UNIVERSITÄT ZU LÜBECK

Module Guide for the Study Path

Bachelor CLS 2023

Version from 1. October 2025

foundations of computer science

mathematics

Interdisciplinary modules

CS1000-KP08, CS1000SJ14-MML/MI, CS1000SJ14-MIW - Introduction to Programming (EinfProg14)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	8

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), foundations of computer science, 1st semester
- Bachelor MES 2020 (compulsory), computer science, 3rd semester
- Bachelor Medical Informatics 2019 (compulsory: aptitude test), computer science, 1st semester
- Bachelor MES 2014 (compulsory), computer science, 3rd semester
- Bachelor CLS 2010 (compulsory), foundations of computer science, 1st semester
- Bachelor Medical Informatics 2014 (compulsory: aptitude test), computer science, 1st semester
- Bachelor CLS 2016 (compulsory), foundations of computer science, 1st semester

Classes and lectures:

- Introduction to Programming (lecture, 2 SWS)
- Lab course Java / C++ (lecture, 2 SWS)
- Lab course Java / C++ (exercise, 2 SWS)

Workload:

- 130 Hours private studies
- 90 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Basic concepts of computer science: representation of information and numbers, hardware, software, operating systems, applications
- Algorithm, Specification, Program
- Syntax und Semantics of Programming Languages
- Basic concepts of imperative and OO programming
- Techniques of secure programming
- Programming in Java or C++
- Development environments for Java or C++

Qualification-goals/Competencies:

- Students can easily calculate in 2, 8 and 16 number systems and convert numbers into each other in these systems.
- Students can convert rational and real numbers into floating point numbers and vice versa.
- Students can explain the principles of text encoding in ASCII, Unicode, and UTF-8.
- Students can independently represent the term 'algorithm' and important properties.
- Students can explain the structure and semantics of imperative programs.
- Students master the technique of reading and understanding imperative algorithms and writing them down for simple problems.
- Students can apply basic algorithmic techniques such as iteration and recursion.
- Students are basically able to apply safe programming techniques.
- Students can design, implement and test simple simple programs
- Students can develop and implement solutions satisfying commonly accepted quality standards

Grading through:

- written exam

Is requisite for:

- Algorithms and Data Structures (CS1001-KP08, CS1001)

Responsible for this module:

- Prof. Dr. Stefan Fischer

Teacher:

- Institute of Telematics

- Prof. Dr. Stefan Fischer

Literature:

- M. Broy: Informatik - eine grundlegende Einführung (Band 1 und 2) - Springer-Verlag 1998
- G. Goos und W. Zimmermann: Vorlesungen über Informatik (Band 1 und 2) - Springer-Verlag, 2006
- B. Stroustrup: Einführung in die Programmierung mit C++ - Pearson Studium - IT, 2010

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- CS1000-L1: Successful completion of exercise assignments as specified at the beginning of the semester

Module Exam(s):
- CS1000-L1: Introduction to programming and programming course, written exam, 90min, 100% of module grade

Students of the study program Bachelor Medical Informatics attend the course 'CS1005-V/Ü: Programming Course Java'. Students of the study programs Bachelor Mathematics in Medicine and Life Sciences and Bachelor Medical Engineering attend the course 'CS1006-V: Programming Course C++'.

CS1001-KP08, CS1001 - Algorithms and Data Structures (AuD)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	8

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), foundations of computer science, 2nd semester
- Bachelor MES 2020 (optional subject), computer science / electrical engineering, 3rd semester at the earliest
- Bachelor Media Informatics 2020 (compulsory), computer science, 2nd semester
- Bachelor Computer Science 2019 (compulsory: aptitude test), foundations of computer science, 2nd semester
- Bachelor Robotics and Autonomous Systems 2020 (compulsory), computer science, 2nd semester
- Bachelor Medical Informatics 2019 (compulsory), computer science, 2nd semester
- Bachelor Computer Science 2016 (compulsory: aptitude test), foundations of computer science, 2nd semester
- Bachelor CLS 2016 (compulsory), foundations of computer science, 2nd semester
- Bachelor Robotics and Autonomous Systems 2016 (compulsory), computer science, 2nd semester
- Bachelor IT-Security 2016 (compulsory: aptitude test), computer science, 2nd semester
- Bachelor Medical Informatics 2014 (compulsory), computer science, 2nd semester
- Bachelor MES 2014 (optional subject), computer science / electrical engineering, 4th or 6th semester
- Bachelor Media Informatics 2014 (compulsory), foundations of computer science, 2nd semester
- Bachelor Computer Science 2014 (compulsory: aptitude test), foundations of computer science, 2nd semester
- Bachelor Medical Informatics 2011 (compulsory), computer science, 2nd semester
- Bachelor MES 2011 (compulsory), foundations of computer science, 4th semester
- Bachelor CLS 2010 (compulsory), foundations of computer science, 2nd semester
- Bachelor Computer Science 2012 (compulsory: aptitude test), foundations of computer science, 2nd semester

Classes and lectures:

- Algorithms and Data Structures (lecture, 4 SWS)
- Algorithms and Data Structures (exercise, 2 SWS)

Workload:

- 125 Hours private studies
- 90 Hours in-classroom work
- 25 Hours exam preparation

Contents of teaching:

- Sorting, algorithm analysis, heaps
- Distribution sort
- Priority queues
- Sets
- Sets
- Sets of strings
- Disjoint sets
- Associating objects
- Graphs
- Search graph for game playing
- Dynamic Programming principle, greedy algorithms
- Optimization problems, sequence alignment (longest common subsequence), knapsack problem, planning and layout problems, determining change coins, notion of completeness of algorithms
- String matching
- Hard problems
- Pruning and subgraph isomorphism
- Approximation

Qualification-goals/Competencies:

- The students can explain the central ideas, define the relevant concepts and explain the functioning of algorithms with help of application scenarios for all the items listed in contents of teaching.

Grading through:

- written exam

Is requisite for:

- Databases (CS2700-KP04, CS2700)
- Lab Course Software Engineering (CS2301-KP06, CS2301)

- Software Engineering (CS2300-KP06, CS2300SJ14)
- Theoretical Computer Science (CS2000-KP08, CS2000)
- Algorithm Design (CS3000-KP04, CS3000)

Requires:

- Introduction to Programming (CS1000-KP08, CS1000SJ14-MML/MI, CS1000SJ14-MIW)
- Introduction to Programming (CS1000-KP10, CS1000SJ14)

Responsible for this module:

- Prof. Dr. rer. nat. Esfandiar Mohammadi

Teacher:

- Institute for IT Security
- Prof. Dr. rer. nat. Esfandiar Mohammadi

Literature:

- Thomas H. Cormen, Charles E. Leiserson, Ronald Rivest, Clifford Stein: Algorithmen - Eine Einführung - Oldenbourg Verlag, 2013

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite.)

Admission requirements for participation in module examination(s):
- Successful completion of exercise sheets as specified at the beginning of the semester.

Module exam(s):
- CS1001-L1: Algorithms and Data Structures, written exam, 90min, 100% of the module grade.

MA1000-KP08, MA1000 - Linear Algebra and Discrete Structures 1 (LADS1)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	8

Course of study, specific field and term:

- Minor in Teaching Mathematics, Bachelor of Arts 2023 (compulsory), mathematics, 3rd semester
- Bachelor CLS 2023 (compulsory), mathematics, 1st semester
- Bachelor Biophysics 2024 (compulsory), mathematics, 1st semester
- Bachelor Biophysics 2024 (compulsory), mathematics, 1st semester
- Bachelor MES 2020 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor Media Informatics 2020 (compulsory), mathematics, 3rd semester
- Bachelor Computer Science 2019 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor Robotics and Autonomous Systems 2020 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor Medical Informatics 2019 (compulsory: aptitude test), mathematics, 1st semester
- Minor in Teaching Mathematics, Bachelor of Arts 2017 (compulsory), mathematics, 3rd semester
- Bachelor Computer Science 2016 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor CLS 2016 (compulsory), mathematics, 1st semester
- Bachelor IT-Security 2016 (compulsory), mathematics, 1st semester
- Bachelor Robotics and Autonomous Systems 2016 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor Biophysics 2016 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor Medical Informatics 2014 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor MES 2014 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor Media Informatics 2014 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor Computer Science 2014 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor Medical Informatics 2011 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor Computer Science 2012 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor MES 2011 (compulsory), mathematics, 1st semester
- Bachelor CLS 2010 (compulsory), mathematics, 1st semester

Classes and lectures:

- Linear Algebra and Discrete Structures 1 (lecture, 4 SWS)
- Linear Algebra and Discrete Structures 1 (exercise, 2 SWS)

Workload:

- 125 Hours private studies and exercises
- 90 Hours in-classroom work
- 25 Hours exam preparation

Contents of teaching:

- Fundamentals: logic, sets, mappings
- Relations, equivalence relations, orderings
- Proof by induction
- Groups: fundamentals, finite groups, permutations, matrices
- Rings, fields, congruencies
- Complex numbers: calculus, representation, roots of unity
- Vector spaces: bases, dimension, scalar product, norms

Qualification-goals/Competencies:

- Students understand the fundamental concepts of linear algebra.
- They understand basic thought processes and methods of proof.
- They can explain fundamental relationships in linear algebra.
- They can apply fundamental concepts and methods of proof to algebraic problems.
- They have an understanding of abstract thought processes.
- Interdisciplinary qualifications:
- Students have basic competency in modelling.
- They can transfer fundamental theoretical concepts to similar applications.
- They can work on elementary mathematics problems within a team.
- They can present elementary solutions to their problems to a group.

Grading through:

- written exam

Is requisite for:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)

Responsible for this module:

- Prof. Dr. rer. nat. Jan Modersitzki

Teacher:

- Institute of Mathematics and Image Computing

- Prof. Dr. rer. nat. Jan Modersitzki
- Prof. Dr. rer. nat. Jan Lellmann

Literature:

- G. Fischer: Lineare Algebra: Eine Einführung für Studienanfänger - Vieweg+Teubner
- G. Strang: Lineare Algebra - Springer
- K. Jänich: Lineare Algebra - Springer
- D. Lau: Algebra und diskrete Mathematik I + II - Springer
- G. Strang: Introduction to Linear Algebra - Cambridge Press
- K. Rosen: Discrete Mathematics and Its Applications - McGraw-Hill

Language:

- offered only in German

Notes:

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Successful completion of homework assignments during the semester
- Successful completion of e-tests during the semester
- Presentation of homework assignment

Module exam:
- MA1000-L1: Linear Algebra and Discrete Structures 1, written exam, 90 min, 100 % of module grade

MA1500-KP08, MA1500 - Linear Algebra and Discrete Structures 2 (LADS2)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	8

Course of study, specific field and term:

- Minor in Teaching Mathematics, Bachelor of Arts 2023 (compulsory), mathematics, 4th semester
- Bachelor CLS 2023 (compulsory), mathematics, 2nd semester
- Bachelor Biophysics 2024 (compulsory), mathematics, 2nd semester
- Bachelor MES 2020 (compulsory), mathematics, 2nd semester
- Bachelor Computer Science 2019 (compulsory: aptitude test), mathematics, 2nd semester
- Bachelor Robotics and Autonomous Systems 2020 (compulsory), mathematics, 2nd semester
- Bachelor Medical Informatics 2019 (compulsory), mathematics, 2nd semester
- Minor in Teaching Mathematics, Bachelor of Arts 2017 (compulsory), mathematics, 4th semester
- Bachelor Computer Science 2016 (compulsory: aptitude test), mathematics, 2nd semester
- Bachelor CLS 2016 (compulsory), mathematics, 2nd semester
- Bachelor Robotics and Autonomous Systems 2016 (compulsory), mathematics, 2nd semester
- Bachelor IT-Security 2016 (compulsory), mathematics, 2nd semester
- Bachelor Biophysics 2016 (compulsory), mathematics, 2nd semester
- Bachelor Medical Informatics 2014 (compulsory), mathematics, 2nd semester
- Bachelor MES 2014 (compulsory), mathematics, 2nd semester
- Bachelor Computer Science 2014 (compulsory: aptitude test), mathematics, 2nd semester
- Bachelor Medical Informatics 2011 (compulsory), mathematics, 2nd semester
- Bachelor CLS 2010 (compulsory), mathematics, 2nd semester
- Bachelor MES 2011 (compulsory), mathematics, 2nd semester
- Bachelor Computer Science 2012 (compulsory: aptitude test), mathematics, 2nd semester

Classes and lectures:

- Linear Algebra and Discrete Structures 2 (lecture, 4 SWS)
- Linear Algebra and Discrete Structures 2 (exercise, 2 SWS)

Workload:

- 125 Hours private studies and exercises
- 90 Hours in-classroom work
- 25 Hours exam preparation

Contents of teaching:

- Systems of linear equations, matrices
- Determinants
- Linear mappings
- Orthogonality
- Eigenvalues

Qualification-goals/Competencies:

- The students understand advanced concepts of linear algebra.
- They understand advanced thought processes and methods of proof.
- They can apply advanced concepts and methods of proof to algebraic problems.
- They can explain advanced relationships in linear algebra.
- Interdisciplinary qualifications:
- Students can transfer advanced theoretical concepts to similar applications.
- They have an advanced competency in modeling.
- They can solve complex problems within a group.
- They can present the solution to complex problems to a group.

Grading through:

- written exam

Is requisite for:

- Image Registration (MA5030-KP05)
- Image Registration (MA5030-KP04, MA5030)
- Mathematical Methods of Image Processing (MA4500-KP05)
- Mathematical Methods in Image Processing (MA4500-KP04, MA4500)
- Optimization (Advanced Mathematics) (MA4031-KP08)

- Module part: Optimization (MA4030 T)
- Optimization (MA4030-KP08, MA4030)

Requires:

- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)

Responsible for this module:

- Prof. Dr. rer. nat. Jan Modersitzki

Teacher:

- Institute of Mathematics and Image Computing

- Prof. Dr. rer. nat. Jan Modersitzki
- Prof. Dr. rer. nat. Jan Lellmann

Literature:

- G. Fischer: Lineare Algebra: Eine Einführung für Studienanfänger - Vieweg+Teubner
- G. Strang: Lineare Algebra - Springer
- K. Jänich: Lineare Algebra - Springer
- D. Lau: Algebra und diskrete Mathematik I + II - Springer
- G. Strang: Introduction to Linear Algebra - Cambridge Press
- K. Rosen: Discrete Mathematics and Its Applications - McGraw-Hill

Language:

- offered only in German

Notes:

Prerequisites for attending the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Prerequisites for the exam:
- Successful completion of homework assignments during the semester
- Successful completion of e-tests during the semester
- Presentation of homework assignment

Module exam:
-MA1500-L1: Linear Algebra and Discrete Structures 2, written exam, 90 min, 100 % of module grade

MA1600-KP04, MA1600, MA1600-MML - Biostatistics 1 (BioStat1)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	4

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), mathematics, 2nd semester
- Bachelor Biophysics 2024 (compulsory), Elective Computer Science, 4th semester
- Bachelor Nutritional Medicine 2024 (compulsory), mathematics / natural sciences, 4th semester
- Bachelor MES 2014 (optional subject), mathematics / natural sciences, 3rd semester at the earliest
- Bachelor Computer Science 2019 (optional subject), Extended optional subjects, Arbitrary semester
- Bachelor Computer Science 2019 (compulsory), Canonical Specialization Bioinformatics and Systems Biology, 6th semester
- Bachelor Medical Informatics 2019 (compulsory), medical computer science, 6th semester
- Bachelor MLS 2018 (compulsory), life sciences, 6th semester
- Bachelor Nutritional Medicine 2018 (compulsory), mathematics / computer science, 6th semester
- Bachelor CLS 2016 (compulsory), mathematics, 2nd semester
- Bachelor CLS 2010 (compulsory), mathematics, 2nd semester
- Bachelor Computer Science 2016 (optional subject), advanced curriculum, Arbitrary semester
- Bachelor Computer Science 2016 (compulsory), Canonical Specialization Bioinformatics, 4th semester
- Bachelor MLS 2016 (compulsory), life sciences, 6th semester
- Bachelor Biophysics 2016 (compulsory), Elective Computer Science, 4th semester
- Bachelor Nutritional Medicine 2016 (compulsory), mathematics / computer science, 6th semester
- Bachelor Medical Informatics 2014 (compulsory), medical computer science, 4th semester
- Bachelor Computer Science 2014 (compulsory), specialization field bioinformatics, 6th semester
- Master MES 2011 (advanced curriculum), biophysics and biomedical optics, 2nd semester
- Bachelor Medical Informatics 2011 (compulsory), medical computer science, 4th semester
- Master Computer Science 2012 (optional subject), specialization field bioinformatics, 2nd or 3rd semester
- Master Computer Science 2012 (compulsory), advanced curriculum stochastics, 2nd semester
- Bachelor Computer Science 2012 (optional subject), specialization field bioinformatics, 6th semester
- Bachelor MLS 2009 (compulsory), life sciences, 6th semester
- Bachelor MES 2011 (optional subject), medical engineering science, 6th semester
- Bachelor Molecular Life Science 2024 (compulsory), mathematics / computer science, 4th semester

Classes and lectures:

- Biostatistics 1 (lecture, 2 SWS)
- Biostatistics 1 (exercise, 1 SWS)

Workload:

- 66 Hours private studies
- 39 Hours in-classroom work
- 15 Hours exam preparation

Contents of teaching:

- Descriptive statistics
- Probability theory, including random variables, density, and cumulative distribution function
- Normal distribution, other distributions
- Diagnostic tests, reference range, normal range, coefficient of variation
- Statistical testing
- Sample size calculations
- Confidence intervals
- Selected statistical tests I
- Selected statistical tests II
- Linear simple regression
- Analysis of variance (one-way-classification)
- Clinical trials
- Multiple Testing: Bonferroni, Bonferroni-Holm, Bonferroni-Holm-Shaffer, Wiens, hierarchical Testing

Qualification-goals/Competencies:

- With regard to the roles of GSP of the University of Lübeck and of the DFG-guidelines the student were able to work with the following statistical methods:The students are able to calculate descriptive statistics.
- They are able to calculate quantiles and surfaces of the normal distribution.
- They are able to explain terms of diagnostic testing, such as sensitivity or specificity.
- They are able to list the basic principles of statistical testing, sample size calculation and confidence interval construction.

