatics
Responsible	Prof. Dr. Agnes Koschmider, Prof. Dr. Niklas Kühl
Learning Outcomes	In this course, students learn how to apply data science methods (especially in the areas of machine/deep learning) to solve Applied AI problems. Students usually apply the programming languages R or Python to the problem.
Content	The course covers elected problems from the entire field of data science (including data collection, method adaptation, visualization).
Duration	One semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (1 h/week)
Credit Points	5
Work Load	150 h total (45 h preparation, participation attendance, 90 h preparation of thesis, 15 h preparation of talk, literature study)
Recommended Prerequisites	Applied AI
Grading	The module includes the submission of a documentation, presentation and defense of the content as well as the active participation in the discussion of other seminar topics.
Frequency	Every year in the Winter semester

Title	Seminar Applied AI
Module Label	F2.6
Module Type	Seminar
Area of Research	Business Informatics
Responsible	Prof. Dr. Agnes Koschmider
Learning Outcomes	In this course, participants learn about current topics from Applied AI in research and assess it from a scientific perspective. Participants learn how to independently research and conduct an appropriate literature search. The students learn how to summarize problems from a scientific perspective as part of a homework assignment. Students develop a presentation that highlights key findings and summarizes key aspects of the written paper within a group discussion.
Content	The topics to be worked on are based on ongoing developments in the field of Applied AI.
Duration	One semester or block seminar
Language	English
Teaching Method	Seminar (2 h/week)
Credit Points	5
Work Load	150 h total (30 h contact, 120 h preparation)
Recommended Prerequisites	Applied AI
Grading	The module includes the submission of a written thesis according to scientific formal requirements, presentation and defense of the content as well as the active participation in the discussion of other seminar topics
Frequency	Every year in the Summer semester

6.3 Obligatory Modules for Specialisation Human-Centered Data Science F3

Title	Introduction to Practical Philosophy
Module Label	F3.1, Fak526053
Module Type	Lecture
Area of Research	Philosophy
Responsible	Prof. Dr. Johanna Thoma
Learning Outcomes	Students learn how to deal with basic texts, concepts, and problems of practical philosophy in a methodically reflective way, thus training their reflective competence.
Content	Essential knowledge and methods within practical philosophy are taught as exemplified in a specific field of practical philosophy (e.g., ethics, political philosophy). Students get to know basic concepts, questions, and approaches of that subfield. Students practice analyzing philosophical thinking and argumentation.
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week)
Credit Points	5
Work Load	150 h total (30 h contact, 120 h self-study)
Recommended Prerequisites	
Grading	Written or oral exam, or semester tasks with written announcement in advance (on eLearning or CampusOnline or cmlife or at start of event).
Frequency	Every year in the Summer semester

Title	Qualitative Research Methods
Module Label	F3.2
Module Type	Seminar
Area of Research	Sociology
Responsible	Prof. Dr. Larissa Schindler
Learning Outcomes	This module provides participants with an overview on current methods of qualitative research in sociology. One main goal is to understand the methodological principles of this approach. The other main goal is to practice specific methods, e.g.: Observation, Interview, or Discourse Analysis. Students will also learn how to gather and how to analyze qualitative data.
Content	The premise of qualitative social research is the assumption that the social world is not simply a given, 'objective' reality, but that it is constituted through constructions of meaning and in material social practice, and hence always already interpreted and pre-structured. The qualitative researchers' aim is to reconstruct how members of societies, groups, or practice fields make sense of and construct their everyday reality in the first place, and to develop methodically controlled "second order constructions" (Alfred Schütz) of these processes. To this end, qualitative researchers collect and produce mainly non-standardized data. Over the last decades, many different methods and methodical approaches of data collection and data analysis have been established in the field of qualitative research. This module provides an overview of key qualitative strategies, for example, participant observation, interviews, or discourse analysis. Building on a general introduction to basic qualitative research principles, we develop both a theoretical and practical understanding of qualitative research methods. We address their epistemological premises, the practice of data collection and production, typical types of data, as well as strategies for data analysis.
Duration	1 semester
Language	English
Teaching Method	2 h/week
Credit Points	5
Work Load	150 h total (30 h contact, 120 h self-study)
Recommended Prerequisites	
Grading	Oral presentation and written exam
Frequency	Every year in the Summer semester

Title	Applied Data Analysis I
Module Label	F3.3
Module Type	Seminar
Area of Research	Data Science
Responsible	Prof. Dr. Mirco Schönfeld
Learning Outcomes	After successful participation, students have developed a basic level of operationalization of research questions and an understanding of the most important conceptual basics to conduct independent data analyses. They are able to apply methodological knowledge to diverse application scenarios selecting the right tools to analyze data appropriately.
Content	This course covers the entire pipeline of data analysis beginning with the formulation of a problem statement, and concluding with a critical reflection of results. It introduces and deepens basic techniques, methodologies, and practical skills to process and analyze data at scale. Students of this course will conduct independent analyses taking fundamental steps of the data science pipeline: data wrangling, data interpretation, data visualization, and reporting. Students are invited to formulate their own relevant research questions to conduct meaningful analyzes of real-world datasets. The results of data analyzes will be curated into a poster which will be presented and defended. The methodological focus of this module should be noticeably different from Applied Data Analysis II. For this module, a methodological focus on social network analysis is appropriate.
Duration	1 semester
Language	English
Teaching Method	2 h/week
Credit Points	5
Work Load	150 h total (30 h contact, 120 h self-study)
Recommended Prerequisites	
Grading	Submission and presentation of a poster according to scientific formal requirements and defense of the poster's content; or semester tasks with written announcement in advance
Frequency	Summer semester

Title	Applied Data Analysis II
Module Label	F3.4
Module Type	Seminar
Area of Research	Data Science
Responsible	Prof. Dr. Mirco Schönfeld
Learning Outcomes	After successful participation, students have strengthened their skill in operationalizing research questions and deepened their competencies to conduct independent data analyses. They are able to transfer methodological knowledge to diverse application scenarios selecting the right tools to analyze data appropriately.
Content	This course covers the entire pipeline of data analysis beginning with the formulation of a problem statement, and concluding with a critical reflection of results. It introduces and deepens basic techniques, methodologies, and practical skills to process and analyze data at scale. Students of this course will conduct independent analyses taking fundamental steps of the data science pipeline: data wrangling, data interpretation, data visualization, and reporting. Students are invited to formulate their own relevant research questions to conduct meaningful analyzes of real-world datasets. The results of data analyzes will be curated into a poster which will be presented and defended. The methodological focus of this module should be noticeably different from Applied Data Analysis I. For this module, a methodological focus on text mining is appropriate.
Duration	1 semester
Language	English
Teaching Method	2 h/week
Credit Points	5
Work Load	150 h total (30 h contact, 120 h self-study)
Recommended Prerequisites	
Grading	Submission and presentation of a poster according to scientific formal requirements and defense of the poster's content or semester tasks with written announcement in advance
Frequency	Every year in the Winter semester

Title	Philosophy of the Social Science
Module Label	F3.5
Module Type	Lectures and Seminars
Area of Research	Philosophy
Responsible	Prof. Dr. Patricia Rich
Learning Outcomes	• Knowledge of central concepts, terms and methods employed in different areas of social scientific research. • The ability to identify and critically evaluate the descriptive and normative presuppositions of social scientific theories. • The ability to integrate philosophical and social scientific theories in an original and cogent fashion • Gain awareness and understanding of the most important issues in the philosophy of the social sciences. • Increase familiarity with the methodological practices of the individual social sciences. • Appreciate both the capacities and limitations of the social sciences that result from their subject matter and methodology. • Practice reading and critically evaluating philosophical texts. • Work to synthesize different arguments and viewpoints for a unified understanding or even a new perspective. • Develop your philosophical writing skills. In particular, gain experience revising, expanding, and following up on your own writing
Content	In this module, students explore the extent to which the social sciences can be objective or instead must proceed through interpretation, subjective judgment, and the application of values. We will see that the traditional conception of science as objective cannot be maintained even for natural science, but that a different kind of objectivity is still attainable. Another aspect of this module examines the primary goal of social science research: Explanation. We consider the main theories of explanation and compare their suitability for diverse scenarios. These foundational aspects will be discussed and explored also in application scenarios to understand particular problems of social science explanations. One such scenario can be the field of economics in which explanatory problems become especially pressing. Overall, in this module, students will learn how philosophical issues play out in everyday scientific practice.
Duration	1 semester
Language	English
Teaching Method	4h/week
Credit Points	10
Work Load	300 h total (60 h contact, 240 h self-study)
Recommended Prerequisites	
Grading	A written examination (40%), essays (totaling approx. 6000 words; 50%), and active participation including answering reading questions (10%).
Frequency	Every year in the Winter semester

Title	AI in Society I
Module Label	F3.6
Module Type	Lecture
Area of Research	Philosophy
Responsible	Prof. Dr. Lena Kästner
Learning Outcomes	In this module, students delve into philosophical reflections on the impact of modern information technologies for society. They get acquainted with philosophical concepts, approaches and arguments and learn to critically reflect upon AI in society.
Content	This module consists of courses offering reflections on the various ways in which information technologies, especially artificial intelligence and machine learning-based systems, impact modern society. The courses will usually be interdisciplinary in nature, combining discussions on philosophical issues with those on technological developments and potentials. On a topic of their choosing, students learn to improve their competencies in dealing with philosophical questions. They practice to present and defend their own positions in light of contemporary and/or historical debates, explain their positions and arguments verbally or in writing, and engage in philosophical debates.
Duration	1 semester
Language	English
Teaching Method	Lecture (2 h/week)
Credit Points	5
Work Load	150 h total (30 h contact, 120 h self-study)
Recommended Prerequisites	Basic knowledge in theoretical and/or practical philosophy, depending on the courses chosen.
Grading	The module examination typically consists of a term paper, oral exam or semester tasks.
Frequency	Every semester