- They are able to carry out a set of elementary statistical tests, such as t-test, test of proportions, X2 independence test, and to interpret the results.
- They are able to explain the basic principles of linear regression.
- They are able to apply the linear simple regression.
- They are able to explain the basic idea for the one-way analysis of variance (ANOVA).
- They are able to explain the results table for the one-way and two-way ANOVA.
- They are able to interpret the results of the ANOVA.
- They know the basic principles of clinical therapeutic studies.
- They know the assumptions that need to be fulfilled for the application of specific statistical tests.
- They are able to calculate simple adjustments for multiple comparisons.

Grading through:

- written exam

Is requisite for:

- Module part: Biostatistics 2 (MA2600 T)
- Biostatistics 2 (MA2600-KP07)
- Biostatistics 2 (MA2600-KP04, MA2600)

Responsible for this module:

- Prof. Dr. rer. biol. hum. Inke König

Teacher:

- Institute of Medical Biometry and Statistics

- Prof. Dr. rer. biol. hum. Inke König
- MitarbeiterInnen des Instituts

Literature:

- Matthias Rudolf, Wiltrud Kuhlisch: Biostatistik: Eine Einführung für Biowissenschaftler - 1. Auflage, Pearson: Deutschland
- Lothar Sachs, Jürgen Hedderich: Angewandte Statistik: Methodensammlung mit R - 15. Auflage, Springer: Heidelberg

Language:

- offered only in German

Notes:

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Active and regular participation in the exercise groups as specified at the beginning of the semester.

Module exam:
-MA1600-L1: Biostatistics 1, written exam, 90 min, 100 % of module grade

MA2000-KP08, MA2000 - Analysis 1 (Ana1KP08)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	8

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), mathematics, 1st semester
- Minor in Teaching Mathematics, Bachelor of Arts 2023 (compulsory), mathematics, 5th semester
- Bachelor Biophysics 2024 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor MES 2020 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor Media Informatics 2020 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor Computer Science 2019 (compulsory), mathematics, 1st semester
- Bachelor Robotics and Autonomous Systems 2020 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor Medical Informatics 2019 (compulsory), mathematics, 1st semester
- Minor in Teaching Mathematics, Bachelor of Arts 2017 (compulsory), mathematics, 5th semester
- Bachelor Computer Science 2016 (compulsory), mathematics, 1st semester
- Bachelor CLS 2016 (compulsory), mathematics, 1st semester
- Bachelor Robotics and Autonomous Systems 2016 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor IT-Security 2016 (compulsory), mathematics, 1st semester
- Bachelor Biophysics 2016 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor Medical Informatics 2014 (compulsory), mathematics, 1st semester
- Bachelor Media Informatics 2014 (compulsory), mathematics, 1st semester
- Bachelor MES 2014 (compulsory: aptitude test), mathematics, 1st semester
- Bachelor Computer Science 2014 (compulsory), mathematics, 1st semester
- Bachelor Medical Informatics 2011 (compulsory), mathematics, 3rd semester
- Bachelor CLS 2010 (compulsory), mathematics, 1st semester
- Bachelor MES 2011 (compulsory), mathematics, 1st semester
- Bachelor Computer Science 2012 (compulsory), mathematics, 3rd semester

Classes and lectures:

- Analysis 1 (lecture, 4 SWS)
- Analysis 1 (exercise, 2 SWS)

Workload:

- 125 Hours private studies
- 90 Hours in-classroom work
- 25 Hours exam preparation

Contents of teaching:

- Sequences and series
- Functions and continuity
- Differentiability, Taylor series
- Metric and normalized spaces, basic topological concepts
- Multivariate differential calculus

Qualification-goals/Competencies:

- Students understand the basic terms of analysis, especially the concept of convergence.
- Students understand the basic thoughts and proof techniques and are able to use them for the analytical treatment of scientifially or technically motivated problems.
- Students can explain basic relationships in real analysis.
- Students can apply the basic concepts and proof techniques of differential calculus.
- Students have an understanding for abstract structures.
- Interdisciplinary qualifications:
- Students have a basic competence in modeling.
- Students can transfer theoretical concepts to similar applications.
- Students can work as a group on elementary mathematical problems.

Grading through:

- written exam

Is requisite for:

- Analysis 2 (MA2500-KP09)
- Analysis 2 (MA2500-KP08)

- Analysis 2 (MA2500-KP05, MA2500-MLS)
- Analysis 2 (MA2500-KP04, MA2500)

Responsible for this module:

- Prof. Dr. rer. nat. Jürgen Prestin

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Jürgen Prestin
- PD Dr. rer. nat. Jörn Schnieder

Literature:

- K. Fritzsche: Grundkurs Analysis 1 + 2
- H. Heuser: Lehrbuch der Analysis 1 + 2
- K. Burg, H. Haf, F. Wille, A. Meister: Höhere Mathematik für Ingenieure
- R. Lasser, F. Hofmaier: Analysis 1 + 2

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments during the semester
- Successful completion of e-tests

Modul exam:
- MA2000-L1: Analysis 1, written exam, 90 min, 100 % of module grade

MA2214-KP04, MA2214 - Clinical Studies (KlinStud)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	4

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), mathematics, 3rd or 5th semester
- Master Nutritional Medicine 2023 (compulsory), medical computer science, 1st semester
- Bachelor Medical Informatics 2019 (optional subject), medical computer science, 4th to 6th semester
- Bachelor CLS 2016 (compulsory), mathematics, 3rd or 5th semester
- Master Nutritional Medicine 2019 (compulsory), medical computer science, 1st semester
- Bachelor Medical Informatics 2014 (optional subject), medical computer science, 5th or 6th semester
- Master Computer Science 2012 (optional subject), specialization field medical informatics, 3rd semester
- Bachelor Medical Informatics 2011 (optional subject), medical computer science, 4th to 6th semester
- Bachelor MES 2011 (optional subject), life sciences, 3rd or 5th semester
- Bachelor CLS 2010 (compulsory), mathematics, 3rd or 5th semester

Classes and lectures:

- Clinical Studies (lecture, 2 SWS)
- Clinical Studies (exercise, 1 SWS)

Workload:

- 60 Hours private studies and exercises
- 45 Hours in-classroom work
- 15 Hours exam preparation

Contents of teaching:

- Definition of a clinical study according to the German Drug Law, classification of clinical studies, clinical development
- Basic principles of clinical trials and measures against bias
- Regulations and study documents
- Development of a clinical study, especially a study protocol
- Contents of a study protocol
- Link to health economics
- Further topics like
- Special study designs
- Advanced statistical analyses
- Report and publication
- Professional fields in clinical studies (study statistics, data management, monitoring, quality management, pharmacovigilance, project management)

Qualification-goals/Competencies:

- Students can describe the regulatory framework of clinical trials with drugs.
- They can describe the main areas of activity in the fields of study statistics, data management, monitoring, information technology and quality assurance.
- They can explain the basic principles of clinical trials and measures to achieve these basic principles.
- They can create relevant parts of a study protocol.
- They can represent study populations descriptively.
- They can perform case number planning for simple clinical studies.
- Students can assign studies and their key points to the stages of clinical development.
- They can explain different study designs.
- They are informed about ethical problems and guidelines and the principles of data protection.
- Acquisition of german and english technical language

Grading through:

- portfolio exam

Requires:

- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)

Responsible for this module:

- Prof. Dr. rer. biol. hum. Inke König
- PD Dr. rer. pol. Reinhard Vonthein

Teacher:

- Institute of Medical Biometry and Statistics

- PD Dr. rer. pol. Reinhard Vonthein
- Prof. Dr. rer. biol. hum. Inke König

Literature:

- Gaus W., Chase D.: Klinische Studien: Regelwerke, Strukturen, Dokumente und Daten - Norderstedt: Books on Demand GmbH 2007 (2. Auflage)
- Stapff M.: Arzneimittelstudien - Eine Einführung in klinische Prüfungen für Ärzte, Studenten, medizinisches Assistenzpersonal und interessierte Laien - Germering/München: W. Zuckschwerdt Verlag GmbH 2008 (5. Auflage)
- Schumacher, M., Schulgen, G.: Methodik klinischer Studien: Methodische Grundlagen der Planung, Durchführung und Auswertung - Berlin: Springer 2008 (3. Auflage)
- Friedman, L.M., Furberg, C.D., DeMets, D.L., Reboussin, D.M., Granger, C.B.: Fundamentals of Clinical Trials - Springer 2015 (5th edition)

Language:

- German and English skills required

Notes:

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- None

Module exam(s):
- MA2214-L1: Clinical Studies, portfolio exam, 100% of module grade with contributions from written exam (50%) and project work (50%)

MA2500-KP09 - Analysis 2 (Ana2KP09)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	9

Course of study, specific field and term:

- Bachelor IT-Security 2016 (optional subject), specific, Arbitrary semester
- Minor in Teaching Mathematics, Bachelor of Arts 2023 (compulsory), mathematics, 6th semester
- Bachelor CLS 2023 (compulsory), mathematics, 2nd semester
- Minor in Teaching Mathematics, Bachelor of Arts 2017 (compulsory), mathematics, 6th semester
- Bachelor CLS 2016 (compulsory), mathematics, 2nd semester

Classes and lectures:

- Analysis 2 (lecture, 4 SWS)
- Analysis 2 (exercise, 3 SWS)

Workload:

- 130 Hours private studies
- 110 Hours in-classroom work
- 30 Hours exam preparation

Contents of teaching:

- Advanced multivariate differential calculus
- Integral calculus for functions of one real variable (indefinite integrals, antiderivatives, substitution, partial integration, definite integrals, fundamental theorem of calculus)
- Curvilinear integrals, bounded variation
- Function series, power series
- Fourier series (trigonometric polynomials, convergence)
- Linear operators in Hilbert spaces
- Working with the programming language Mathematica

Qualification-goals/Competencies:

- Students understand the advanced terms of analysis, such as even convergence.
- Students understand the advanced thoughts and proof techniques of real analysis.
- Students can apply the advanced concepts and proof techniques.
- Students can explain advanced relationships in analysis.Interdisciplinary qualifications:
- Interdisciplinary qualifications:
- Students can transfer advanced theoretical concepts to similar applications.
- Students have an advanced competence in modeling.
- Students can work as a group on complex mathematical problems.

Grading through:

- written exam

Requires:

- Analysis 1 (MA2000-KP09)
- Analysis 1 (MA2000-KP08, MA2000)

Responsible for this module:

- Prof. Dr. rer. nat. Jürgen Prestin

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Jürgen Prestin
- PD Dr. rer. nat. Jörn Schnieder

Literature:

- H. Heuser: Lehrbuch der Analysis 1+2
- K. Fritzsche: Grundkurs Analysis 1+2
- K. Burg, H. Haf, F. Wille, A. Meister: Höhere Mathematik für Ingenieure
- R. Lasser, F. Hofmaier: Analysis 1 + 2

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments during the semester
- Successful completion of e-tests and Mathematica notebooks

Module exam(s):
- MA2500-L1: Analysis 2, written exam, 90 min, 100 % of module grade

Module MA2500-KP09 is identical to module MA2500-MML.

MA2510-KP04, MA2510 - Stochastics 1 (Stoch1)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	4

Course of study, specific field and term:

- Minor in Teaching Mathematics, Bachelor of Arts 2023 (compulsory), mathematics, 8th semester
- Bachelor CLS 2023 (compulsory), mathematics, 2nd semester
- Bachelor MES 2020 (optional subject), mathematics / natural sciences, 3rd semester at the earliest
- Bachelor Biophysics 2024 (optional subject), mathematics, 6th semester
- Bachelor Computer Science 2019 (compulsory), mathematics, 4th semester
- Bachelor Robotics and Autonomous Systems 2020 (compulsory), mathematics, 4th semester
- Bachelor Medical Informatics 2019 (optional subject), mathematics, 4th to 6th semester
- Minor in Teaching Mathematics, Bachelor of Arts 2017 (compulsory), mathematics, 8th semester
- Bachelor Computer Science 2016 (compulsory), mathematics, 4th semester
- Bachelor CLS 2016 (compulsory), mathematics, 2nd semester
- Bachelor Robotics and Autonomous Systems 2016 (compulsory), mathematics, 4th semester
- Bachelor IT-Security 2016 (compulsory), mathematics, 2nd semester
- Bachelor Biophysics 2016 (optional subject), mathematics, 6th semester
- Bachelor Medical Informatics 2014 (optional subject), mathematics, 5th or 6th semester
- Bachelor MES 2014 (optional subject), mathematics / natural sciences, 4th or 6th semester
- Bachelor Computer Science 2014 (compulsory), mathematics, 4th semester
- Bachelor Computer Science 2012 (compulsory), mathematics, 4th semester
- Bachelor MES 2011 (compulsory), mathematics, 4th semester
- Bachelor CLS 2010 (compulsory), mathematics, 2nd semester

Classes and lectures:

- Stochastics 1 (lecture, 2 SWS)
- Stochastic 1 (exercise, 1 SWS)

Workload:

- 65 Hours private studies and exercises
- 45 Hours in-classroom work
- 10 Hours exam preparation

Contents of teaching:

- probability spaces
- basics of combinatorics
- conditional probability and stochastic independency
- random variables
- important discrete and continuous one-dimensional probability distributions
- characteristics of distributions
- law of large numbers, central limit theorem
- modeling examples from the life sciences

Qualification-goals/Competencies:

- Students are able to explain basic stochastic models formally correct and in the context of their application
- They are able to formalize stochastic problems
- They are able to identify basic combinatorial patterns and to use them for solving stochastic problems
- They understand central statements of elementary stochastics

Grading through:

- written exam

Is requisite for:

- Stochastic processes (MA4610-KP05)
- Stochastic processes and modeling (MA4610-KP04, MA4610)
- Modeling Biological Systems (MA4450-KP08, MA4450-MML)
- Modeling Biological Systems (MA4450-KP07)
- Module part: Modeling Biological Systems (MA4450 T-INF)
- Module part: Modeling Biological Systems (MA4450 T)
- Modeling Biological Systems (MA4450)
- Modeling (MA4449-KP07)

- Module part: Stochastics 2 (MA4020 T)
- Stochastics 2 (MA4020-KP05)
- Stochastics 2 (MA4020-MML)
- Stochastics 2 (MA4020-KP04, MA4020)

Responsible for this module:

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Teacher:

- Institute for Mathematics

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Literature:

- N. Henze: Stochastik für Einsteiger - Vieweg
- U. Krengel: Einführung in die Wahrscheinlichkeitstheorie - Vieweg

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments during the semester

Module exam(s):
- MA2510-L1: Stochastics 1, written exam, 90 min, 100 % of module grade

MA2600-KP07 - Biostatistics 2 (BioSt2KP07)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	7

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), mathematics, 4th semester
- Bachelor CLS 2016 (compulsory), mathematics, 4th semester

Classes and lectures:

- Biostatistics 2 (lecture, 2 SWS)
- Biostatistics 2 (exercise, 1 SWS)
- Biostatistics 2 (practical course, 2 SWS)

Workload:

- 85 Hours programming
- 70 Hours in-classroom work
- 40 Hours private studies
- 15 Hours exam preparation

Contents of teaching:

- Assumptions in the classical linear model
- Last squares method and geometric representation
- Stochastic properties, testing the general linear hypothesis, construction of confidence intervals and confidence ellipsoids
- Regression diagnostics and model choice
- Logistic regression: basics, model specification, threshold model, maximum likelihood estimation, tests and confidence intervals
- Survival Analysis: Kaplan-Meier curves, Log-Rank test, assumptions and parameter estimation in Cox regression
- Data structures in R, functions and functionals in R
- Statistical analysis in R: descriptive statistics (frequency tables, metrics), graphical representation, statistical tests (t-, X2-, U-, Log-Rank-), executable protocolls (literate programming) with knitr, bootstrapping, cross-validation, linear regression, logistic regression, Cox regression

Qualification-goals/Competencies:

- The students are able to enumerate and explain the assumptions of the classical linear model.
- They are able to describe typical applications of the classical linear model.
- They are able to list the differences between the linear model and the logistic regression model.
- They are able to describe possible error sources in modelling the linear model.
- They are able to calculate the estimators (point and interval estimators, residual, prediction) in the linear model by hand.
- They are able to evaluate the graphics for regression diagnostics in the linear model.
- They are able to interpret the results of studies, where a linear, a logistic or a Cox regression model was applied.
- They are able to draw and interpret Kaplan-Meier curves.
- They are able to perform data transformations.
- They are able to program their own R functions.
- They are able to present data by suitable and pleasing graphics.
- They are able to conduct linear, logistic and Cox regression analysis by means of R packages and to evaluate the results on the computer.
- They are able to execute statistical tests (t-, X2-, U-, Log-Rank-) in R, to formulate the hypotheses and to make a test decision.
- They are able to illustrate the principle of bootstrapping and cross-validation and to implement it in R.
- They are able to create a report that meets the requirements of academic work by means of the R package knitr.

Grading through:

- written exam

Is requisite for:

- Genetic Epidemiology 2 (MA4661-KP08, MA4661)
- Interdisciplinary Seminar (MA3300-KP04)
- Generalized Linear Models (MA4962-KP05)
- Multivariate Statistics (MA4944-KP05)

Requires:

- Introduction to Programming (CS1000-KP08, CS1000SJ14-MML/MI, CS1000SJ14-MIW)
- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)

Responsible for this module:

- Prof. Dr. rer. biol. hum. Inke König

Teacher:

- Institute of Medical Biometry and Statistics

- Dr. rer. hum. biol. Björn-Hergen Laabs
- MitarbeiterInnen des Instituts

Literature:

- Fahrmeir, Ludwig; Kneib, Thomas; Lang, Stefan (2009): Regression: Modelle, Methoden und Anwendungen - Springer: Heidelberg
- Dobson, Annette J & Barnett, Adrian (2008): An Introduction to Generalized Linear Models, 3rd ed. - Chapman & Hall/CRC: Boca Raton
- Sachs, Lothar; Hedderich, Jürgen: Angewandte Statistik: Methodensammlung mit R - 15. Auflage, Springer: Heidelberg
- Ligges, Uwe: Programmieren mit R - 3. Auflage, Springer: Heidelberg

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Examination prerequisites can be defined at the beginning of the semester. If preliminary work is defined, it must have been completed and positively evaluated before the first examination.

Module exam(s):
- MA2600-L1: Biostatistics 2, written exam, 90 min, 100 % of module grade

MA2700-KP04 - Proseminar (ProsemKP04)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	4 (Typ B)

Course of study, specific field and term:

- Minor in Teaching Mathematics, Bachelor of Arts 2023 (compulsory), mathematics, 8th semester
- Bachelor CLS 2023 (compulsory), mathematics, 3rd semester
- Minor in Teaching Mathematics, Bachelor of Arts 2017 (compulsory), mathematics, 8th semester
- Bachelor CLS 2016 (compulsory), Interdisciplinary modules, 3rd semester

Classes and lectures:

- Proseminar (seminar, 2 SWS)

Workload:

- 90 Hours oral presentation (including preparation)
- 30 Hours in-classroom work

Contents of teaching:

- Reading scientific literature

Qualification-goals/Competencies:

- Preparing and giving a scientific talk
- Practising scientific discussion
- Training of English language

Grading through:

- Oral presentation and written report

Requires:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)
- Analysis 2 (MA2500-KP09)
- Analysis 1 (MA2000-KP08, MA2000)

Responsible for this module:

- PD Dr. rer. nat. Christian Bey

Teacher:

- Institute for Mathematics

- PD Dr. rer. nat. Christian Bey
- Prof. Dr. rer. nat. Andreas Rößler

Language:

- offered only in English

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Preparing and giving a scientific talk

Module exam(s):
- MA2700-L1: Proseminar, ungraded seminar, 0 % of module grade, must be passed

MA3110-KP06 - Numerics 1 (Num1KP06)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	6

Course of study, specific field and term:

- Minor in Teaching Mathematics, Bachelor of Arts 2023 (compulsory), mathematics, 7th semester
- Bachelor CLS 2023 (compulsory), mathematics, 3rd semester
- Minor in Teaching Mathematics, Bachelor of Arts 2017 (compulsory), mathematics, 7th semester
- Bachelor CLS 2016 (compulsory), mathematics, 3rd semester

Classes and lectures:

- Numerics 1 (lecture, 2 SWS)
- Numerics 1 (exercise, 2 SWS)

Workload:

- 100 Hours private studies and exercises
- 60 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Round-off errors and condition
- Direct solvers for linear equations
- LR decomposition
- Perturbation theory
- Cholesky decomposition
- QR decomposition, least squares fit

Qualification-goals/Competencies:

- Basic understanding of numeric tasks
- Mastering the modern programming language MATLAB
- Experience in the implementation of theoretical algorithms
- Ability to judge the quality of a method (accuracy, stability, complexity)

Grading through:

- written exam

Requires:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)
- Analysis 2 (MA2500-KP09)
- Analysis 1 (MA2000-KP08, MA2000)

Responsible for this module:

- Prof. Dr. rer. nat. Andreas Rößler

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Andreas Rößler

Literature:

- W. Dahmen, A. Reusken: Numerische Mathematik für Ingenieure und Naturwissenschaftler - 2. Auflage, Springer (2008)
- P. Deuflhard, A. Hohmann: Numerische Mathematik I - 4. Auflage, De Gruyter (2008)
- P. Deuflhard, F. Bornemann: Numerische Mathematik II - 4. Auflage, De Gruyter (2013)
- M. Hanke-Bourgeois: Grundlagen der Numerischen Mathematik und des Wissenschaftlichen Rechnens - 3. Auflage, Teubner (2009)
- H. R. Schwarz, N. Köckler: Numerische Mathematik - 8. Auflage, Teubner (2011)
- J. Stoer: Numerische Mathematik I - 10. Auflage, Springer (2007)
- J. Stoer, R. Bulirsch: Numerische Mathematik II - 6. Auflage, Springer (2011)
- A. M. Quarteroni, R. Sacco, F. Salieri: Numerical Mathematics - 2. Auflage, Springer (2007)

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Examination prerequisites can be defined at the beginning of the semester. If preliminary work is defined, it must have been completed and positively evaluated before the first examination.

Module exam(s):
- MA3110-L1: Numerics 1, written exam, 90 min, 100 % of module grade

MA3200-KP04, MA3200 - Genetic Epidemiology 1 (GenEpi1)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	4

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), mathematics, 3rd or 5th semester
- Master Medical Informatics 2019 (optional subject), Medical Data Science / Artificial Intelligence, 1st or 2nd semester
- Bachelor CLS 2016 (compulsory), mathematics, 3rd or 5th semester
- Master Medical Informatics 2014 (optional subject), ehealth / infomatics, 1st or 2nd semester
- Master Computer Science 2012 (optional subject), specialization field medical informatics, 3rd semester
- Bachelor CLS 2010 (compulsory), mathematics, 3rd or 5th semester

Classes and lectures:

- Genetic Epidemiology 1 (lecture, 2 SWS)
- Genetic Epidemiology 1 (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 45 Hours in-classroom work
- 15 Hours exam preparation

Contents of teaching:

- Monogenic and complex diseases
- Hardy-Weinberg-equilibrium
- Coupling imbalance
- Genetic markers and genotyping
- Quality control
- Basics of association analysis
- Genome-wide association studies
- Population stratification
- Gene-environment interaction
- Replication, meta-analysis and imputation
- Ethical aspects

Qualification-goals/Competencies:

- Students are able to describe the generation of genetic data, its error sources and methods of detection.
- They can select and describe the most important approaches for genetic epidemiological association studies on the level of single markers.
- They are able to apply the basic test procedures manually and to interpret the results.
- They are able to describe the statistical evaluation steps in a genome-wide association study and interpret the results.

Grading through:

- Written or oral exam as announced by the examiner

Is requisite for:

- Seminar Genetic Epidemiology (MA5129-KP04, MA5129)
- Genetic Epidemiology 2 (MA4661-KP08, MA4661)

Requires:

- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)

Responsible for this module:

- Prof. Dr. rer. nat. Silke Szymczak

Teacher:

- Institute of Medical Biometry and Statistics

- Prof. Dr. rer. nat. Silke Szymczak
- MitarbeiterInnen des Instituts

Literature:

- Ziegler A, König IR.: A statistical approach to genetic epidemiology. Concepts and applications. - 2010. ISBN: 978-3-527-32389-0

- Bickeböller H, Fischer, C: Einführung in die Genetische Epidemiologie - 2007. ISBN: 978-3-540-25616-8

Language:

- German or English

Notes:

Prerequisites for attending the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Prerequisites for the exam:
- Examination prerequisites can be defined at the beginning of the semester. If preliminary work is defined, it must have been completed and positively evaluated before the first examination.

Module exam(s):
- MA3200-L1: Genetic Epidemiology 1, oral exam, 30 min, or written exam, 90 min, 100% of module grade

MA3400-KP05 - Biomathematics (BioMaKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	5

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), mathematics, 3rd semester
- Bachelor Biophysics 2024 (compulsory), mathematics, 3rd semester
- Bachelor Computer Science 2019 (optional subject), Extended optional subjects, Arbitrary semester
- Bachelor Computer Science 2019 (compulsory), Canonical Specialization Bioinformatics and Systems Biology, 5th semester
- Bachelor Medical Informatics 2019 (optional subject), medical computer science, 4th to 6th semester
- Master MLS 2018 (optional subject), interdisciplinary competence, 1st semester
- Bachelor Computer Science 2016 (optional subject), advanced curriculum, Arbitrary semester
- Bachelor Computer Science 2016 (compulsory), Canonical Specialization Bioinformatics, 5th semester
- Master MLS 2016 (optional subject), mathematics / computer science, 1st semester
- Bachelor CLS 2016 (compulsory), mathematics, 3rd semester
- Bachelor Biophysics 2016 (compulsory), mathematics, 3rd semester

Classes and lectures:

- Biomathematics (lecture, 2 SWS)
- Biomathematics (exercise, 2 SWS)

Workload:

- 70 Hours private studies and exercises
- 60 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Examples and elementary solution methods for ordinary differential equations
- Existence and uniqueness theorems
- Dependence of solutions on initial conditions
- Linear systems (in particular with constant coefficients)
- Higher-Order linear differential equations
- Qualitative theory of nonlinear systems

Qualification-goals/Competencies:

- Students are able to explain basic notions from the theory of ordinarydifferential equations.
- Students can explain bad phenomena of solutions of differential equations using examples.
- Students can specify conditions under which good phenomena of solutions are guaranteed by applying theorems from the theory of ordinary differential equations.
- Students are able to find explicit solutions of simple differential equations.
- Students are able to explain how solutions of differential equations can beanalysed qualitatively.
- Students are able to present important models of the natural sciences which canbe analysed by differential equations.

Grading through:

- written exam

Requires:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)
- Analysis 2 (MA2500-KP04, MA2500)
- Analysis 1 (MA2000-KP08, MA2000)

Responsible for this module:

- PD Dr. rer. nat. Christian Bey

Teacher:

- Institute for Mathematics

- PD Dr. rer. nat. Christian Bey

Literature:

- G. Birkhoff, G.-C. Rota: Ordinary Differential Equations

- H. Heuser: Gewöhnliche Differentialgleichungen - Teubner Verlag 2009 (6. Auflage)
- M.W. Hirsch, S. Smale: Differential Equations, Dynamical Systems, and Linear Algebra
- J. D. Murray: Mathematical Biology - Springer
- J. Scheurle: Gewöhnliche Differentialgleichungen
- R. Schuster: Biomathematik - Vieweg + Teubner Studienbücher 2009
- W. Walter: Gewöhnliche Differentialgleichungen

Language:

- offered only in German

Notes:

Admission requirememnts for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments during the semester

Module exam(s):
- MA3400-L1: Biomathematics, written exam, 90 min, 100 % of module grade

MA3445-KP05 - Graph Theory (GraphTKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Minor in Teaching Mathematics, Master of Education 2023 (optional subject), mathematics, 2nd or 3rd semester
- Bachelor Computer Science 2019 (optional subject), Extended optional subjects, Arbitrary semester
- Minor in Teaching Mathematics, Master of Education 2017 (optional subject), mathematics, 2nd or 3rd semester
- Bachelor Computer Science 2016 (optional subject), advanced curriculum, Arbitrary semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Graph theory (lecture, 2 SWS)
- Graph theory (exercise, 1 SWS)

Workload:

- 85 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Hamiltonian graphs and degree sequences
- Menger's theorem - new proofs
- Matchings and decompositions of graphs
- The theorems of Turan and Ramsey
- Vertex and edge colourings
- The four colour theorem

Qualification-goals/Competencies:

- Ability to solve discrete problems using graph theoretical methods
- Knowledge of proof techniques and ideas of discrete mathematics
- Knowledge of fundamental and selected recent research results
- Ability to learn independently by studying relevant literature

Grading through:

- Oral examination

Requires:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)

Responsible for this module:

- PD Dr. rer. nat. Christian Bey

Teacher:

- Institute for Mathematics

- PD Dr. rer. nat. Christian Bey

Literature:

- F. Harary: Graph Theory - Reading, MA:.Addison-Wesley 1969
- R. Diestel: Graphentheorie - Berlin: Springer 2010 (4th edition)
- D. Jungnickel: Graphen, Netzwerke und Algorithmen - Mannheim: BI-Wissenschaftsverlag1994
- J. Bang-Jensen, G. Gutin: Digraphs: Theory, Algorithms and Applications - London: Springer 2001
- B. Bollobas: Modern Graph Theory - Berlin: Springer 1998

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA3445-L1: Graph Theory, oral exam, 30 min, 100 % of module grade

MA4020-KP07 - Stochastics 2 (Stoch2KP07)		
Duration: 1 Semester	**Turnus of offer:** each winter semester	**Credit points:** 7

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), mathematics, 3rd semester

Classes and lectures:

- Stochastics 2 (lecture, 3 SWS)
- Stochastics 2 (exercise, 2 SWS)

Workload:

- 115 Hours private studies and exercises
- 75 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Lebesgue integral und Riemann integral
- transformations of measures and integrals
- product measures and Fubini's theorem
- moments and dependency measures
- normally distributed random vectors and distributions closely related to the normal distribution
- characteristic functions
- conditional expectations
- basis ideas of information theory

Qualification-goals/Competencies:

- Studends get insights into basic stochastic structures
- They master techniques of integration being relevant to stochastics
- They master the treatment of (particularly normally distributed) random vectors and their distributions
- They acquire a basic understanding of information theory approaches
- They are able to formalize complex stochastic problems

Grading through:

- Exercises
- written exam

Requires:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Stochastics 1 (MA2510-KP04, MA2510)
- Analysis 2 (MA2500-MML)

Responsible for this module:

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Teacher:

- Institute for Mathematics

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Literature:

- J. Elstrodt: Maß- und Integrationstheorie - Springer
- M. Fisz: Wahrscheinlichkeitsrechnung und mathematische Statistik - Deutscher Verlag der Wissenschaften

Language:

- offered only in German

Notes:

Admission requirememnts for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments during the semester

Module exam(s):
- MA4020-L1: Stochastics 2, written exam, 90 min, 100 % of module grade

The lecture is identical to the one in module MA4020.

MA4030-KP08, MA4030 - Optimization (Opti)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	8

Course of study, specific field and term:

- Minor in Teaching Mathematics, Bachelor of Arts 2023 (compulsory), mathematics, 8th semester
- Bachelor CLS 2023 (compulsory), mathematics, 4th semester
- Master Auditory Technology 2022 (optional subject), mathematics, 2nd semester
- Master MES 2020 (optional subject), mathematics / natural sciences, Arbitrary semester
- Bachelor Computer Science 2019 (optional subject), Extended optional subjects, Arbitrary semester
- Master Robotics and Autonomous Systems 2019 (optional subject), Additionally recognized elective module, Arbitrary semester
- Minor in Teaching Mathematics, Bachelor of Arts 2017 (compulsory), mathematics, 8th semester
- Master Auditory Technology 2017 (optional subject), mathematics, 1st or 2nd semester
- Bachelor Computer Science 2016 (optional subject), advanced curriculum, Arbitrary semester
- Bachelor CLS 2016 (compulsory), mathematics, 4th semester
- Master MES 2014 (optional subject), mathematics / natural sciences, Arbitrary semester
- Master MES 2011 (optional subject), mathematics, 2nd semester
- Master Computer Science 2012 (optional subject), advanced curriculum numerical image processing, 2nd or 3rd semester
- Bachelor MES 2011 (optional subject), medical engineering science, 6th semester
- Master Computer Science 2012 (optional subject), advanced curriculum analysis, 2nd or 3rd semester
- Bachelor CLS 2010 (compulsory), mathematics, 4th semester

Classes and lectures:

- Optimization (lecture, 4 SWS)
- Optimization (exercise, 2 SWS)

Workload:

- 130 Hours private studies and exercises
- 90 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Linear optimization (simplex method)
- Unconstrained nonlinear optimization (gradient descent, conjugate gradients, Newton method, Quasi-Newton methods, globalization)
- Equality- and inquality-constrained nonlinear optimization (Lagrange multipliers, active set methods)
- Stochastic methods for machine learning

Qualification-goals/Competencies:

- Students can model real-life problems as optimization problems.
- They understand central optimization techniques.
- They can explain central optimization techniques.
- They can compare and assess central optimization techniques.
- They can implement central optimization techniques.
- They can assess numerical results.
- They can select suitable optimization techniques for practical problems.
- Interdisciplinary qualifications:
- Students can transfer theoretical concepts into practical solutions.
- They are experienced in implementation.
- They can think abstractly about practical problems.

Grading through:

- Written or oral exam as announced by the examiner

Is requisite for:

- Non-smooth Optimization and Analysis (MA5035-KP05)

Requires:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Analysis 2 (MA2500-KP09)
- Analysis 2 (MA2500-KP04, MA2500)

Responsible for this module:

- Prof. Dr. rer. nat. Jan Modersitzki

Teacher:

- Institute of Mathematics and Image Computing

- Prof. Dr. rer. nat. Jan Modersitzki
- Prof. Dr. rer. nat. Jan Lellmann

Literature:

- J. Nocedal, S. Wright: Numerical Optimization - Springer
- F. Jarre: Optimierung - Springer
- C. Geiger: Theorie und Numerik restringierter Optimierungsaufgaben - Springer

Language:

- offered only in German

Notes:

Prerequisites for attending the module:
- None (Familiarity with the topics of the required modules is assumed, but the modules are not a formal prerequisite for attending the course).

Prerequisites for the exam:
- Examination prerequisites can be defined at the beginning of the semester. If preliminary work is defined, it must have been completed and positively evaluated before the first examination.

Examination:
- MA4030-L1: Optimization, written examination (90 min) or oral examination (30 min) as decided by examiner, 100 % of final mark

MA4040-KP06 - Numerics 2 (Num2KP06)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	6

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), mathematics, 4th semester
- Minor in Teaching Mathematics, Master of Education 2017 (compulsory), mathematics, 2nd semester
- Bachelor CLS 2016 (compulsory), mathematics, 4th semester

Classes and lectures:

- Numerics 2 (lecture, 2 SWS)
- Numerics 2 (exercise, 2 SWS)

Workload:

- 100 Hours private studies and exercises
- 60 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Polynomial interpolation
- Hermite interpolation
- Approximation
- Numerical quadrature

Qualification-goals/Competencies:

- Becoming acquainted with fundamental munerical methods
- Understanding the transformation of a continuous problem into a discrete one
- Secure competencies in using both stable and robust numeric algorithms
- Experience in the implementation of practical tasks

Grading through:

- written exam

Requires:

- Numerics 1 (MA3110-KP06)
- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)
- Analysis 2 (MA2500-KP09)
- Analysis 1 (MA2000-KP08, MA2000)

Responsible for this module:

- Prof. Dr. rer. nat. Andreas Rößler

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Andreas Rößler

Literature:

- W. Dahmen, A. Reusken: Numerische Mathematik für Ingenieure und Naturwissenschaftler - 2. Auflage, Springer (2008)
- P. Deuflhard, A. Hohmann: Numerische Mathematik I - 4. Auflage, De Gruyter (2008)
- P. Deuflhard, F. Bornemann: Numerische Mathematik II - 4. Auflage, De Gruyter (2013)
- M. Hanke-Bourgeois: Grundlagen der Numerischen Mathematik und des Wissenschaftlichen Rechnens - 3. Auflage, Teubner (2009)
- H. R. Schwarz, N. Köckler: Numerische Mathematik - 8. Auflage, Teubner (2011)
- J. Stoer: Numerische Mathematik I - 10. Auflage, Springer (2007)
- J. Stoer, R. Bulirsch: Numerische Mathematik II - 6. Auflage, Springer (2011)
- A. M. Quarteroni, R. Sacco, F. Salieri: Numerical Mathematics - 2. Auflage, Springer (2007)

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Examination prerequisites can be defined at the beginning of the semester. If preliminary work is defined, it must have been completed and positively evaluated before the first examination.