Title	Critical Data Studies
Module Label	F3.7
Module Type	Seminar
Area of Research	Data Science
Responsible	Prof. Dr. Mirco Schönfeld
Learning Outcomes	By successfully participating in this seminar, students develop an understanding of data practices and a critical view of them.
Content	The collection and analysis of large amounts of data now influences all areas of our lives. Critical Data Studies (CDS) explores the cultural, ethical and socio-technical challenges at the interface between computer science, the humanities and social sciences, and society. Students critically examine topics such as artificial intelligence, big data, data science, data ethics, privacy, fake news, and discuss how data systems and algorithms can contribute to solving social problems. Students develop their own scientific questions and work on them in small groups during the semester.
Duration	1 semester
Language	English
Teaching Method	2 h/week
Credit Points	6
Work Load	180 h total (30 h contact, 150 h self-study)
Recommended Prerequisites	
Grading	Submission and presentation of a poster according to scientific formal requirements and defense of the poster's content; or semester tasks with written announcement in advance
Frequency	Every year in the Summer semester

Title	Digital Humanities / Computational Social Science Lab
Module Label	F3.8
Module Type	Practical Course
Area of Research	Data Science
Responsible	Prof. Dr. Mirco Schönfeld
Learning Outcomes	Students gain profound insights into the process of knowledge production in the field of humanities and/or social sciences. They deepen their understanding of data analyzes in diverse application scenarios. By successfully participating, students have also acquired basic communication skills to discuss research questions with scholars and students from other disciplines.
Content	An important skill for data scientists is their ability to understand problems and questions from other (scientific) fields, being able to select appropriate data as well as applying or adapting an appropriate tool or method to provide insights into the original question. In this module, students will work on real-world problems following inter- and transdisciplinary research questions that might stem from the humanities, social sciences, or other fields.
Duration	1 semester
Language	English
Teaching Method	2 h/week
Credit Points	10
Work Load	300 h total (60 h contact, 240 h self-study)
Recommended Prerequisites	Profound understanding of data analysis; some knowledge of data scientific methods for diverse application scenarios; ability to conduct independent data analyzes.
Grading	Scientific paper, including its presentation and defense; or written essays including their presentation and defense; or semester tasks with written announcement in advance.
Frequency	Every year in the Summer semester

Title	Probability Theory and Statistics (for HCDS)
Module Label	F3.9
Module Type	Lecture
Area of Research	Mathematics
Responsible	Prof. Dr. Melanie Birke
Learning Outcomes	• Understanding mathematical arguments behind probabilistic and statistical methods • Knowledge of standard statistical methods to analyze data sets • Ability to statistically analyze data sets
Content	• Basic probability theory (probability space, probability measure, measurability, random variables) • Advanced concepts (independence and conditional probability, distribution function, density, standard distributions, expectation, variance and covariance) • Descriptive statistics (primarily visualization) • Maximum-likelihood estimation and confidence intervals (uncertainty quantification); optionally concentration inequalities (Hoeffding) • Bayesian statistics (prior / posterior distribution, Bayes estimator / risk)
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (1 h/week)
Credit Points	5
Work Load	2 h lectures plus 2 h post-processing per week = 60 h; 1 h discussion sections plus 3 h preparation/post-processing = 60 h; 30 h preparation for exam, in total: 150 h
Recommended Prerequisites	Foundations of Higher Mathematics, Mathematical Analysis, Linear Algebra
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every year in the Summer semester

7 Module Section G: Additional Topics

7.1 Elective Modules for Specialisation Natural and Life Sciences G3

Title	Applied Theoretical Physics
Module Label	G3.1, Fak116370
Module Type	Lab Course
Area of Research	Physics
Responsible	Prof. Dr. Stephan Gekle
Learning Outcomes	• Ability to apply the methods and approaches of theoretical physics to actual scientific problems • Ability to describe complex systems with physical models • Ability to derive concrete predictions from physical models
Content	Computer experiments selected from the fields of biological physics, soft matter physics, physics of chaos and turbulence, charge transport simulations, and machine learning.
Duration	1 semester
Language	English
Teaching Method	Computer experiments conducted by the students using both already prepared codes and small programs implemented by the students
Credit Points	5
Work Load	150 h total (10 h project discussion, 120 h computer experiment preparation, 20 h preparation of report and presentation)
Recommended Prerequisites	General Physics I & II, Linear Algebra, Introduction to Programming
Grading	Presentation
Frequency	Every semester