Module exam(s):
- MA4040-L1: Numerics 2, written exam, 90 min, 100 % of module grade

Module MA4040-KP06 is identical to module MA4040-MML.

MA4100-KP05 - Survival Analysis (UebAnaKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional suject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Survival Analysis (lecture, 2 SWS)
- Survival Analysis (exercise, 1 SWS)

Workload:

- 90 Hours private studies
- 30 Hours work on project
- 15 Hours in-classroom work
- 15 Hours exam preparation

Contents of teaching:

- Introduction to survival analysis
- Kaplan-Meier method
- Log rank test
- The Cox regression model and its characteristics
- Evaluating the proportional hazards assumption
- Stratified Cox model
- Parametric survival analysis
- Event time analyses for recurrent events
- Event time analysis for competing risks
- Design aspects for RCTs

Qualification-goals/Competencies:

- The students are able to explain the different censoring mechanisms leading to survival analysis.
- They are able to define the most important terms of survival analysis.
- They are able to calculate point and interval estimators for the Kaplan-Meier approach.
- They are able to calculate the log-rank test for two or more groups.
- They are able to explain the assumption of proportionality of the Cox model.
- They are able to estimate Cox models.
- They are able to check the assumption of proportionality.
- They are able to calculate exponential and Weibull models.
- They can explain the specifics of recurrent events and competing risks.
- They can estimate models for recurrent events and competing risks.
- They can design an RCT with a time-to-event endpoint.

Grading through:

- Oral examination

Requires:

- Biostatistics 2 (MA2600-KP07)
- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)
- Stochastics 2 (MA4020-KP07)
- Stochastics 1 (MA2510-KP04, MA2510)

Responsible for this module:

- Dr. Maren Vens

Teacher:

- Institute of Medical Biometry and Statistics

- Dr. Maren Vens

Literature:

- Kleinbaum DG, Klein M: Survival Analysis: A Self-Learning Text - 3rd Edition - 2012

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4100-L1: Survival Analysis, oral exam, 30 min, 100 % of module grade

MA4320-KP05 - Optimisation methods for machine learning (OptvML)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Bachelor CLS 2016 (optional subject), mathematics, 6th semester
- Master CLS 2016 (optional subject), mathematics, 2nd or 4th semester
- Bachelor CLS 2023 (optional subject), mathematics, 6th semester
- Master CLS 2023 (optional subject), mathematics, 2nd or 4th semester

Classes and lectures:

- MA4320-V: Optimisation methods for machine learning (lecture, 2 SWS)
- MA4320-Ü: Optimisation methods for machine learning (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Objective functions in machine learning (e.g. hinge loss, log loss, expected risk, empirical risk)
- Optimisation methods for machine learning (e.g. stochastic gradient method,Adam, stochastic quasi-Newton method)
- Applications (e.g. classification, regression, speech and image recognition)

Qualification-goals/Competencies:

- Students can model machine learning problems as optimisation problems.
- They understand the advantages and disadvantages and areas of application of individual optimisation methods.
- They can apply typical proof techniques.
- They can select optimisation methods and implement them in practice for new models.
- Interdisciplinary aspects:
- Students can put theoretical concepts into practice.
- They have implementation experience.
- They are able to abstract practical problems.

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Optimization (MA4030-KP08, MA4030)
- Optimization (Advanced Mathematics) (MA4031-KP08)

Responsible for this module:

- Prof. Dr. rer. nat. Jan Modersitzki

Teacher:

- Institute of Mathematics and Image Computing

- Prof. Dr. rer. nat. Jan Modersitzki
- Prof. Dr. rer. nat. Jan Lellmann
- Dr. rer. nat. Florian Mannel

Literature:

- Goodfellow, Bengio, Courville: Deep Learning - MIT Press
- Bottou, Curtis, Nocedal: Optimization Methods for Large-Scale Machine Learning - SIAM
- Bubeck: Convex Optimization: Algorithms and Complexity - Now Publishers Inc
- Lan: First-order and Stochastic Optimization Methods for Machine Learning - Springer

Language:

- German and English skills required

Notes:

Admission requirements for taking the module:
- None (the competences of the modules mentioned under Requires are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Ungraded preliminary examinations are exercises and their presentation. These must have been completed and positively assessed before the first examination.

Module Exam(s):
- MA4320-L1: Optimisation methods for machine learning, written exam, 90min, or oral exam, 30min, according to the lecturer, 100% of the module grade

MA4341-KP05 - Time series analysis (ZeitAnKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Minor in Teaching Mathematics, Master of Education 2023 (optional subject), mathematics, 2nd or 3rd semester
- Minor in Teaching Mathematics, Master of Education 2017 (optional subject), mathematics, 2nd or 3rd semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Time series analysis (lecture, 2 SWS)
- Time series analysis (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Simple discriptive and explorative methods: smoothing, differentiating, autocorrelation, cross correlation
- Linear time series models: MA-processes, AR-processes, ARIMA-processes
- Time series and models with long-range dependencies
- Time series in the frequency domain:autocorrelation function, spectral density and its estimation
- nonlinear methods by examples
- analysis and modelling of data from life sciences (software: R, Mathematica, SPSS)

Qualification-goals/Competencies:

- Students have basic knowledge of concepts and ideas of time series analysis
- They master simple linear methods of time series analysis
- They have competencies in analysis and modelling of real-world time series

Grading through:

- Oral examination

Requires:

- Stochastics 2 (MA4020-KP07)

Responsible for this module:

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Teacher:

- Institute for Mathematics

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Literature:

- R. Schlittgen, B.Streitberg: Zeitreihenanalyse - Oldenburg-Verlag, München, Wien 1994
- P.J. Brockwell, R.A. Davis: Time Series: Theory and Methods - Springer, New York 1991

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4341-L1: Time series analysis, oral exam, 30 min, 100 % of module grade

MA4345-KP05 - Functional Analysis (AKFunkKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Minor in Teaching Mathematics, Master of Education 2023 (optional subject), mathematics, 2nd or 3rd semester
- Minor in Teaching Mathematics, Master of Education 2017 (optional subject), mathematics, 2nd or 3rd semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Functional Analysis (lecture, 2 SWS)
- Functional Analysis (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- metric spaces
- elements of topology, in particular, compactness
- Banach and Hilbert spaces
- L^p-spaces
- duality
- bounded linear functionals and operators

Qualification-goals/Competencies:

- Understanding the transfer of simple analytic ideas to general structures
- Learning and applying techniques of functional analysis

Grading through:

- written exam

Requires:

- Analysis 2 (MA2500-KP04, MA2500)

Responsible for this module:

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Teacher:

- Institute for Mathematics

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Literature:

- A. N. Kolmogorov, S. V. Fomin: Reelle Funktionen und Funktionalanalysis - Deutscher Verlag der Wissenschaften, Berlin 1975

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4345-L1: Functional Analysis, oral exam, 30 min, 100 % of module grade

MA4400-KP05 - Chaos and Complexity (ChaKomKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master Biophysics 2019 (optional subject), Elective, 1st or 2nd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Chaos and Complexity (lecture, 2 SWS)
- Chaos and Complexity (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Time-discrete dynamical systems and stochastic processes
- Nonlinearity and chaos
- Ergodicity
- Symbolic dynamics
- Information-theoretic complexity measures
- Ordinal time series analysis
- Biological and medical applications, in particular EEG analysis

Qualification-goals/Competencies:

- Students get insights into basic aspects of nonlinear dynamics
- They have skills in analyzing and modeling complex data and time series
- They have competencies in simulating and illustrating nonlinear dynamic phenomena

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Stochastics 1 (MA2510-KP04, MA2510)
- Analysis 1 (MA2000-KP08, MA2000)

Responsible for this module:

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Teacher:

- Institute for Mathematics

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Literature:

- M. Brin, G. Stuck: Introduction to Dynamical Systems - Cambridge University Press 2002
- J. M. Amigó: Permutation Complexity in Dynamical Systems - Springer 2010
- R. L. Devaney: An Introduction to Chaotic Dynamical Systems - Westview Press 2003

Language:

- depends on the chosen courses

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4400-L1: Chaos and Complexity, oral exam, 30 min, 100 % of module grade

Lecture notes in English

MA4410-KP05 - Approximation Theory (ApproxKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Minor in Teaching Mathematics, Master of Education 2023 (optional subject), mathematics, 2nd or 3rd semester
- Minor in Teaching Mathematics, Master of Education 2017 (optional subject), mathematics, 2nd or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Approximation theory (lecture, 2 SWS)
- Approximation theory (exercise, 1 SWS)

Workload:

- 65 Hours private studies and exercises
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Fundamentals of functional analysis
- Best approximation
- Linear methods, trigonometric kernels
- Theorems of Jackson and Bernstein
- Moduli of continuity
- Singular integrals
- Theorem of Banach-Steinhaus
- Interpolation methods
- Stability inequalities

Qualification-goals/Competencies:

- practicing mathematical techniques (developing mathematical intuition and its formal justification, training the ability to abstract, reasoning)
- application of basic concepts from functional analysis and the theory of function spaces
- Learning the basic principles of approximation theory
- Understanding the relationship between order of convergence and smoothness
- Knowledge of the basic approximation methods
- application of computer algebra for visualization and better understanding of the methods used

Grading through:

- exercises, project, oral or written exam

Responsible for this module:

- Prof. Dr. rer. nat. Jürgen Prestin

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Jürgen Prestin

Literature:

- P. L. Butzer, R. J. Nessel: Fourier Analysis and Approximation - Birkhäuser Verlag 1971
- R. A. Devore, G. G. Lorentz: Constructive Approximation - Springer 1993

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4410-L1: Approximation Theory, oral exam, 30 min, 100 % of module grade

MA4453-KP05 - Evolutionary Dynamics: Population Genetic and Ecological Models (EDPGEMKP05)		
Duration:	**Turnus of offer:**	**Credit points:**
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Evolutionary Dynamics: Population Genetic and Ecological Models (lecture, 2 SWS)
- Evolutionary Dynamics: Population Genetic and Ecological Models (exercise, 1 SWS)

Workload:

- 65 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Basics of mathematical population genetics
- Discrete stochastic models
- Genetic drift
- Natural selection
- Coupling of genetic and ecological models
- Dynamics of infectious diseases
- Handling publicly available data on the spread of infectious diseases

Qualification-goals/Competencies:

- The students can explain the basic biological and mathematical concepts of population genetics.
- The students can construct simple stochastic models and analyse them formally.
- The students can perform approximations of simple models.
- The Students will be able to contextualize mathematical models and data.

Grading through:

- Oral examination

Responsible for this module:

- Prof. Dr. Arne Traulsen

Teacher:

- Max Planck Institute for Evolutionary Biology
- Institute for Mathematics

- Prof. Dr. Arne Traulsen
- MitarbeiterInnen des Instituts
- Dr. Christian Hilbe
- Dr. Hildegard Uecker
- Dr. Chaitanya Gokhale

Literature:

- S.P. Otto and T.Day: A Biologist s Guide to Mathematical Modeling in Ecology and Evolution. - Princeton University Press, 2007

Language:

- offered only in English

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4453-L1: Evolutionary Dynamics: Population Genetic and Ecological Models, oral exam, 30 min, 100 % of module grade

MA4454-KP05 - Evolutionary Dynamics: Game Theory (EvDyGTKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Evolutionary Game Theory - from Basics to Recent Developments (lecture, 2 SWS)
- Evolutionary Game Theory - from Basics to Recent Developments (exercise, 1 SWS)

Workload:

- 65 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Basics of classical game theory
- Deterministic and stochastic evolutionary game theory
- The evolution of cooperation and punishment
- Repeated games
- Applications in genetics, ecology and social dynamics

Qualification-goals/Competencies:

- The students can explain and apply the basic concepts of game theory.
- They can construct evolutionary models based on game theoretic interactions.
- They can analyse evolutionary games formally.

Grading through:

- Oral examination

Responsible for this module:

- Prof. Dr. Arne Traulsen

Teacher:

- Max Planck Institute for Evolutionary Biology
- Institute for Mathematics

- Prof. Dr. Arne Traulsen
- N.N.

Literature:

- M.A. Nowak: Evolutionary Dynamics - Exploring the equations of life - Harvard University Press, 2006
- Broom & Rychtar: Game-Theoretical Models in Biology - Chapman & Hall, 2013

Language:

- offered only in English

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4454-L1: Evolutionary Dynamics: Game Theory, oral exam, 30 min, 100 % of module grade

MA4510-KP05 - Wavelet Theory (WaveThKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Wavelet Theory (lecture, 2 SWS)
- Wavelet Theory (exercise, 1 SWS)

Workload:

- 65 Hours private studies and exercises
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Haar system
- Discrete Haar transformation
- Orthonormal wavelet bases
- Multiresolution Analysis
- Algorithms for reconstruction and decomposition
- Periodic wavelets
- Multivariate generalizations

Qualification-goals/Competencies:

- practicing mathematical techniques (developing mathematical intuition and its formal justification, training the ability to abstract, reasoning)
- application of basic concepts from functional analysis and the theory of function spaces
- Knowledge of the basic principles of wavelet analysis
- Understanding the applications in signal analysis
- The students learn how to work with wavelet algorithms and wavelet software.
- application of computer algebra for visualization and better understanding of the methods used

Grading through:

- exercises, project, oral or written exam

Responsible for this module:

- Prof. Dr. rer. nat. Jürgen Prestin

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Jürgen Prestin

Literature:

- I. Daubechies: Ten lectures on wavelets - SIAM Publ., Philadelphia, 1992
- A.K. Louis, P. Maass, A. Rieder: Wavelets - Teubner Studienbücher Mathematik, 1994

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4510-L1: Wavelet Theory, oral exam, 30 min, 100 % of module grade

MA4611-KP05 - Markov Processes (MarkPrKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Markov Processes (lecture, 2 SWS)
- Markov Processes (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Markov chains and random walks
- time-continuous Markov processes
- Brownian Motion
- Poisson process
- birth-and-death processes
- life science applications

Qualification-goals/Competencies:

- Mastering some important classes of stochastic processes and understanding possible applications

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Teacher:

- Institute for Mathematics
- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4611-L1: Markov Processes, oral exam, 30 min, 100 % of module grade

MA4614-KP05 - Numerical methods for partial differential equations (NMPDGKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Numerical methods for partial differential equations (lecture, 2 SWS)
- Numerical methods for partial differential equations (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Introduction to the theory of partial differential equations
- Numerics for partial differential equations
- Discretization of initial and boundary value problems
- Numerical approximation schemes
- Error analysis
- Stability and consistency

Qualification-goals/Competencies:

- To impart basic principles of numerics for partial differential equations
- To learn methods of proofs as well as the application of results from numerics for partial differential equations
- Accomplished handling of essential concepts and results as well as of selected advanced topics

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Numerics 2 (MA4040-KP06)
- Numerics 1 (MA3110-KP06)
- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)
- Analysis 2 (MA2500-KP09)
- Analysis 1 (MA2000-KP08, MA2000)

Responsible for this module:

- Prof. Dr. rer. nat. Andreas Rößler

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Andreas Rößler
- MitarbeiterInnen des Instituts

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4614-L1: Numerical methods for partial differential equations, written exam (90 min) or oral exam (30 min), 100 % of module grade

Literature will be announced in the lecture.

MA4615-KP05 - Numerical methods for stochastic processes (NuStPrKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Numerical methods for stochastic processes (lecture, 2 SWS)
- Numerical methods for stochastic processes (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Basic principles of stochastic processes in continuous time
- Stochastic differential equations
- Discrete time approximations for solutions of stochastic differential equations
- Numerical schemes for strong and weak approximations

Qualification-goals/Competencies:

- To impart basic principles of stochastic processes and of some numerical schemes
- To learn methods of proof as well as the application of algorithms
- Accomplished handling of essential concepts and results as well as of selected advanced topics

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Stochastic processes (MA4610-KP05)
- Stochastics 2 (MA4020-KP07)
- Stochastics 1 (MA2510-KP04, MA2510)

Responsible for this module:

- Prof. Dr. rer. nat. Andreas Rößler

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Andreas Rößler

Literature:

- P. E. Kloeden, E. Platen: Numerical Solution of Stochastic Differential Equations - Springer-Verlag, Berlin, 1999
- P. E. Kloeden, E. Platen, H. Schurz: Numerical Solution of SDE Through Computer Experiments - Springer-Verlag, Berlin, 2003
- G. N. Milstein, M. V. Tretyakov: Stochastic Numerics for Mathematical Physics - Springer-Verlag, Berlin, 2004

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4615-L1: Numerical methods for stochastic processes, written exam (90 min) or oral exam (30 min), 100 % of module grade

MA4616-KP05 - Advanced Numerics (HoeNumKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Minor in Teaching Mathematics, Master of Education 2023 (optional subject), mathematics, 2nd or 3rd semester
- Minor in Teaching Mathematics, Master of Education 2017 (optional subject), mathematics, 2nd or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Advanced Numerics (lecture, 2 SWS)
- Advanced Numerics (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Numerics for ordinary differential equations
- One-step methods, local and global error analysis
- Orders of consistence and convergence
- Stiff differential equations, implicit schemes, stability

Qualification-goals/Competencies:

- To impart basic principles of numerics for differential equations
- To learn methods of proofs as well as the application of results from numerics for differential equations
- Accomplished handling of essential concepts and results as well as of selected advanced topics

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Numerics 2 (MA4040-KP06)
- Numerics 1 (MA3110-KP06)

Responsible for this module:

- Prof. Dr. rer. nat. Andreas Rößler

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Andreas Rößler

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4616-L1: Advanced Numerics, written exam (90 min) or oral exam (30 min), 100 % of module grade

Literature will be announced in the lecture.

MA4630-KP05 - Fourier Analysis (FouAnaKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional suject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Fourier Analysis (lecture, 2 SWS)
- Fourier Analysis (exercise, 1 SWS)

Workload:

- 65 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Theory of the Fourier transform
- Fourier transform in the Hilbert space
- Summability methods
- Applying Fourier transforms in solving differential equations
- Laplace and Mellin transforms
- Numerical aspects and relation to discrete Fourier transforms

Qualification-goals/Competencies:

- Practicing mathematical techniques (developing mathematical intuition and its formal justification, training the ability to abstract, reasoning)
- Application of basic concepts from functional analysis and the theory of function spaces
- Knowledge of integral transforms
- A comprehensive understanding for the Fourier transform
- Application of computer algebra for visualization and better understanding of the methods used

Grading through:

- exercises, project, oral or written exam

Responsible for this module:

- Prof. Dr. rer. nat. Jürgen Prestin

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Jürgen Prestin

Literature:

- Chandrasekharan, K.: Classical Fourier Transforms - Springer 1989
- Pinsky, M. A.: Introduction to Fourier Analysis and Wavelets - Brooks/Cole 2002

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4630-L1: Fourier Analysis, oral exam, 30 min, 100 % of module grade

MA4650-KP05 - Matrix algebra (MatAlgKP05)

Duration:	Turnus of offer:	Credit points:	Max. group size:
1 Semester	every second year	5	20

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Matrix algebra (lecture, 2 SWS)
- Matrix algebra (exercise, 1 SWS)

Workload:

- 60 Hours private studies and exercises
- 45 Hours in-classroom work
- 30 Hours work on project
- 15 Hours exam preparation

Contents of teaching:

- Properties of matrices
- Special matrices
- Quadratic forms
- Decompositions
- Generalized inverses
- Differentiation
- Probability calculation
- Derivation and calculation of estimators
- Design matrices
- Linear hypotheses
- Examples: multiple linear regression, weighted least-squares estimation, shrinkage estimation

Qualification-goals/Competencies:

- Students know numerous rules of matrix algebra.
- They understand proofs, especially concerning generalized linear models and multivariate procedures.
- They command matrix calculus.
- They apply linear algebra to linear models.
- They can deal with practical problems from statistics in an abstract manner.

Grading through:

- written exam

Requires:

- Biostatistics 2 (MA2600-KP07)
- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)
- Analysis 2 (MA2500-KP09)

Responsible for this module:

- PD Dr. rer. pol. Reinhard Vonthein

Teacher:

- Institute of Medical Biometry and Statistics

- PD Dr. rer. pol. Reinhard Vonthein
- MitarbeiterInnen des Instituts

Literature:

- Schmidt, K., Trenkler, G.: Einführung in die Moderne Matrix-Algebra: Mit Anwendungen in der Statistik - Springer: Heidelberg 2006, ISBN 9783540330073
- Toutenburg, H.: Lineare Modelle - Physica: Heidelberg 1992 und 2006, ISBN 978-3790815191
- Fahrmeir, L., Kneib, T., Lang, S.: Regression: Modelle, Methoden und Anwendungen - Springer: Heidelberg 2007, ISBN 9783642343339

- Healy, Michael: Matrices for Statistics - ISBN 9780198507024

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4650-L1: Matrix algebra, written exam, 90 min, 100 % of module grade

MA4661-KP08, MA4661 - Genetic Epidemiology 2 (GenEpi2)

Duration:	Turnus of offer:	Credit points:	Max. group size:
1 Semester	each summer semester	8	20

Course of study, specific field and term:

- Master CLS 2023 (compulsory), MML with specialization in Genetic Statistics, 2nd semester
- Bachelor CLS 2023 (optional suject), mathematics, 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 6th semester
- Master CLS 2016 (compulsory), MML with specialization in Genetic Statistics, 2nd semester
- Bachelor CLS 2010 (optional subject), mathematics, 6th semester
- Master CLS 2010 (optional subject), mathematics, Arbitrary semester

Classes and lectures:

- Genetic Epidemiology 2 (lecture, 2 SWS)
- Genetic Epidemiology 2 (exercise, 1 SWS)
- Genetic Epidemiology 2 (practical course, 2 SWS)

Workload:

- 135 Hours private studies
- 75 Hours in-classroom work
- 30 Hours exam preparation

Contents of teaching:

- Classical methods of genetic epidemiology: - Familial aggregation and heritability - Model-based linkage analysis - Model-free linkage analysis - Linkage analysis for quantitative phenotypes - Linkage analyses for quantitative phenotypes - Family-based association tests
- Current topics in genetic epidemiology, e.g.: - Association tests for rare variants - Analysis of Omics data - Polygenic scores - Mendelian randomization
- Analysis of genetic data using specialized software packages (such as PLINK and MERLIN): - Genome-wide association studies - Family studies (linkage and association analyses)

Qualification-goals/Competencies:

- Students will be able to name and describe the most important procedures for linkage and association analysis in family studies.
- They know current analysis methods in genetic epidemiology.
- They can perform elementary tests by hand and interpret the results.
- They will be able to use software for more complex testing procedures and interpret the results.

Grading through:

- Written or oral exam as announced by the examiner

Is requisite for:

- Seminar Genetic Epidemiology (MA5129-KP04, MA5129)

Requires:

- Biostatistics 2 (MA2600-KP07)
- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)
- Genetic Epidemiology 1 (MA3200-KP04, MA3200)

Responsible for this module:

- Prof. Dr. rer. nat. Silke Szymczak

Teacher:

- Institute of Medical Biometry and Statistics

- Prof. Dr. rer. nat. Silke Szymczak
- MitarbeiterInnen des Instituts

Literature:

- Ziegler, Andreas; König Inke R (2010): A Statistical Approach to Genetic Epidemiology. Concepts and Applications - 2nd ed., Wiley-VCH: Weinheim
- Bickeböller, Heike; Fischer, Christine (2007): Einführung in die Genetische Epidemiologie - Springer: New York
- Recent review articles: (to be announced in lecture)

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Examination prerequisites can be defined at the beginning of the semester. If preliminary work is defined, it must have been completed and positively evaluated before the first examination.

Module exam(s):
- MA4661-L1: Genetic Epidemiology 2, written exam (90 min) or oral exam (30 min), 100 % of module grade
- MA4661-L2: Practical Course Genetic Epidemiology 2, ungraded practical course, 0 % of module grade, must be passed

(Share of Institute of Medical Biometry and Statistics in V is 100%)
(Share of Institute of Medical Biometry and Statistics in Ü is 100%)
(Share of Institute of Medical Biometry and Statistics in P is 100%)

MA4665-KP05 - Statistical Learning (StaLerKP05)

Duration:	Turnus of offer:	Credit points:	Max. group size:
1 Semester	every second year	5	20

Course of study, specific field and term:

- Master Medical Informatics 2019 (optional subject), Medical Data Science / Artificial Intelligence, 1st or 2nd semester
- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Statistical Learning (lecture, 2 SWS)
- Statistical Learning (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 15 Hours exam preparation

Contents of teaching:

- Application scenarios and research questions for prediction models (focus: risk prediction)
- Study design and data preprocessing
- Overview of different machine learning methods (concepts, advantages and disadvantages)
- Development of prediction models
- Evaluation of prediction performance
- Comparison of prediction models
- Variable selection
- Extension to time-to-event outcomes with censoring

Qualification-goals/Competencies:

- Students can define research questions for applications of pediction models
- They can explain the individual steps in the development and evaluation of prediction models
- They can describe frequently occurring errors and problems as well als possible solutions
- They can describe central ideas of different machine learning methods and select suitable methods for applications
- They can develop and evaluate models in the programming language R

Grading through:

- project work
- Viva Voce or test

Requires:

- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)

Responsible for this module:

- Prof. Dr. rer. nat. Silke Szymczak

Teacher:

- Institute of Medical Biometry and Statistics

- Prof. Dr. rer. nat. Silke Szymczak
- MitarbeiterInnen des Instituts

Literature:

- Thomas Gerds und Michael Kattan: Medical Risk Prediction Models With Ties to Machine Learning - CRC Press: Bota Raton, FL (2022)

Language:

- German or English

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- None

Module exam(s):
- MA4665-L1: Statistical Learning, oral exam (20 min) or written exam (60 min), 50 % of module grade
- MA4665-L2: Research project incl. presentation and code documentation, 50 % of module grade

MA4666-KP05 - Interpretable Statistical Learning (IStLern)			
Duration:	**Turnus of offer:**	**Credit points:**	**Max. group size:**
1 Semester	every second year	5	20

Course of study, specific field and term:

- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2023 (optional subject), mathematics, Arbitrary semester
- Master CLS 2016 (optional subject), mathematics, Arbitrary semester
- Master Medical Informatics 2019 (optional subject), Medical Data Science / Artificial Intelligence, 1st or 2nd semester

Classes and lectures:

- Interpretable Statistical Learning (lecture, 2 SWS)
- Interpretable Statistical Learning (exercise, 1 SWS)

Workload:

- 60 Hours private studies and exercises
- 45 Hours in-classroom work
- 30 Hours programming
- 15 Hours exam preparation

Contents of teaching:

- Definition: Interpretable statistical learning
- Interpretable models
- Global model-agnostic methods
- Partial Dependence Plots (PDP)
- Accumulated Local Effects (ALE)
- Variable importance measures
- Local model-agnostic methods
- Individual Conditional Expectation (ICE)
- Local Surrogates (LIME)
- Counterfactional Explanations
- Shapley Werte, SHAP

Qualification-goals/Competencies:

- Students can explain the central ideas of interpretable statistical learning.
- They know the difference between model-based and model-agnostic methods.
- The can explain the differences between different methods for model interpretation.
- They can choose suitable methods for a given applicational setting.
- They can implement and apply these methods in R.

Grading through:

- Viva Voce or test

Requires:

- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)

Teacher:

- Institute of Medical Biometry and Statistics

- Dr. rer. hum. biol. Björn-Hergen Laabs

Literature:

- Molnar, C.: Interpretable Machine Learning: A Guide for Making Black Box Models Explainable - Springer, New York 2022 (2nd ed.)
- Hastie, T., Tibshirani, R., Friedmann, J.: The Elements of Statistical Learning: Data Mining, Inference and Prediction - Springer, New York 2009 (2nd ed.)
- Wu, X., Kumar, V.: The Top Ten Algorithms in Data Mining - CRC Press, Boca Raton 2009

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module
- None (the competences of the modules mentioned under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- None

Module Exam(s):
- MA4666-L1: Interpretable Statistical Learning, oral exam (20 min) or written exam (60 min), 100% of the module grade

MA4670-KP05 - Combinatorics (KombiKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Minor in Teaching Mathematics, Master of Education 2023 (optional subject), mathematics, 2nd or 3rd semester
- Minor in Teaching Mathematics, Master of Education 2017 (optional subject), mathematics, 2nd or 3rd semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- combinatorics (lecture, 2 SWS)
- combinatorics (exercise, 1 SWS)

Workload:

- 85 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Permutations, combinations, variations
- Partitions
- Generating functions
- Recurrence equations
- Sums and differences
- Inclusion - exclusion

Qualification-goals/Competencies:

- Learning the basics of combinatorics
- Knowledge of different proof techniques and combinatorial approaches
- Teaching fundamental results and deepening some selected aspects of combinatorics
- Ability to learn independently by studying relevant literature

Grading through:

- Oral examination

Requires:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)
- Analysis 1 (MA2000-KP08, MA2000)

Responsible for this module:

- PD Dr. rer. nat. Christian Bey

Teacher:

- Institute for Mathematics

- PD Dr. rer. nat. Christian Bey

Literature:

- Peter Tittmann: Einführung in die Kombinatorik - Spektrum Akademischer Verlag 2000
- Richard A. Brualdi: Introductory Combinatorics - Pearson Prentice Hall 2004

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4670-L1: Combinatorics, oral exam, 30 min, 100 % of module grade

MA4675-KP05 - Algebra (AlgebrKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Algebra (lecture, 2 SWS)
- Algebra (exercise, 1 SWS)

Workload:

- 85 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Groups (semigroups, subgroups, homomorphisms, invariant subgroups, isomorphism theorems, products of groups)
- Rings (units, ring homomorphisms, polynomial rings, quotient fields, ideals)
- Field extensions (field characteristic, prime fields, field degree, algebraic and transcendent elements, algebraical field extensions, splitting field of a polynomial)
- Geometric constructions (compass-and-straightedge construction, field of constructible points, constructing regular polygons)

Qualification-goals/Competencies:

- Learning the basics of algebra
- Knowledge of different proof techniques and algebraic approaches
- Teaching fundamental results and deepening some selected aspects of algebra
- Ability to learn independently by studying relevant literature

Grading through:

- Oral examination

Requires:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)

Responsible for this module:

- PD Dr. rer. nat. Christian Bey

Teacher:

- Institute for Mathematics

- PD Dr. rer. nat. Christian Bey

Literature:

- G. Fischer: Lehrbuch der Algebra - Vieweg, 2011 (2. Auflage)
- M. Artin: Algebra - Birkhäuser, 1998
- B. L. van der Waerden: Algebra I - Springer, 1993 (9. Auflage)

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4675-L1: Algebra, oral exam, 30 min, 100 % of module grade

MA4735-KP05 - Geometry (GeoKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Minor in Teaching Mathematics, Master of Education 2023 (optional subject), mathematics, 2nd or 3rd semester
- Minor in Teaching Mathematics, Master of Education 2017 (optional subject), mathematics, 2nd or 3rd semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Geometry (lecture, 2 SWS)
- Geometry (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Euclidean Geometry
- Non-Euclidean Geometries
- Introduction to Differential Geometry

Qualification-goals/Competencies:

- Mastery of basic geometric results
- Gaining an overview over different geometries and their specifics

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Analysis 2 (MA2500-KP09)
- Analysis 1 (MA2000-KP08, MA2000)
- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)

Responsible for this module:

- PD Dr. rer. nat. Christian Bey

Teacher:

- Institute for Mathematics

- PD Dr. rer. nat. Christian Bey

Literature:

- Bär: Elementare Differentialgeometrie
- Berger: Geometry I, II
- Coxeter: Introduction to Geometry
- Knörrer: Geometrie
- Kumaresan, Santhanam: An Expedition to Geometry
- Nikulin, Shafarevich: Geometries and Groups
- McCleary: Geometry from a Differentiable Viewpoint
- Rees: Notes on Geometry
- Sossinsky: Geometries
- Stahl: A Gateway to Modern Geometry, The Poincare Half-Plane

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4735-L1: Geometry, oral exam, 30 min, 100 % of module grade

MA4750-KP05 - Topology (TopoKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Topology (lecture, 2 SWS)
- Topology (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Topological spaces and continuous maps
- Fundamental group and covering spaces
- Introduction to Homology
- Applications

Qualification-goals/Competencies:

- Mastery of basic results and proof techniques of topology
- Understanding of applications of topological methods

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Analysis 2 (MA2500-KP09)
- Analysis 1 (MA2000-KP08, MA2000)
- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)

Responsible for this module:

- PD Dr. rer. nat. Christian Bey

Teacher:

- Institute for Mathematics
- PD Dr. rer. nat. Christian Bey

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4750-L1: Topology, oral exam, 30 min, 100 % of module grade

MA4760-KP05 - Integral Theorems in Analysis (IntAnaKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Integral Theorems in Analysis (lecture, 2 SWS)
- Integral Theorems in Analysis (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Integration on submanifolds
- Gauss' Integral Theorem and applications
- One-forms, line integrals, Green's Integral Theorem
- Higher-order differential forms, Integration
- Stokes' Integral Theorem and applications
- Cauchy's Integral Theorem and applications

Qualification-goals/Competencies:

- Mastery of basic results and proof techniques of vector analysis
- Understanding of applications of vector analysis

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Analysis 2 (MA2500-KP09)
- Analysis 1 (MA2000-KP08, MA2000)
- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)

Responsible for this module:

- PD Dr. rer. nat. Christian Bey

Teacher:

- Institute for Mathematics

- PD Dr. rer. nat. Christian Bey

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4760-L1: Integral Theorems in Analysis, oral exam, 30 min, 100 % of module grade

MA4801-KP05 - Elliptic Functions and Function Theory (EFFThKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Elliptic Functions and Function Theory (lecture, 2 SWS)
- Elliptic Functions and Function Theory (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 15 Hours exam preparation

Contents of teaching:

- Complex analysis
- Periodic functions and lattices
- Simple and double periods
- Liouville Theorem, residue theorem
- Weierstrass P-, Zeta- and Sigma-function
- The field of elliptic functions
- Elliptic integrals
- Moduls of elliptic functions

Qualification-goals/Competencies:

- Getting familiar with and developing skills in concepts and techiques in complex analysis
- Extension of the background for different applications, e.a. signal processing, to develop problem solving strategies
- Getting familiar with Mathematica in the considered topic
- Developing competencies for self-sufficient problem solving
- Gaining experience in project work in the field

Grading through:

- exercises, project, oral or written exam

Responsible for this module:

- Prof. Dr. Reinhard Schuster

Teacher:

- Institute for Mathematics

- Prof. Dr. Reinhard Schuster

Literature:

- Andrews, G. E., Askey, R. and Roy, R.: Special Functions - Cambridge University Press 1999
- Armitage, J. V. and Eberlein, W. F.: Elliptic Functions - Cambridge University Press 2006
- Hurwitz, A.: Vorlesungen über Allgemeine Funktionentheorie und Elliptische Funktionen - Springer 2000
- Koecher, M und Krieg, A.: Elliptische Funktionen und Modulformen - Springer 2007
- Stramp, W., Ganzha, V. und Vorozhtsov, E.: Höhere Mathematik mit Mathematica - Vieweg 1997
- Werner, A.: Elliptische Kurven in der Kryptographie - Springer 2002
- Whittaker, E. T. and Watson, G. N.: A course of modern analysis - Cambridge University Press 1902 (Reprinted 1999)

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4801-L1: Elliptic Functions and Function Theory, written exam (90 min) or oral exam (30 min), 100 % of module grade

MA4802-KP05 - Theory of Relativity (RelaThKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Theory of Relativity (lecture, 2 SWS)
- Theory of Relativity (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 15 Hours exam preparation

Contents of teaching:

- Part A, Special Relativity:
- Classical space time references system and Newton laws
- Electrodynamics, Lorentz and Minkowsky geometry
- Hyperbolic geometry und trigonometry
- Time-like, space-like and light cone
- Relativistic kinematics
- Simultaneity and velocity addition
- Length contraction and time dilatation
- Twin paradox
- Mass and energy relativistic
- Part B, General Theory of Relativity:
- Four-dimensional space time as a manifold
- Christoffel symbols, curvature tensor, covariant derivative
- Coupling of matter and fields with geometry by the Einstein equation
- Equivalence principle for mass

Qualification-goals/Competencies:

- Getting familiar with concepts and gaining competencies on special and general relativity
- Extension of the mathematic and physical background for different applications to develop problem solving strategies
- Getting familiar with Mathematica in the considered field
- Developing competencies for self-sufficient problem solving of tasks on the theory of relativity
- Gaining experience in project work in the field

Grading through:

- exercises, project, oral or written exam

Responsible for this module:

- Prof. Dr. Reinhard Schuster

Teacher:

- Institute for Mathematics

- Prof. Dr. Reinhard Schuster

Literature:

- Baumann, G.: Mathematica for Theoretical Physics. Part 1: Classical Mechanics and Nonlinear Dynamics. Part 2: Electrodynamics, Quantum Mechanics, General Relativity, and Fractals - Springer 2005
- Goenner, H.: Spezielle Relativitätstheorie und die klassische Feldtheorie - Spectrum 2003
- Gray A., Abbena, E. and Salomon, S.: Modern Differential Geometry of Surfaces with Mathematica. Studies in Advanced Mathematics - Chapman and Hall 2006
- Haken, H. und Wolf, H. Ch.: Atom- und Quantenphysik. Einführung in die experimentellen und theoretischen Grundlagen - Springer

2003
- Hawking, S. W. and Ellis, G. F. R.: The large scale structure of space-time - Cambridge Monographs on Mathematical Physics 1973, 2006
- Helgason, S.: Differential Geometry, Lie Groups and Symmetric Spaces. Graduate Studies in Mathematics - American Mathematical Society 1978, 2001
- Kobayashi, S. and Nomizu, K.: Foundations of Differential Geometry I, II - Interscience Publishers 1963
- Schröder, U. E.: Gravitation. Einführung in die Allgemeine Relativitätstheorie - Harri Deutsch 2007
- Weber, H. J. und Arfen, G. B.: Essential Mathematical Methods for Physics - Elsevier 2004
- Weil, H.: Raum - Zeit - Materie. Vorlesungen über allgemeine Relativitätstheorie - Springer 1923
- Wald, R. M.: General Relativity - The University of Chicago Press 1984

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4801-L1: Theory of Relativity, written exam (90 min) or oral exam (30 min), 100 % of module grade

MA4803-KP05 - Number Theory (ZahlThKP05)		
Duration:	**Turnus of offer:**	**Credit points:**
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Minor in Teaching Mathematics, Master of Education 2023 (optional subject), mathematics, 2nd or 3rd semester
- Minor in Teaching Mathematics, Master of Education 2017 (optional subject), mathematics, 2nd or 3rd semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Number Theory (lecture, 2 SWS)
- Number Theory (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 15 Hours exam preparation

Contents of teaching:

- Divisibility of integers, Farey sequencees, Fibonacci Numbers
- Approximation of real numbers by rational numbers
- Modulo operations: Complete and reduced residue system, Theorems of Euler and Fermat
- Representation of natural numbers sums of 2, 3 or 4 squares
- Quadratic residues
- Quadratic reciprocity
- Prime number criteria and pseudo prime numbers
- Pythagorean triples
- Rational points on curves of degree 2
- Number theoretic functions
- Prime number theorem, prime numbers in arithmetic progression
- Riemann zeta function and its functional equation
- Known problems and conjectures, i.e. Goldbach conjecture
- Stochastic prime numbers

Qualification-goals/Competencies:

- Theoretical knowledge of the mentioned topics
- Historical and most recent issues
- Solve questions in this filed
- Recognize interdisciplinary aspects

Grading through:

- exercises, project, oral or written exam

Responsible for this module:

- Prof. Dr. Reinhard Schuster

Teacher:

- Institute for Mathematics

- Prof. Dr. Reinhard Schuster

Literature:

- Chandrasekharan: Einführung in die analytische Zahlentheorie - Springer Lecture Notes 2008
- Bundschuh: Einführung in die Zahlentheorie - Springer 1992
- Menzer: Zahlentheorie: Fünf ausgewählte Themenstellungen der Zahlentheorie - Oldenbourg Wissenschaftsverlag 2010
- Remmert u. Ullrich: Elementare Zahlentheorie - Birkhäuser 1995
- Rempe: Primzahltests für Einsteiger: Zahlentheorie - Algorithmik - Kryptographie - Vieweg+Teubner 2009
- Scharlau, Opolka: Von Fermat bis Minkowski: Eine Vorlesung über Zahlentheorie und ihre Entwicklung - Springer 2009

- Scheid: Zahlentheorie - Spektrum 2003
- Schmidt: Einführung in die algebraische Zahlentheorie - Springer 2009
- Weil: Zahlentheorie - Spektrum 1992
- Winogradow: Elemente der Zahlentheorie - Prestel-Verlag 1956

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4803-L1: Number Theory, written exam (90 min) or oral exam (30 min), 100 % of module grade

MA4804-KP05 - Special Functions (SpFunkKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Minor in Teaching Mathematics, Master of Education 2023 (optional subject), mathematics, 2nd or 3rd semester
- Minor in Teaching Mathematics, Master of Education 2017 (optional subject), mathematics, 2nd or 3rd semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Special Functions (lecture, 2 SWS)
- Special Functions (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 15 Hours exam preparation

Contents of teaching:

- Algebraic operations with complex numbers
- Exponential function, angle functions, hyperbolic angle functions, derived functions
- Gamma and beta functions
- Hypergeometric function
- Bessel function, Legendre function, Laguerre function, Tscheybyscheff function, Hermite function, Jacobi hypergeometric function
- Elliptic functions, theta functions
- Number theoretic functions
- Riemann zeta function
- Used mathematical theories and concepts:
- Complex function theory
- Infinite products
- Differential equations (ordinary, partial)
- Functional equations
- Integral representation
- Taylor series expansions for eigenvalues and eigenfunctions (using space and time, defined on geometric objects)
- Producing functions (a Taylor series in two variables is considered as a series in one variable and the coefficients are special functions in the other variable)
- Addition theorems
- Fourier transformations
- Transformation groups, matrix groups

Qualification-goals/Competencies:

- Theoretical knowlege of the mentioned topics
- Historical and latest questions
- Solve questions in this field
- Recognize interdisciplinary aspects

Grading through:

- exercises, project, oral or written exam

Responsible for this module:

- Prof. Dr. Reinhard Schuster

Teacher:

- Institute for Mathematics

- Prof. Dr. Reinhard Schuster

Literature:

- Andrews G.E., Askey R., Roy R.: Special Functions.Encyclopedia of Mathematics and its Application 71 - Cambridge University Press 2006
- Courant, R., Hilbert, D.: Methoden der mathematischen Physik - Springer 1993
- Erdélyi, A. , Magnus, W., Oberhettinger, F., Tricomi, F.: Higher Transcendental Functions - McGraw-Hill, New York, 1953
- Fichtenholz, G.M.: Differential- und Integralrechnung, Band 1-3 - H. Deutsch 1997
- Hurwitz, A., Courant, R.: Vorlesungen über Allgemeine Funktionentheorie und Elliptische Funktionen - Springer 2000
- Stegun, I. A., Abramowitz, M.: Handbook of Mathematical Functions - Dover Press
- Strampp, W., Ganzha, V., Vorozhtsov, E.: Höhere Mathematik mit Mathematica, Bd.4, Funktionentheorie, Fouriertransformationen und Laplacetransformationen: Funktionentheorie, Fourier- und Laplacetransformation - Vieweg 1997
- Wawrzynczyk, A.: Group Representations and Special Functions - Reidel Publishing Company 1983
- Whittaker, E. T., Watson, G. N.: A Cource of Modern Analysis - Cambridge University Press 1902 ... 1999

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4804-L1: Special Functions, written exam (90 min) or oral exam (30 min), 100 % of module grade

MA4944-KP05 - Multivariate Statistics (MulStaKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	every second year	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Multivariate Statistics (lecture, 2 SWS)
- Multivariate Statistics (exercise, 1 SWS)

Workload:

- 55 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 20 Hours exam preparation

Contents of teaching:

- Multivariate probability distributions
- Multiple and multivariate regression
- Discriminant analysis and logistic regression
- Cluster analysis with various distance and similarity measures
- Principal component and factor analysis
- Correspondence analysis and multidimensional scaling
- Structural equation models

Qualification-goals/Competencies:

- Students command a broad repertoire of multivariate statistical methods.
- They are able to explain the ideas behind several representative methods.
- They apply these methods by hand and with R packages.
- They analyse problems and choose suitable methods.
- They are able to decide for a better option, e.g. standardization, variance structures, distance measures, factor numbers or rotations.
- They develop multivariate models.

Grading through:

- written exam

Requires:

- Biostatistics 2 (MA2600-KP07)
- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)
- Stochastics 2 (MA4020-KP07)
- Stochastics 1 (MA2510-KP04, MA2510)

Responsible for this module:

- PD Dr. rer. pol. Reinhard Vonthein

Teacher:

- Institute of Medical Biometry and Statistics

- PD Dr. rer. pol. Reinhard Vonthein
- MitarbeiterInnen des Instituts

Literature:

- Fahrmeir, Ludwig; Hamerle, Alfred; Tutz, Gerhard: Multivariate statistische Verfahren - ISBN-13 9783110138061
- Johnson, R. J.; Wichern, D. W.: Applied Multivariate Statistical Analysis - 5. Ed. Prentice Hall, 2002 - ISBN-13: 000-0131877151

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4944-L1: Multivariate Statistics, written exam, 90 min, 100 % of module grade

MA4947-KP05 - Modern Nonparametric statistics (NpStatKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	every second year	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Nonparametric statistics (lecture, 2 SWS)
- Nonparametric statistics (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 15 Hours exam preparation

Contents of teaching:

- Application scenarios for modern nonparametric methods
- Permutation tests
- Rank-based tests and effect measures
- Evaluation of methods through simulation studies

Qualification-goals/Competencies:

- Knowledge of the most important nonparametric statistical methods
- Understanding of the respective advantages and disadvantages of parametric and nonparametric methods
- Competence in the selection of appropriate methods in application situations
- Experience in planning, conducting and interpreting simulation studies for method s evaluation

Grading through:

- project work
- Viva Voce or test

Requires:

- Biostatistics 2 (MA2600-KP07)
- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)

Responsible for this module:

- Prof. Dr. rer. nat. Silke Szymczak

Teacher:

- Institute of Medical Biometry and Statistics

- Prof. Dr. rer. nat. Silke Szymczak
- MitarbeiterInnen des Instituts

Literature:

- Edgar Brunner, Arne C. Bathke, Frank Konietschke: Rank and Pseudo-Rank Procedures for Independent Observations in Factorial Designs - ISBN   978-3-030-02912-8

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- None

Module exam(s):
- MA4947-L1: Nonparametric statistics, oral exam (20 min) or written exam (60 min), 60 % of module grade
- MA4947-L2: Small group research project including lecture and code documentation, 40 % of module grade

MA4948-KP05 - Introduction to Bayesian Statistics (BayesKP05)		
Duration:	**Turnus of offer:**	**Credit points:**
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Introduction to Bayesian statistics (lecture, 2 SWS)
- Introduction to Bayesian statistics (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 45 Hours exam preparation
- 45 Hours in-classroom work

Contents of teaching:

- Bayesian perspective of uncertainty
- Versions of the Theorem of Bayes
- Conjugacy and conditional independence
- Elicitation of prior information
- Linear and generalized linear regression models in Bayesian framework
- Gibbs sampler, Metropolis-Hastings and other MCMC algorithms
- Models of missing values
- Prior and model robustness
- Connections to the non-Bayesian approach and asymptotics
- Empirical Bayes
- Applications to laboratory experiments, meta-analysis, machine learning, and decisions

Qualification-goals/Competencies:

- Students know the framework of Bayesian data analysis
- They understand the interplay of prior and accumulating information
- They are able to apply Bayesian linear and generalized linear models for data analysis
- They understand and can perform convergence diagnostics
- They elicit prior information from literature and communicate posterior and predictive results thoughtfully
- They are able to design and code algorithms for customized analyses
- They are able to augment their repertoire of models to fit new applications
- Acquisition of english technical language

Grading through:

- Oral examination

Requires:

- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)
- Biostatistics 2 (MA2600-KP07)

Responsible for this module:

- Prof. Dr. rer. biol. hum. Inke König

Teacher:

- Institute of Medical Biometry and Statistics
- PD Dr. rer. pol. Reinhard Vonthein

Literature:

- Andrew Gelman, John B. Carlin, Hal S. Stern, Donald B. Rubin: Bayesian Data Analysis - ISBN: 0 412-03991-5
- Leonhard Held: Methoden der statistischen Inferenz: Likelihood und Bayes - ISBN 978-3-8274-1939-2
- Jean-Michel Marin, Christian P. Robert: Bayesian Core: A Practical Approach to Computational Bayesian Statistics - ISBN 978-0-387-38983-7

Language:

-

Notes:

Notes:
Prerequisite:
- Sufficient English (competencies acquired in the modules named at Requires are needed for this module, but no formal requirement)

Prerequisites for taking the exam:
- By announcement in the first week s lecture

Exam:
- MA4948-L1: Introduction to Bayesian Statistics, oral examination, 100% of module grade.

MA4955-KP05 - Applied Multiple Regression (AMuRegKP05)

Duration:	Turnus of offer:	Credit points:	Max. group size:
1 Semester	every second year	5	20

Course of study, specific field and term:

- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Applied Multiple Regression (lecture, 2 SWS)
- Applied Multiple Regression (exercise, 1 SWS)

Workload:

- 85 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Need and use of multivariable analyses in epidemiological and clinical research
- Types of outcome variables and available multivariable models
- Incorporation of independent variables in the model
- Dealing with the issues of limited sample size and missing data
- Coding and entering the variables in the model
- Assessing the regression coefficient and strength of the model
- Checking the underlying assumptions and improving the fit of the model
- Communicating the results to the publishing house
- R programming for applied regression

Qualification-goals/Competencies:

- The students are able to understand different study designs and multivariable models.
- They are able to understand impact of a variable on an outcome in a multivariable model.
- They are able to understand assumptions underlying the model.
- They are able to design their own multivariable analysis plan.
- They are able to interpret and critically evaluate the published studies.
- They are able to communicate their own study results using the standard available guidelines.
- They are able to program multiple regression analyses in R.

Grading through:

- project work

Requires:

- Generalized Linear Models (MA4962-KP05)
- Biostatistics 2 (MA2600-KP07)

Responsible for this module:

- PD Dr. rer. pol. Reinhard Vonthein

Teacher:

- Institute of Medical Biometry and Statistics

- Louis Macias, Ph.D.

Literature:

- John Fox. 2016: Applied Regression Analysis - 3rd ed. Los Angeles SAGE. ISBN -13: 978-1-4522-0566-3
- Mitchell H. Katz 2011: Multivariable Analysis: A Practical Guide for Clinicians and Public Health Researchers - 3rd ed. Cambridge University Press. ISBN -13: 978-0-521-14107-9
- Andrew Gelman, Jennifer Hill, Aki Vehtari, 2020: Regression and Other Stories - Cambridge University Press. ISBN 13:978-1-1391-6187-9
- Werner Vach. 2012: Regression Models as a Tool in Medical Research - Chapman and Hall/CRC. ISBN: 978-1-466-51748-6

Language:

- offered only in English

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4955-L1: Project work with documentation and presentation

MA4962-KP05 - Generalized Linear Models (VLModKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th and 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Generalized Linear Models (lecture, 2 SWS)
- Generalized Linear Models (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 45 Hours in-classroom work
- 30 Hours programming
- 15 Hours exam preparation

Contents of teaching:

- General overview of generalized linear models (GLM): - link and response function, - GLM algorithms: Newton-Raphson, Fisher Scoring, iterated weighted least squares, - convergence, - quality of the adaption, - residuals
- Continuous response models: Gaussian, log-normal, Gamma, log-Gamma for survival analysis, inverse Gaussian
- Dichotomous response models: logit, probit, cloglog
- Count data: Poisson, negative binomial with over- and underdispersion
- Ordinal response models: proportional odds model
- Disordered categorial response models: Multinomial logit and probit model
- Censored continuous response models: Tobit model

Qualification-goals/Competencies:

- The students are able to explain the theoretical bases of generalized linear models (GLM).
- They are able to explain areas of application for GLM.
- They are able to select a suitable GLM.
- They are able to estimate GLMs in R.
- They are able to explain the R source code in a presentation.
- They are able to judge the results of GLMs in R critically.
- They are able to evaluate algorithmic challenges of GLMs.
- They are able to explain conceptual problems of GLMs for categorialresponse variables.
- They are able to implement GLM in R.
- They are able to apply regression diagnostics to GLMs and to judge the results.
- They are able to describe the most important estimation algorithms for GLMs.
- They are able to list the statistical properties of GLMs.

Grading through:

- Viva Voce or test

Requires:

- Biostatistics 2 (MA2600-KP07)

Responsible for this module:

- Prof. Dr. rer. biol. hum. Inke König

Teacher:

- Institute of Medical Biometry and Statistics

- Prof. Dr. rer. biol. hum. Inke König

Literature:

- Agresti, Alan: Foundations of Linear and Generalized Linear Models - Wiley, 2015

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4962-L1: Generalized Linear Models, written exam (90 min) or oral exam (30 min), 100 % of module grade

MA4970-KP05 - Design of Experiments and Analysis of Variance (VerVarKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Design of Experiments and Variance Analysis (lecture, 2 SWS)
- Design of Experiments and Variance Analysis (exercise, 1 SWS)

Workload:

- 85 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Regression modeling and analysis of variance
- Generalized inverse
- Singular linear models
- Factorial designs
- The Latin square and the Graeco-Latin square designs
- Experiments with block factors
- Fixed and random effects
- The split-plot design

Qualification-goals/Competencies:

- Students know the differences between planned experiments and observational studies.
- Students can enumerate the advantages of the statistical multi-factorial design.
- Students can interpret correctly the analysis of variance results of experimental designs.
- Students can select and implement an appropriate experimental design and conduct corresponding variance analysis.
- Students can formulate the analysis of variance as a regression model in matrix notation.
- Students understand the statistical properties of linear regression model with a singular design matrix and a singular hypothesis matrix.
- Students can estimate linear regression model with a singular design matrix and a singular hypothesis matrix.
- Students can create and interpret graphs for summarizing results and model diagnostics.
- Acquisition of knowledge in English technical language.

Grading through:

- Viva Voce or test

Requires:

- Biostatistics 2 (MA2600-KP07)
- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)

Responsible for this module:

- PD Dr. rer. pol. Reinhard Vonthein

Teacher:

- Institute of Medical Biometry and Statistics

- Dr. Maren Vens
- Louis Macias, Ph.D.