Title	Methods of Molecular Simulation
Module Label	G3.2, Fak114087
Module Type	Lecture
Area of Research	Physics
Responsible	Prof. Dr. Harald Oberhofer
Learning Outcomes	Upon successful completion of the course students are able to list basic techniques and algorithms of molecular simulation and state their qualitative concepts. They know the use and contribution of these techniques to address molecular problems. They can classify the applicability and limitations of the different techniques. They are able to use the acquired methods to perform simple simulations.
Content	• Local and global geometry optimization • Ab initio thermodynamics • Molecular dynamics • Monte Carlo approaches • Free energy simulation methods • Long-time scale simulation and kinetic Monte Carlo
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (2 h/week)
Credit Points	5
Work Load	150 h total (60 h attendance, 60 h preparation and follow-up, 30 h exam preparation)
Recommended Prerequisites	General Physics I & II
Grading	Oral or written exam; active participation in the tutorials
Frequency	Every year in the Summer semester

Title	Seminar Science and Life sciences
Module Label	G3.3
Module Type	Seminar
Area of Research	Science, Engineering and Life Science
Responsible	Professors of the Science and Life Sciences specialisation
Learning Outcomes	In this seminar, participants learn about current topics from the Sciences and Life Sciences and assess them from a scientific perspective. They will be assigned specific current publications and learn how to interpret and scientifically summarize them. Students will give a presentation that highlights key aspects of the assigned paper. Next to the scientific content, the main learning goal will be how to effectively present scientific results to an audience.
Content	The topics to be worked on are based on ongoing developments in the Sciences and Life Sciences.
Duration	1 semester
Language	English
Teaching Method	seminar (2 h/week)
Credit Points	5
Work Load	150 h total (60 h participation and attendance, 90 h literature study and preparation of talk)
Recommended Prerequisites	General Physics I & II, General Chemistry I & II, General Life Sciences
Grading	Tasks to be completed throughout and at the end of the semester in the form of written reports, oral contributions, presentations, or practical work (e.g., programming assignments, literature overview).
Frequency	Every year in the Summer semester

Title	Quantum Chemistry: Methods and Algorithms
Module Label	G3.4
Module Type	Lecture
Area of Research	Chemistry
Responsible	Prof. Dr. Johannes Margraf
Learning Outcomes	Knowledge on quantum chemical methods and algorithms for predicting the electronic properties of molecules. Participants will learn how to implement important algorithms and how to use these methods in example problems of molecular design or computational chemistry.
Content	This lecture treats the theoretical foundations of modern quantum chemistry, including the LCAO approach to molecular electronic structure, density functional theory (DFT) for exchange and correlation, basis sets, molecular integrals, density fitting, self-consistent field algorithms (solvers, convergence acceleration, direct methods), energy gradients, exact exchange and hybrid DFT, many-body methods for electron correlation (CI, MP2, CC), and property prediction. The practical course will cover the implementation of a self-consistent field and MP2 code, and the use of this code in examplary applications.
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and practical course (3 weeks)
Credit Points	5
Work Load	2 h lectures plus 2 h post-processing per week = 60 h; 60 h practical course; 30 h preparation for exam; in total: 150 h
Recommended Prerequisites	General Chemistry I & II, General Physics I & II, Linear Algebra, Mathematical Analysis
Grading	Oral or written exam; active participation in the practical course
Frequency	Every year in the Winter semester

Title	Biochemistry and Biotechnology
Module Label	G3.5, Fak726346
Module Type	Lecture
Area of Research	Life Sciences/Biochemistry
Responsible	Prof. Dr. Gerald Lackner
Learning Outcomes	Students will be introduced to foundational concepts in biochemistry and biotechnology, with a focus on their applications in food technology. The biochemistry segment will provide the molecular groundwork necessary to understand the biotechnological techniques explored in subsequent sections. This knowledge will prepare students to effectively use and critically evaluate biotechnological methods in production or research scenarios.
Content	Basics of biochemistry • Protein and enzyme biochemistry • Bioenergetics • Biochemical pathways of microorganisms relevant in food production • Basics of molecular biology of bacteria Basics of Biotechnology: • Molecular cloning, DNA technology • Protein / enzyme technology • Fermentation technology Practical course (examples): • Genetic techniques • Fermentation • Protein purification
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and laboratory course (3 h/week)
Credit Points	5
Work Load	150 h total (75 h attendance, 75 h preparation and follow-up)
Recommended Prerequisites	General Chemistry I & II, General Life Sciences
Grading	Oral or written exam (70%); practical course and lab records (30%)
Frequency	Every year in the Winter semester