Literature:

- Kursbuch: Montgomery, Douglas C. 2012: Design and Analysis of Experiments. 10th ed. - John Wiley & Sons, New York. ISBN 978-1-119-49244-3
- Supplementary literature: Mason, Robert L., Gunst, Richard F., Hess, James L. 2003: Statistical Design and Analysis of Experiments. 2nd ed. - John Wiley & Sons, New York. ISBN 0-471-37216-1

Language:

- German or English

Notes:

Admission requirements for taking the module:
- MA1600-KP04: Biostatistics 1 and
- MA2600-KP07: Biostatistics 2 successfully completed

Admission requirements for participation in module examination(s):
- Successful completion of exercises as specified at the beginning of the semester

Module exam(s):
- MA4970-L1: Experimental design and analysis of variance, written exam (90 min) or oral exam (30 min), 100% of module grade

(share of Institute of Medical Biometry and Statistics in V is 100%)
(share of Institute of Medical Biometry and Statistics in Ü is 100%)

MA5008-KP05 - Mathematical course (PrakMaKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	on request	5 (Typ B)

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 2nd or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 2nd or 3rd semester

Classes and lectures:

- Mathematical course (practical course, 5 SWS)

Workload:

- 120 Hours in-classroom work
- 30 Hours written report

Contents of teaching:

- Planning and execution of a scientific project by mathematical methods
- Presenting the methods and results in a detailed written report

Qualification-goals/Competencies:

- Ability to analyze a given problem and to develop mathematical approaches for it
- Ability to make oneself familiar with adequate mathematical structures without any help
- Ability to integrate partial results into the overall solution
- Proficiency in documenting and presenting results

Grading through:

- Written report

Responsible for this module:

- Prof. Dr. rer. nat. Jürgen Prestin

Teacher:

- Institutes of the Department of Computer Science/ Engineering
- Alle prüfungsberechtigten Dozentinnen/Dozenten des Studienganges

Language:

- German or English

Notes:

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- Written report

Module exam(s):
- MA5008-L1: Mathematical course, ungraded course, 0 % of module grade, must be passed

MA5032-KP05 - Numerical Methods for Image Computing (NumBVKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	5

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), mathematics, 5th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th semester
- Master CLS 2016 (optional subject), mathematics, 1st or 3rd semester

Classes and lectures:

- Numerical Methods for Image Computing (lecture, 2 SWS)
- Numerical Methods for Image Computing (exercise, 1 SWS)

Workload:

- 65 Hours private studies and exercises
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Imaging process an imaging modalities
- Grids and image representation
- Image operators and finite differences
- Stationary partial differential equations in image processing
- Image and video compression
- Variation formulation and statistical interpretation
- Correctness and regularisation

Qualification-goals/Competencies:

- The students are familiar with fundamental numerical concepts in image computing.
- They have experience in realizing practical solutions.
- They can implement numerical algorithms on a computer.
- Interdisciplinary qualifications:
- Students have advanced skills in modeling.
- They can translate theoretical concepts into practical solutions.
- They are experienced in implementation.
- They can think abstractly about practical problems.

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr. rer. nat. Jan Modersitzki

Teacher:

- Institute of Mathematics and Image Computing

- Prof. Dr. rer. nat. Jan Modersitzki
- Prof. Dr. rer. nat. Jan Lellmann

Literature:

- Bredies, Lorenz: Mathematische Bildverarbeitung - Springer, 2010
- Gonzalez, Woods: Digital Image Processing - Prentice Hall, 2007
- Hackbusch: Iterative Lösung großer schwachbesetzter Systeme - Teubner, 1993
- Briggs: A Multigrid Tutorial - SIAM, 2000
- Nocedal, Wright: Numerical Optimization - Springer, 2006

Language:

- German and English skills required

Notes:

Prerequisites for attending the module:
- None (Familiarity with the topics of the required modules is assumed, but the modules are not a formal prerequisite for attending the course).

Prerequisites for the exam:
- Homework assignments and their presentation are ungraded examination prerequisites which have to be completed and positively evaluated before the first examination.

Examination:
- MA5032-L1: Numerical Methods for Image Computing, written examination (90 min) or oral examination (30 min) as decided by examiner, 100 % of final mark

MA5033-KP05 - Quantum Image Computing (QuantumIC)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 2nd or 4th semester
- Bachelor CLS 2023 (optional subject), mathematics, 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 6th semester
- Master CLS 2016 (optional subject), mathematics, 2nd or 4th semester

Classes and lectures:

- Quantum Image Computing (lecture, 2 SWS)
- Quantum Image Computing (exercise, 1 SWS)

Workload:

- 65 Hours private studies and exercises
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Foundations (unitary transformations, qubits, measurements, quantum circuits)
- Quantum image models and quantum image operations
- Recent quantum image processing algorithms
- Adiabatic quantum computing
- Quantum optimization for computer vision

Qualification-goals/Competencies:

- Students know the mathematical foundations of quantum computing and their application.
- Students are familiar with advanced quantum computing models, in particular in image processing and computer vision.
- Students are able to translate practical problems into working algorithms.
- Students can implement algorithms on quantum computers in a modern programming language.
- Interdisciplinary qualifications:
- Students have advanced modeling skills.
- Students can translate theoretical concepts into practical solutions.
- Students have implementation experience.
- Students can think abstractly about practical problems.

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)

Responsible for this module:

- Prof. Dr. rer. nat. Jan Lellmann

Teacher:

- Institute of Mathematics and Image Computing

- Prof. Dr. rer. nat. Jan Lellmann
- Prof. Dr. rer. nat. Jan Modersitzki

Literature:

- Nielsen, Chuang: Quantum Computation and Quantum Information - Cambridge University Press
- Yan, Venegas-Andraca: Quantum Image Processing - Springer

Language:

- German and English skills required

Notes:

Prerequisites for attending the module:
- None (Familiarity with the topics of the required modules is assumed, but the modules are not a formal prerequisite for attending the course).

Prerequisites for the exam:
- Homework assignments and their presentation are ungraded examination prerequisites which have to be completed and positively evaluated before the first examination.

Examination:
- MA5033-L1: Quantum Image Computing, written examination (90 min) or oral examination (30 min) as decided by examiner, 100% of final mark

MA5034-KP05 - Calculus of Variations and Partial Differential Equations (VarPDGKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	every second summer semester	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 2nd or 4th semester
- Bachelor CLS 2023 (optional subject), mathematics, 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 6th semester
- Master CLS 2016 (optional subject), mathematics, 2nd or 4th semester

Classes and lectures:

- Calculus of Variations and Partial Differential Equations (lecture, 2 SWS)
- Calculus of Variations and Partial Differential Equations (exercise, 1 SWS)

Workload:

- 65 Hours private studies and exercises
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Motivation and application examples
- Functional-analytic foundations
- Direct methods in the calculus of variations
- The dual space, weak convergence, Sobolev spaces
- Optimality conditions
- Classification of partial differential equations and typical PDEs
- Fundamental solutions, maximum principle
- Finite elements for elliptical partial differential equations

Qualification-goals/Competencies:

- Students understand variational modeling.
- They are able to formulate basic physical problems in a variational setting.
- They understand the connections between variational methods and partial differential equations.
- They can derive optimality conditions for energy functionals.
- They understand the mathematical theory behind selected variational problems.
- They can implement selected fundamental variational problems.
- They can formulate selected practical problems in the variational setting.
- Interdisciplinary qualifications:
- Students have advanced skills in modeling.
- They can translate theoretical concepts into practical solutions.
- They are experienced in implementation.
- They can think abstractly about practical problems.

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr. rer. nat. Jan Modersitzki

Teacher:

- Institute of Mathematics and Image Computing

- Prof. Dr. rer. nat. Jan Modersitzki
- Prof. Dr. rer. nat. Jan Lellmann

Literature:

- Vogel: Computational Methods for Inverse Methods - SIAM
- Aubert, Kornprobst: Mathematical Problems in Image Processing: Partial Differential Equations and the Calculus of Variations - Springer
- Scherzer, Grasmair, Grossauer, Haltmeier, Lenzen: Variational Methods in Imaging - Springer

Language:

- German and English skills required

Notes:

Prerequisites for attending the module:
- None (Familiarity with the topics of the required modules is assumed, but the modules are not a formal prerequisite for attending the course).

Prerequisites for the exam:
- Homework assignments and their presentation are ungraded examination prerequisites which have to be completed and positively evaluated before the first examination.

Examination:
- MA5034-L1: Calculus of Variations and Partial Differential Equations, written examination (90 min) or oral examination (30 min) as decided by examiner, 100 % of final mark

MA5035-KP05 - Non-smooth Optimization and Analysis (NiOpAnKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 2nd or 4th semester
- Bachelor CLS 2023 (optional subject), mathematics, 6th semester
- Master CLS 2016 (optional subject), mathematics, 2nd or 4th semester
- Bachelor CLS 2016 (optional subject), mathematics, 6th semester

Classes and lectures:

- Non-smooth Optimization and Analysis (lecture, 2 SWS)
- Non-smooth Optimization and Analysis (exercise, 1 SWS)

Workload:

- 65 Hours private studies and exercises
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Introduction to non-smooth analysis: convexity, subdifferentials, existence, Legendre- Fenchel conjugate, duality
- First- and higher-order numerical optimization methods: PDHG and interior-point methods
- Approximation of discrete and non-convex problems
- Generalized derivatives and Clarke subdifferential, semismooth Newton methods
- Applications in image processing and computer vision

Qualification-goals/Competencies:

- The students understand the strengths of non-smooth models.
- They can devise and analyse models for simple problems.
- They understand the advantages, disadvantages, and application areas of each optimization method.
- They know how to select and specialize a suitable optimization method for a given model.
- Interdisciplinary qualifications:
- Students have advanced skills in modeling.
- They can translate theoretical concepts into practical solutions.
- They are experienced in implementation.
- They can think abstractly about practical problems.

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Optimization (Advanced Mathematics) (MA4031-KP08)
- Optimization (MA4030-KP08, MA4030)

Responsible for this module:

- Prof. Dr. rer. nat. Jan Lellmann

Teacher:

- Institute of Mathematics and Image Computing

- Prof. Dr. rer. nat. Jan Lellmann
- Prof. Dr. rer. nat. Jan Modersitzki

Literature:

- Rockafellar, Wets: Variational Analysis - Springer
- Boyd, Vandenberghe: Convex Optimization - Cambridge University Press
- Ben-Tal, Nemirovski: Lectures on Modern Convex Optimization - SIAM
- Paragios, Chen, Faugeras: Handbook of Mathematical Models in Computer Vision - Springer

Language:

- German and English skills required

Notes:

Prerequisites for attending the module:
- None (Familiarity with the topics of the required modules is assumed, but the modules are not a formal prerequisite for attending the course).

Prerequisites for the exam:
- Homework assignments and their presentation are ungraded examination prerequisites which have to be completed and positively evaluated before the first examination.

Examination:
- MA5035-L1: Non-smooth Optimization and Analysis, written examination (90min) or oral examination (30 min) as decided by examiner, 100 % of final mark

MA5037-KP05 - Optimization of Complex Systems (OpkoSy05)		
Duration:	**Turnus of offer:**	**Credit points:**
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 2nd or 4th semester
- Bachelor CLS 2023 (optional subject), mathematics, 6th semester
- Master CLS 2016 (optional subject), mathematics, 2nd or 4th semester
- Bachelor CLS 2016 (optional subject), mathematics, 6th semester

Classes and lectures:

- Optimization of Complex Systems (lecture, 2 SWS)
- Optimization of Complex Systems (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Model problems (e.g. optimal control of heating processes, optimal design)
- Optimum conditions
- Optimization process

Qualification-goals/Competencies:

- Students know how the control of selected complex systems can be modeled as an optimization problem.can be modeled as an optimization problem.
- They know the optimality conditions of these optimization problems.
- They can select optimization methods and implement them in practice for new models.
- Interdisciplinary aspects:
- Students can put theoretical concepts into practice.
- They have experience in implementation.
- They can abstract practical problems.

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Optimization (Advanced Mathematics) (MA4031-KP08)
- Optimization (MA4030-KP08, MA4030)

Responsible for this module:

- Prof. Dr. rer. nat. Jan Modersitzki

Teacher:

- Institute of Mathematics and Image Computing

- Prof. Dr. rer. nat. Jan Lellmann
- Prof. Dr. rer. nat. Jan Modersitzki
- Dr. rer. nat. Florian Mannel

Literature:

- Tröltzsch:: Optimale Steuerung partieller Differentialgleichungen - Vieweg+Teubner Verlag
- Hinze, Ulbrich, Ulbrich, Pinnau: Optimization with PDE Constraints - Springer Dordrecht
- Ulbrich: Semismooth Newton Methods for Variational Inequalities and Constrained Optimization Problems in Function Spaces - SIAM

Language:

- German and English skills required

Notes:

Prerequisites for attending the module:
- None (Familiarity with the topics of the required modules is assumed, but the modules are not a formal prerequisite for attending the course).

Prerequisites for the exam:
- Homework assignments and their presentation are ungraded examination prerequisites which have to be completed and positively evaluated before the first examination.

Examination:
- MA5035-L1: Optimization of Complex Systems, written examination (90min) or oral examination (30 min) as decided by examiner, 100% of final mark

CS4013-KP04 - Bioinformatics (BioinfKP04)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	4

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), specialization field bioinformatics, 5th semester
- Bachelor Medical Informatics 2019 (compulsory), medical computer science, 5th semester
- Bachelor CLS 2016 (compulsory), specialization field bioinformatics, 5th semester

Classes and lectures:

- Bioinformatics (lecture, 2 SWS)
- Bioinformatics (exercise, 1 SWS)

Workload:

- 55 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Life, Evolution & the Genome
- Sequence assembly - Industrial reading of genetic information
- DNA sequence models & hidden markov models
- Viterbi-Algorithm
- Sequence alignment & dynamic programming
- Unsupervised data analysis (k-means, PCA, ICA)
- DNA microarrays & GeneChip technologies

Qualification-goals/Competencies:

- Students are able to explain the basic concepts of coding, transcription and translation of information in living beings.
- They are able to explain how a solution of the shortest common superstring problem can be estimated with a simple greedy algorithm.
- They are able to create a Markov chain or a Hidden Markov Model (HMM) for a given modelling problem.
- They are able to give examples on how to solve a problem using dynamic programming.
- They are able to implement the introduced algorithms (in Matlab)
- They are able to use unsupervised learning methods and they are able to interpret the results.
- They are able to explain basic Microarray-and DNA-Chip-Technologies.

Grading through:

- portfolio exam

Responsible for this module:

- Prof. Dr. rer. nat. Amir Madany Mamlouk

Teacher:

- Institute for Neuro- and Bioinformatics

- Prof. Dr. rer. nat. Amir Madany Mamlouk

Literature:

- H. Lodish, A. Berk, S. L. Zipursky and J. Darnell: Molekulare Zellbiologie - Spektrum Akademischer Verlag, 4. Auflage, 2001, ISBN-13: 978-3827410771
- A. M. Lesk: Introduction to Bioinformatics - Oxford University Press, 3. Auflage, 2008, ISBN-13: 978-0199208043
- R. Merkl and S. Waack: Bioinformatik Interaktiv: Grundlagen, Algorithmen, Anwendungen - Wiley-VCH Verlag, 2. Auflage, 2009, ISBN-13: 978-3527325948
- M. S. Waterman: Introduction to Computational Biology - Chapman and Hall, 1995

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- See portfolio

Module exam(s):
- CS4013-L1: Bioinformatics, portfolio exam, the specific examination elements and their weightings are announced at the beginning of the semester

LS1000-KP08, LS1000-MLS - Biology 1 (Bio1KP08)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	8

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), life sciences, 1st semester
- Bachelor Nutritional Medicine 2024 (compulsory), life sciences, 1st semester
- Bachelor Molecular Life Science 2024 (compulsory), life sciences, 1st semester
- Bachelor MLS 2018 (compulsory), life sciences, 1st semester
- Bachelor Nutritional Medicine 2018 (compulsory), life sciences, 1st semester
- Bachelor CLS 2016 (compulsory), life sciences, 1st semester
- Bachelor Nutritional Medicine 2016 (compulsory), life sciences, 1st semester
- Bachelor MLS 2016 (compulsory), life sciences, 1st semester

Classes and lectures:

- Basic Biology (lecture, 4 SWS)
- Basic Biology (practical course, 2 SWS)

Workload:

- 150 Hours private studies
- 90 Hours in-classroom work

Contents of teaching:

- Lectures:
- Introduction
- Structure and functions of the prokaryotic cell
- Structure of the eukaryotic cells
- Selected topics of multicellular organisation
- Storage, duplication and realization of the hereditary information
- Cell cycle
- Fertilization and development
- Formal and molecular genetics, evolution
- Practical course:
- Individual testHandling of light microscopes
- Structure of prokaryotic cells
- Structure of cells from metazoan
- Human chromosomes
- Cell cycle and mitosis
- Genetics
- Bacteria

Qualification-goals/Competencies:

- Improvement of basic knowledge for life-science education
- Ability to understand, reproduce and use in the further studies basics of all areas listed in
- Basal practical skills in light microscopy

Grading through:

- written exam (test achievement)

Responsible for this module:

- Prof. Dr. rer. nat. Enno Hartmann

Teacher:

- Institute for Biology

- Prof. Dr. rer. nat. Enno Hartmann
- Prof. Dr. rer nat. Rainer Duden
- PD Dr. rer. nat. Kai-Uwe Kalies
- PD Dr. rer. nat. Bärbel Kunze

Literature:

- : Cambell Biology

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- Successful participation in practical course

Module exam(s):
- LS1000-L1: Biology 1, written exam, 90 min, 100% of module grade

See also HM1-10050.