Title	Food Chemistry and Analytics I
Module Label	G3.6
Module Type	Lecture
Area of Research	Life Sciences/Biochemistry
Responsible	Prof. Dr. Susanne Baldermann
Learning Outcomes	The students acquire basic knowledge about the composition of food. After completing the course, students will: • know the structure and properties of macronutrients such as carbohydrates, proteins and lipids • have acquired basic knowledge of micronutrients such as vitamins, minerals and secondary plant metabolites • be able to characterize important food ingredients
Content	Lecture • basic knowledge in food chemistry, including macro and minor components, minerals, trace elements, vitamins and phytochemicals • basic knowledge about analytical methodologies used in food analysis Lab work • basic analysis of the food composition
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and practical work in the lab (30 hours)
Credit Points	5
Work Load	150 h total (60 h attendance, 90 h self-study incl. assessment)
Recommended Prerequisites	General Chemistry I
Grading	Oral or written exam (60%); practical course and lab records (40%)
Frequency	Every year in the Summer Semester

Title	Food Chemistry and Analytics II
Module Label	G3.7
Module Type	Lecture
Area of Research	Life Sciences/Biochemistry
Responsible	Prof. Dr. Susanne Baldermann
Learning Outcomes	The students acquire detailed and differentiated knowledge about the composition of food. Upon completion of the course, students will: • have profound knowledge of the composition of different categories of food • have a basic knowledge of residues and contaminants • understand important chemical reactions during the processing, storage and preparation of foods
Content	Lecture • different categories of food • residues and contaminants • changes induced by processing, storage and preparation of foods • instrumental analytical techniques used in food analysis such as spectroscopy, chromatography and mass spectrometry Lab work • sample preparation, instrumental analysis as well as data analysis and interpretation
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and practical work in the lab (30 hours)
Credit Points	5
Work Load	150 h total (60 h attendance, 90 h self-study incl. assessment)
Recommended Prerequisites	General Chemistry I & II, General Life Sciences, Food Chemistry and Analytics I
Grading	Oral or written exam (60%); practical course and lab records (40%)
Frequency	Every year in the Winter semester

Title	Fundamentals of Signals and Systems for Electrochemical Energy Storage Systems
Module Label	G3.8, Fak626619
Module Type	Lecture
Area of Research	Engineering
Responsible	Prof. Dr.-Ing. Jan Philipp Schmidt
Learning Outcomes	By the end of the course, students will be able to: • perform classification of signals and systems • apply convolution for simple problems • understand Fourier-Series, Fourier and Laplace transforms and apply these to solve simple problems • explain the relationship between signals and systems • master different approaches to mathematically describe the output-input behaviour • explain the relationship between transfer function and complex impedance • perform time discretization of continuous systems • explain and apply the Nyquist-Shannon sampling theorem • apply the z-transform to simple problems
Content	The understanding of signals and systems is used in many specialised methods when dealing with batteries (i.e., impedance spectroscopy). This alignment module is intended to provide a basis for understanding basic modeling and simulation methods as applied to battery technology. It includes Fourier series, Fourier transform, Laplace transform in the application for the analysis of signals but also for the solution of differential equations. Basic signals like unit step, Delta-Dirac and pulse train are introduced. Hereby it becomes possible to switch between periodic and aperiodic signals, as well as between continuous-time and discrete-time signals and systems. Finally, the z-transform is introduced for discrete-time systems.
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (2 h/week)
Credit Points	5
Work Load	150 h total (60 h attendance, 45h preparation and follow-up, 45h exam preparation)
Recommended Prerequisites	Mathematical Analysis, Linear Algebra
Grading	written exam
Frequency	Every Semester

Title	Fundamentals of Electrical Engineering for Electrochemical Energy Storage Systems
Module Label	G3.9, Fak626617
Module Type	Lecture
Area of Research	Engineering
Responsible	Prof. Dr.-Ing. Vincent Lorentz
Learning Outcomes	Understanding of the physical electromagnetic effects occurring in electric resistors, capacitors, inductors, and transformers. Analyzing (node-voltage analysis) all kinds of electric networks containing voltage and current sources (DC and AC), resistors, capacitors, inductors, and transformers.
Content	• The electrostatic field (i.e., electric charges and electric charge densities; Coulomb's law; Coulomb force; the electric field strength; the electric flux density and the electric flux; Gauss's law; field lines and equipotential lines; the electric potential; potential difference and electric voltage; work, power and energy; the electric induction and the electric polarization; the capacitance and the capacitor) • The stationary electric flow field (i.e., the electric current and the electric current density; Ohm's law in differential and integral form; conductivity and resistivity; the electric resistance and the electric resistor) • DC networks (i.e., ideal and real voltage and current sources; networks; one-port and two-port component; branch, mesh and node; Kirchhoff's circuit laws: Kirchhoff current law (KCL) and Kirchhoff voltage law (KVL)) • The magnetostatic field (i.e., magnets; the Laplace force; the Lorentz force; the magnetic field strength; the magnetic flux density, the magnetic flux and the magnetic total flux; Ørsted's law and Ampère's circuital law; the current linkage) • The electromagnetic field (i.e., Faraday's law of induction; Lenz's law; the self-induction; the inductance and the inductor; the inductive coupling and the mutual inductance; turns and windings; the transformer and the transformation ratio; Maxwell's equations) • AC networks (i.e., characteristic parameters of periodic signals; complex calculus with phasors and amplitude phasors; impedance and admittance; resistance und conductance; reactance and susceptance; active power, reactive power, apparent power and complex apparent power; power factor and displacement angle) • Transient states (i.e., continuity conditions in capacitors and inductors; analysis of networks with one storage element)
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (2 h/week)
Credit Points	5
Work Load	150 h total (60 h attendance, 45h preparation and follow-up, 45 h exam preparation)
Recommended Prerequisites	
Grading	written exam
Frequency	Every Semester

Title	Geology and Geophysics
Module Label	G3.10, Fak110541
Module Type	Lecture
Area of Research	Geophysics
Responsible	Prof. Dr. Gregor Golabek
Learning Outcomes	• Understanding basic physical and chemical principles that operate in and on the Earth • Understanding of geologic time and length scales • Application of basic physical and chemical principles in a planetary context
Content	• Earth's basic internal structure, minerals, Earth's rock cycle, magmatic rocks, volcanism, sedimentary rocks, weathering and erosion, metamorphic rocks, rock deformation, basics on plate tectonics, Earth's formation and evolution until present-day. • Gravity and shape of the Earth, earthquakes and seismology, Earth structure, Earth's magnetic field and the geodynamo.
Duration	1 semester
Language	English
Teaching Method	Lectures (4 h/week)
Credit Points	5
Work Load	150 h total (60 h attendance, 60h preparation and follow-up, 30 h exam preparation)
Recommended Prerequisites	
Grading	oral or written exam
Frequency	Every year in the Summer semester

Title	Physics of Planetary Bodies
Module Label	G3.11
Module Type	Lecture
Area of Research	Geophysics
Responsible	Prof. Dr. Gregor Golabek
Learning Outcomes	• Comparison of Earth with other planets in our solar system • Advanced understanding of terrestrial, ice giant and gas giant planets • Application of physics and numerical methods to understand planetary dynamics.
Content	• Earth's thermal structure and composition, rheology of Earth's mantle, fluid dynamics relevant for Earth and terrestrial planets, mantle convection, driving mechanisms of plate tectonics, plumes and hotspots, lithosphere deformation, Earth's deep interior dynamics, early Earth dynamics, Dynamics of the other terrestrial planets. • Atmospheres of terrestrial, ice giant and gas giant planets, Planetary surfaces of terrestrial and icy objects, Interior structures of terrestrial, ice giant and gas giant planets, asteroids and meteorites, comets and icy objects in the outer solar system, planetary rings, magnetospheres of terrestrial, ice giant and gas giant planets, comparison of the Sun vs. other stars, star and planet formation, exoplanets and astrobiology
Duration	1 semester
Language	English
Teaching Method	Geodynamics: Lectures (2 h/week) and exercises (1 h/week) Planetary Physics: Lecture (2 h/week) and exercises (1 h/week)
Credit Points	7
Work Load	210 h total (120 h attendance, 60 h preparation and follow-up, 30 h exam preparation)
Recommended Prerequisites	Geology and Geophysics
Grading	oral or written exam
Frequency	Every year in the Winter semester

Title	Bioinformatics: Molecular Modeling
Module Label	G3.12
Module Type	Lecture and practical course
Area of Research	Prof. Dr. Matthias Ullmann
Responsible	Bioinformatics / Structural Biology
Learning Outcomes	Knowledge on modeling and analysis of biomolecular processes such as enzymatic reactions
Content	The lecture treats the theoretical foundations of molecular modeling (molecular force fields, biomolecular electrostatics, classical and statistical mechanics), their numerical designs (molecular dynamics simulations, energy minimization and normal mode analysis, Monte Carlo simulations), fundamentals quantum chemical methods as well as the modeling of biochemical reactions and ligand binding. In the practical course, various techniques (including analysis of biomolecular structures, computation of electrostatic properties of biomolecules, normal-mode analysis) will be exemplified by selected case studies to provide students with practical demonstrations of these methods.
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and practical course (3 weeks)
Credit Points	5
Work Load	150 h total (2 h lectures plus 2 h post-processing per week = 60 h; practical course = 45 h; 15 h preparation for exam)
Recommended Prerequisites	General Chemistry I & II, General Life Sciences
Grading	Oral or written exam; active participation in the practical course
Frequency	Every year in the Winter semester

7.2 Elective Modules for Specialisation Applied AI and Data Science G4

Title	Data Analysis and Visualization
Module Label	G4.1
Module Type	Lecture
Area of Research	Business Informatics
Responsible	Prof. Dr. Agnes Koschmider
Learning Outcomes	In this course, students will learn the principles of data analysis and visualization. This module primarily focuses on essential statistics for data analysis and data visualization.
Content	The lecture is essentially divided into two parts. In the first part, the understanding of statistical methods and techniques are further enhanced. This includes formulating hypotheses, testing statistical significance, applying various regression models, and identifying and understanding outliers and anomalies in data. In the second part, students learn advanced techniques for data and information visualization. They use a range of tools and techniques to visually represent complex datasets and effectively communicate their findings.
Duration	1 semester
Language	Engish
Teaching Method	Lectures (2 h/week) and tutorials (1 h/week)
Credit Points	5
Work Load	150 h total (45 h attendance, 45 h preparation and follow-up, 30 h exam preparation)
Recommended Prerequisites	Probability Theory and Statistics
Grading	Written exam
Frequency	Every year

7.3 Elective Modules for Specialisation Human-Centered Data Science G5

Title	Introduction to Theoretical Philosophy
Module Label	G5.1
Module Type	Lecture
Area of Research	Philosophy
Responsible	Prof. Dr. Cristina Borgoni
Learning Outcomes	Students learn basic concepts in theoretical philosophy (e.g., knowledge, language, mind, science) and build reflective competences they can apply broadly by engaging with various questions in the field.
Content	The module covers core concepts and methods in theoretical philosophy, focusing on a specific area such as epistemology, philosophy of science, philosophy of mind, or philosophy of language. It introduces foundational concepts, questions, and approaches within that area and includes practice in analyzing philosophical ideas and arguments.
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week)
Credit Points	5
Work Load	150 h total (30 h contact, 120 h self-study)
Recommended Prerequisites	
Grading	Written or oral exam, or semester tasks with written announcement in advance (on eLearning or CampusOnline or cmlife or at start of event).
Frequency	Every year in the Summer semester

Title	Data Modeling and Knowledge Generation
Module Label	G5.2, Fak421728
Module Type	Lecture
Area of Research	Data Science
Responsible	Prof. Dr. Mirco Schönfeld
Learning Outcomes	After successful participation, students have a profound understanding of different methods for data analysis and knowledge generation with a focus on different ways how knowledge is produced. Students become aware of the requirements for the necessary data models that the various analysis methods entail. Students understand how to critically question data analyzes, how to identify implicit modeling decisions, and how to evaluate analysis results against the background of these decisions.
Content	Data models represent the real world in the analysis process, they act as a kind of placeholder. As such, they create their own reality for the analyzes. The formulation of data models is always subject to conscious and unconscious selection and transformation decisions. These decisions suddenly influence the way in which algorithms and analysts understand and process the real world. At the same time, data models act as blueprints for a real world after analysis. Finally, analysis results are produced, evaluated and communicated as new knowledge with the help of data models. The aforementioned decisions therefore have far-reaching implications for the expected results and the insights that can be gained from these results. This dual role of description and prescription opens up a field of tension for the analysis process in interdisciplinary research as well as in numerous business areas that make use of “data-driven decision making”. Only when the data model, algorithm and results are considered as a holistic unit of an analysis process can reliable knowledge be gained from data. This course provides insights into different methods for data analysis and knowledge generation – including methods from the fields of machine learning, data mining, text mining, social network analysis and information visualization. These methods, which are currently used extensively in science, business and beyond, entail different requirements for the modeling of data. These requirements are critically examined. The implications for the expected results and the knowledge derived from them are explicitly stated.
Duration	1 semester
Language	English
Teaching Method	Lectures (2 h/week) and tutorials (1 h/week)
Credit Points	5
Work Load	150 h total (45 h contact, 105 h self-study)
Recommended Prerequisites	-
Grading	Oral or written exam, or semester tasks with written announcement in advance
Frequency	Every year in the Winter semester

Title	Causal Inference
Module Label	G5.3
Module Type	Seminar
Area of Research	Data Science
Responsible	Prof. Dr. Karolina Milewicz
Learning Outcomes	By the end of term, you will be able to apply basic regression discontinuity; matching; difference-in-differences; and instrumental variable designs.
Content	Why can't we just run a linear regression and claim that its estimates tell us something about how the world works? While methodological advances have made it easier than ever to run complex models of all kinds, the causal revolution tells us that it at least as important to be aware what our research design can tell us about actual effects - and when they fail to do this. This course introduces the fundamental problem of causal inference and the limitations of regression-based analysis. Combining theory and practice, we will discuss the foundations of identification strategies that allows us to make causal claims and apply them in our weekly labs.
Duration	1 semester
Language	English
Teaching Method	4 h/week
Credit Points	5
Work Load	150 h total (60 h contact, 90 h self-study)
Recommended Prerequisites	
Grading	Oral or written exam
Frequency	Every year in the Summer semester

Title	Technology and Society I
Module Label	G5.4
Module Type	Seminar, Lecture, or Practical Course
Area of Research	Interdisciplinary Topics
Responsible	Prof. Dr. Mirco Schönfeld
Learning Outcomes	After successful participation, students have developed a basic level of interdisciplinary communicative skills. They have either acquired new methodological competencies in methods of humanities or social sciences, or they have developed an understanding of conducting independent data analyses in interdisciplinary contexts. In any case, students are able to transfer methodological knowledge to diverse application scenarios selecting the right tools to approach various problems appropriately.
Content	In this module, students familiarize themselves with interdisciplinary settings by attending courses with relation to the humanities or social sciences that may introduce methods of said fields, that relate to data collection, data management, data analysis, or data modeling or that take a critical look at information systems, social media, artificial intelligence, or other related topics.
Duration	1 semester
Language	English
Teaching Method	2 h/week
Credit Points	5
Work Load	150 h total (30 h contact, 120 h self-study)
Recommended Prerequisites	
Grading	Examination typically consists of an oral or written exam, or semester tasks with written announcement in advance, or presentation, or written report
Frequency	Every year in the Summer semester

Title	Technology and Society II
Module Label	G5.5
Module Type	Seminar, Lecture, or Practical Course
Area of Research	Interdisciplinary Topics
Responsible	Prof. Dr. Mirco Schönfeld
Learning Outcomes	After successful participation, students have strengthened their level of interdisciplinary communicative skills. They have further strengthened their methodological knowledge in the field of humanities or social sciences, or they deepened an understanding of conducting independent data analyses in interdisciplinary contexts. Students are competent to transfer methodological knowledge to diverse application scenarios selecting the right methods to approach various interdisciplinary problems appropriately.
Content	In this module, students familiarize themselves with interdisciplinary settings by attending courses with relation to the humanities or social sciences that may introduce methods of said fields, that relate to data collection, data management, data analysis, or data modeling or that take a critical look at information systems, social media, artificial intelligence, or other related topics.
Duration	1 semester
Language	English
Teaching Method	2 h/week
Credit Points	5
Work Load	150 h total (30 h contact, 120 h self-study)
Recommended Prerequisites	
Grading	Examination typically consists of an oral or written exam, or semester tasks with written announcement in advance, or presentation, or written report
Frequency	Every year in the Winter semester

Title	AI in Society II
Module Label	G5.6
Module Type	Lecture
Area of Research	Philosophy
Responsible	Prof. Dr. Lena Kästner
Learning Outcomes	In this module, students delve into philosophical reflections on the impact of modern information technologies for society. They get acquainted with philosophical concepts, approaches and arguments and learn to critically reflect upon AI in society.
Content	This module consists of courses offering reflections on the various ways in which information technologies, especially artificial intelligence and machine learning-based systems, impact modern society. The courses will usually be interdisciplinary in nature, combining discussions on philosophical issues with those on technological developments and potentials. On a topic of their choosing, students learn to improve their competencies in dealing with philosophical questions. They practice to present and defend their own positions in light of contemporary and/or historical debates, explain their positions and arguments verbally or in writing, and engage in philosophical debates.
Duration	1 semester
Language	English
Teaching Method	Lecture (2 h/week)
Credit Points	5
Work Load	150 h total (30 h contact, 120 h self-study)
Recommended Prerequisites	Basic knowledge in theoretical and/or practical philosophy, depending on the courses chosen.
Grading	The module examination typically consists of a term paper, oral exam or semester tasks.
Frequency	Every semester

8 Module Section H: Bachelor Thesis

Title	Bachelor Thesis
Module Label	H1
Module Type	Bachelor Thesis
Area of Research	all areas
Responsible	Program moderator
Learning Outcomes	• Ability to conduct an independent scientific work in the chosen area of specialisation • Ability to present the results of own scientific work in written form as a thesis
Content	• The topic of the bachelor thesis is assigned by an authorized (prüfungsberechtigt) faculty member of the University of Bayreuth in agreement with the program moderator • The bachelor thesis must be submitted on time (15 weeks after the assignment of the topic for full-time students and 30 weeks for part-time students) in electronic form (pdf document) • The bachelor thesis must be written in English and must conform to the general guidelines for bachelor theses of the University of Bayreuth
Duration	2 semesters
Language	English
Teaching Method	
Credit Points	12
Work Load	360 h (editing time)
Recommended Prerequisites	
Grading	Written thesis
Frequency	

Title	Colloquium on Bachelor Thesis
Module Label	H2
Module Type	Bachelor Thesis
Area of Research	all areas
Responsible	Program moderator
Learning Outcomes	• Ability to present own scientific work in understandable and structured form • Ability to discuss and explain own scientific results • Ability to discuss and analyze other students' scientific results
Content	• Students prepare a presentation on the topic and the results of their bachelor thesis • Students give a 20-30 min. presentation on their bachelor thesis followed by a 10 min. discussion • Students attend all presentations given in bachelor colloquium and participate in discussions
Duration	1 semester
Language	English
Teaching Method	
Credit Points	3
Work Load	90 hours total (weekly or block seminars 30 h attendance, 60 h presentation preparation)
Recommended Prerequisites	
Grading	Presentation
Frequency	