LS1100-KP04 - General Chemistry (ACKP04)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	4

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), life sciences, 3rd semester
- Bachelor Biophysics 2024 (compulsory), life sciences, 1st semester
- Bachelor Computer Science 2019 (optional subject), Extended optional subjects, Arbitrary semester
- Bachelor Computer Science 2019 (optional subject), Canonical Specialization Bioinformatics and Systems Biology, 3rd semester
- Bachelor MES 2020 (optional subject), mathematics / natural sciences, 3rd semester at the earliest
- Bachelor Medical Informatics 2019 (optional subject), medical computer science, 4th to 6th semester
- Bachelor Computer Science 2016 (optional subject), advanced curriculum, Arbitrary semester
- Bachelor Medical Informatics 2014 (optional subject), medical computer science, 5th or 6th semester
- Bachelor Computer Science 2016 (optional subject), Canonical Specialization Bioinformatics, 3rd semester
- Bachelor CLS 2016 (compulsory), life sciences, 3rd semester
- Bachelor Biophysics 2016 (compulsory), life sciences, 1st semester

Classes and lectures:

- General Chemistry (lecture, 3 SWS)
- General Chemistry (exercise, 1 SWS)

Workload:

- 60 Hours in-classroom work
- 60 Hours private studies

Contents of teaching:

- Lectures:
- The structure of atoms and the periodic table of the elements
- Chemical bonds, molecules and Ions
- Reaction equations and stoichiometry
- The threedimensional structure of molecules: From the VSEPR model to molecular orbitals
- Special properties of water
- Chemical equilibrium
- Acids and bases
- Redox reactions and electrochemistry
- Complexes and metal-ligand bonds
- Interactions between mater and radiation - Molecular spectroscopy
- Thermodynamics
- Chemical kinetics
- Roles of Environmental and occupational health and safety in the handling of hazardous materials (Globally Harmonized System of Classification and Labeling of Chemicals (GHS)) and of GSP of the University of Lübeck and of the DFG-guidelines
- Exercises:
- Students discuss problems covering all topics of the lectures on the black board

Qualification-goals/Competencies:

- Students have fundamental knowledge of general and inorganic chemistry.
- Students understand the fundamental concepts of general and inorganic chemistry and can apply them to reactions and general scientific topics.
- Students are able to perform chemical calculations from all subareas of the course.
- They know the roles for GSP of the University of Lübeck.
- They can transfer the acquired knowledge to problems of other branches in chemistry and related sciences and are thus able to participate in continuative courses.

Grading through:

- written exam

Is requisite for:

- Practical Course Chemistry (LS1610-KP04)
- Organic Chemistry (LS1600-KP04)

Responsible for this module:

- PD Dr. phil. nat. Thomas Weimar

Teacher:

- Institute of Chemistry and Metabolomics

- PD Dr. phil. nat. Thomas Weimar

Literature:

- Schmuck et al.: Chemie für Mediziner - Pearson Studium
- Binnewies et al.: Allgemeine und Anorganische Chemie - Spektrum Verlag

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Modul exam(s):
- LS1100-L1: General Chemistry, written exam, 90 min, 100% of module grade

LS1500-KP04 - Biology 2 (Bio2KP04)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	4

Course of study, specific field and term:

- Bachelor CLS 2023 (optional subject), life sciences, 6th semester
- Bachelor CLS 2016 (optional subject), life sciences, 6th semester

Classes and lectures:

- Genetics (lecture, 2 SWS)
- Histology (lecture, 1 SWS)
- Histology (practical course, 1 SWS)

Workload:

- 60 Hours in-classroom work
- 60 Hours private studies

Contents of teaching:

- Part A, Genetics:
- a) Bacterial Genetics
- The bacterial cell
- Cell division and replication of the bacterial chromosome
- Gene organization and gene expression
- Bacterial pathogenicity factors
- Mutations in bacteria
- Accessory genetic elements and gene transfer mechanisms
- b) Human Genetics
- Hereditary transmissions, mechanisms and definitions
- Overwiew: Cytogenetics
- Trinukleotid-Repeat-Expansions (TRE)
- Epigenetics
- Molecular pathology
- Mutations
- Methods in molecular genetics
- Part B, Histology:
- a) Lecture:
- Preparation of tissue specimen:Epithelium, glands
- b) Practical course Microscopy, Histology:
- Microscopy of cell structure and cell size as taught in the histology lectures. Critical investigation under the microscope. Drawing of the corresponded tissues (from the histology lectures)

Qualification-goals/Competencies:

- Part A, Genetics:
- Understanding of the heredity
- Mutations and verific
- Bacterial genetics
- Part B, Histology section:
- They can identify different histological stainings
- They can explain the structure of tissues containing site-specific cells and extracellular matrix molecules
- They can distiguish various cell shapes and functions, especially of epithelial tissues.

Grading through:

- written exam

Responsible for this module:

- Prof. Dr. rer. nat. Kathrin Kalies

Teacher:

- Research Center Borstel, Leibniz Lung Center
- Institute of Human Genetics
- Institute of Anatomy

- Prof. Dr. med. Malte Spielmann
- Dr. rer. nat. Kristian Händler
- Prof. Dr. rer. nat. Martin Kircher
- PD Dr. rer. nat. Kai-Uwe Kalies

Literature:

- Lüllmann-Rauch: Histologie - Thieme Verlag, Stuttgart
- Jeremy W. Dale, Simon F. Park: Molecular Genetics of Bacteria - Wiley Blackwell
- Larry Snyder, Joseph E. Peters, Tina M. Henkin, Wendy Champness: Molecular Genetics of Bacteria - ASM Books

Language:

- offered only in German

Notes:

The total score achievable in the final exam is composed of equal parts (arithmetic mean) of answers to questions from the two lectures Genetics and Histology.

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- Regular and successful participation in the practical course, at least 80 %

Module exam(s):
LS1500-L1: Biology 2, written exam, 90 min, 100 % of module grade (arithmetic mean of the parts Genetics and Histology)

(Human genetics accounts for 100% of genetics)
(Anatomy accounts for 100 % of Histology)

LS1600-KP04 - Organic Chemistry (OCKP04)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	4

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), life sciences, 4th semester
- Bachelor Biophysics 2024 (compulsory), life sciences, 2nd semester
- Master Medical Informatics 2019 (optional subject), bioinformatics, 1st or 2nd semester
- Master Medical Informatics 2014 (optional subject), bioinformatics, 1st or 2nd semester
- Bachelor CLS 2016 (compulsory), life sciences, 4th semester
- Bachelor Biophysics 2016 (compulsory), life sciences, 2nd semester

Classes and lectures:

- Organic Chemistry (lecture, 3 SWS)
- Organic Chemistry (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 60 Hours in-classroom work

Contents of teaching:

- Lectures:
- Alkanes, cycloalkanes
- Alkenes and Alkynes
- Aromatics
- Stereochemistry
- Substitution and elimination reactions
- Alcohols, phenols and thiols
- Ether and epoxides
- Aldehydes and ketones
- Carboxylic acids and derivativs
- Amines and derivativs
- Heterocycles
- Lipids
- Carbohydrates
- Amino acids and peptides
- Nucleotides and nucleic acids
- Exercises:
- Students discuss problems covering all topics of the lectures on the black board

Qualification-goals/Competencies:

- After successful completion of the course, students have a fundamental knowledge of organic chemistry. They are confident using structural formulas of substance classes and functional groups presented in the course. They are confident in the nomenclature and can correctly describe relative and absolute configurations of molecules.
- Students know the most important reactions, reaction types and reaction principles of organic chemistry. They understand the structural properties of functional groups and are able to formulate organic chemical reaction mechanisms of these groups.
- Students can transfer and apply the acquired skills to problems of other branches of chemistry and related sciences and are thus able to participate in continuative courses.

Grading through:

- written exam

Requires:

- General Chemistry (LS1100-KP04)

Responsible for this module:

- PD Dr. phil. nat. Thomas Weimar

Teacher:

- Institute of Chemistry and Metabolomics

- PD Dr. phil. nat. Thomas Weimar

Literature:

- Hart, H., L. E. Craine, D. J. Hart: Organische Chemie - Wiley-VCH
- Buddrus, J.: Organische Chemie - De Gruyter Verlag

Language:

- offered only in German

Notes:

Knowledge of basic chemistry (such as from LS1100-INF) is required.

Prerequisites for attending the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Prerequisites for the exam:
- Examination prerequisites can be defined at the beginning of the semester. If preliminary work is defined, it must have been completed and positively evaluated before the first examination.

Module exam:
LS1600-L1: Organic Chemistry, written exam, 90 min, 100 of % module grade

LS1610-KP04 - Practical Course Chemistry (ACPKP04)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	4

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), life sciences, 4th semester
- Bachelor Biophysics 2024 (compulsory), life sciences, 1st and 2nd semester
- Bachelor CLS 2016 (compulsory), life sciences, 4th semester
- Bachelor Biophysics 2016 (compulsory), life sciences, 1st and 2nd semester

Classes and lectures:

- Practical Course Chemistry (practical course, 4 SWS)

Workload:

- 80 Hours private studies
- 40 Hours in-classroom work

Contents of teaching:

- Practical course:
- The students work independently under supervision with regards to the role of GSP of the University of Lübeck
- Selected experiments related to topics of the lectures general and organic chemistry

Qualification-goals/Competencies:

- From their independent work in the lab course students have fundamental practical skills to perform simple experiments and analyzes in the chemical laboratory within the roles of Good Scientific Praxis of the University of Lübeck. They are competent in basic techniques of the handling of hazardous materials according to GHS (Globally Harmonized System of Classification and Labeling of Chemicals).
- Students are capable to document, interpret and present the results of conducted experiments (laboratory journal and concluding discussion) with regards to the role of GSP of the University of Lübeck and the DFG-guidelines.

Grading through:

- Continuous, successful participation in practical course. All experiments have to be conducted.

Requires:

- General Chemistry (LS1100-KP04)

Responsible for this module:

- PD Dr. phil. nat. Thomas Weimar

Teacher:

- Institute of Medical Engineering
- Dr. rer. nat. Kerstin Lüdtke-Buzug

Literature:

- Thomas Weimar: Script of the practical course

Language:

- offered only in German

Notes:

Prerequisites for attending the module:
- Passing of LS1100-L1 and participation in the general health and safety briefing

Prerequisites for admission to the examination:
- Successful participation in the practical course with all tests

Module exam:
- In order to pass the course students have to conduct experiments within defined error margins and present an experiment of the course in a talk. Not graded, 100%.

LS2200-KP04, LS2200 - Introduction into Biophysics (EinBiophy)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	4

Course of study, specific field and term:

- Bachelor CLS 2023 (optional subject), life sciences, 5th semester
- Bachelor Biophysics 2024 (compulsory), biophysics, 3rd semester
- Bachelor Molecular Life Science 2024 (compulsory), life sciences, 3rd semester
- Bachelor MES 2020 (optional subject), mathematics / natural sciences, 3rd semester at the earliest
- Bachelor MLS 2018 (compulsory), life sciences, 3rd semester
- Bachelor MLS 2016 (compulsory), life sciences, 3rd and 4th semester
- Bachelor CLS 2016 (optional subject), life sciences, 5th semester
- Bachelor Nutritional Medicine 2016 (compulsory), biophysics, 3rd semester
- Bachelor Biophysics 2016 (compulsory), biophysics, 3rd semester
- Bachelor MES 2014 (optional subject), mathematics / natural sciences, 3rd or 5th semester
- Bachelor MLS 2009 (compulsory), life sciences, 3rd and 4th semester
- Bachelor CLS 2010 (optional subject), life sciences, 5th semester
- Bachelor MES 2011 (compulsory), medical engineering science, 5th semester

Classes and lectures:

- Introduction into Biophysics (lecture, 2 SWS)
- Biophysics (Excercise or practical course, 1 SWS)

Workload:

- 50 Hours private studies
- 45 Hours in-classroom work
- 15 Hours written report
- 10 Hours exam preparation

Contents of teaching:

- Biological macro molecules, structure, forces
- Proteins, structure, properties
- Biomembranes, structure, properties
- Mechanical properties of cells
- Thermo dynamics of biological processes

Qualification-goals/Competencies:

- You can assign forces in biological systems
- You become familiar with the basic aspects of living matter
- You gain the expertise to simplify complex living systems
- You can choose and apply appropriate experimental methods for the study of living matter

Grading through:

- written exam

Responsible for this module:

- Dr. Young-Hwa Song

Teacher:

- Institute of Physics

- Dr. Young-Hwa Song
- Prof. Dr. rer. nat. Christian Hübner

Literature:

- Volker Schünemann: Biophysik: Eine Einführung
- Werner Mäntele: Biophysik

Language:

- offered only in German

Notes:

Prerequisites for the module:
- None

Prerequisites for admission to the written examination:
- Successful participation in the exercises as specified at the beginning of the semester

Module exam:
- LS2200-L1: Introduction into Biophysics, written exam, 120 min, 100 % of module grade

The lecture and exercises take place in the winter semester, the practical course in the summer semester.
Whether exercises or a practical course take place is specified in the SGO of the respective study program.
Prerequisite for the understanding of the lecture is the knowledge of the basics of inorganic and organic chemistry.

LS3500-KP04 - Introduction into Structural Analysis (EStrukKP04)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	4

Course of study, specific field and term:

- Bachelor CLS 2023 (optional subject), life sciences, 6th semester
- Bachelor CLS 2016 (optional subject), life sciences, 6th semester

Classes and lectures:

- Introduction into Structural Analysis (lecture, 2 SWS)
- Introduction into Structural Analysis (seminar / exercises, 2 SWS)

Workload:

- 120 Hours private studies
- 60 Hours in-classroom work

Contents of teaching:

- Part A: Protein structure analysis by crystal X-ray diffraction:
- Crystal growth: precipitant and phasediagram
- Crystal morphology: symmetry and space groups
- X-ray diffraction: Bragg's law, reciprocal lattice and the Ewald-sphere construction
- Phase determination: Patterson map and molecular replacement
- Part B: Basic NMR spectroscopy for the investigation of biomolecular structures: Basics of NMR spectroscopy: NMR experiments, Spin systems, the classical vector model
- The nuclear Overhauser effect
- Identification and characterisation of protein-ligand interactions: The transfer nOe, the STD-NMR-experiment, the HSQC experiment, the cross-saturation experiment
- Building blocks for NMR experiments
- Part C: Basics of mass spectrometry:Indroduction and basics
- Ion sources and their fields of application
- Mass analysers
- Structural analysis of biomolecules

Qualification-goals/Competencies:

- The students will acquire basic skills in selected biophysical techniques to analyze the structure and dynamics of biological macromolecules. The emphasis is on understanding the concepts behind these techniques.
- Furthermore, the students will learn how to elucidate the structure of small organic molecules.
- The students will improve their ability in presentation and analysis of complex data.

Grading through:

- written exam

Responsible for this module:

- Dr. Alvaro Mallagaray

Teacher:

- Research Center Borstel, Leibniz Lung Center
- Institute of Biochemistry
- Institute of Chemistry and Metabolomics

- Dr. Alvaro Mallagaray
- Dr. math. et dis. nat. Jeroen Mesters
- Prof. Dr. rer. nat. Karsten Seeger
- Dr. Dominik Schwudke

Literature:

- : Will be adapted to the current conditions and stated in the lecture. See also in the corresponding scripts
- Teil B: Horst Friebolin: Ein- und zweidimensionale NMR-Spektroskopie. Eine Einführung - Wiley-VCH
- Alexander Mc Pherson: Introduction to Macromolecular Crystallography - 1st edition, 2003, Wiley

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- LS3500-L1: Introduction into Structural Analysis, written exam, 90 min, 100 % of module grade

For the successful attendance of the NMR part of the lecture the study of chapters 1 to 3, page 1 to 109 in Friebolin is required.
MML: mandatory for Life Science specialization

ME1500-KP04 - Fundamentals of Physics (GrPhysKP04)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	4

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), life sciences, 5th semester
- Bachelor Computer Science 2019 (optional subject), Extended optional subjects, Arbitrary semester
- Bachelor Computer Science 2019 (optional subject), Canonical Specialization Bioinformatics and Systems Biology, 5th semester
- Bachelor Computer Science 2016 (optional subject), advanced curriculum, Arbitrary semester
- Bachelor Computer Science 2016 (optional subject), Canonical Specialization Bioinformatics, 5th semester
- Bachelor CLS 2016 (compulsory), life sciences, 5th semester

Classes and lectures:

- Fundamentals of Physics (lecture, 2 SWS)
- Fundamentals of Physics (exercise, 1 SWS)

Workload:

- 60 Hours private studies and exercises
- 45 Hours in-classroom work
- 15 Hours exam preparation

Contents of teaching:

- Mechanics: Newton s laws, laws of conversation, molecular dynamics, flow in vascular system
- Mechanical oscillations and waves: wave propagation, ultrasound, Doppler effect
- Thermodynamics: temperature, entropy, ideal gas, laws of thermodynamics
- Electricity & magnetism: electrostatic field, Coulomb s law, Ohm s law, Lorentz force, oscillating circuit, electromagnetic waves
- Optics: wave optics, polarization, geometrical optics, law of reflection, image equation
- Atomic physics: atomic structure, radioactivity, X-ray tube

Qualification-goals/Competencies:

- The students are able to describe the content of the fundamentals of physics and to develop and draw mathematically the corresponding models by use of physical formula.
- They can judge what fundamental physics can and cannot achieve in principle.
- They are able to transfer their acquired knowledge to simple practical applications.
- They are able to classify physical problems according to their complexity and draw the solutions. Thereby, they have the expertise to first analyze complex tasks and to structure them into subtasks.
- The students have social and communication competencies to discuss within smaller tutorial groups and the methodological competence to elucidate a common solution for the physical exercises.
- They have the communication competency to present their results in front of the tutorial group.

Grading through:

- written exam

Responsible for this module:

- Prof. Dr. rer. nat. Robert Huber

Teacher:

- Institute of Biomedical Optics

- Dr. rer. nat. Norbert Linz

Literature:

- Giancoli: Physik

Language:

- offered only in German

Notes:

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Examination prerequisites can be defined at the beginning of the semester. If preliminary work is defined, it must have been completed and positively evaluated before the first examination.

Module exam(s):
- ME1500-L1: Fundamentals of Physics, written exam, 90 min, 100 % of module grade

ME2053-KP03 - Physics Lab Course (PhyPraKP03)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	3

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), physics, 5th semester
- Bachelor CLS 2016 (compulsory), physics, 5th semester

Classes and lectures:

- Physics Lab Course (practical course, 2 SWS)

Workload:

- 45 Hours written report
- 30 Hours in-classroom work
- 15 Hours exam preparation

Contents of teaching:

- Experiment 1: non stationary current
- Experiment 2: stationary current
- Experiment 3: sound and ultrasound
- Experiment 4: spectrometer
- Experiment 5: diffusion
- Experiment 6: radio activity

Qualification-goals/Competencies:

- The students can practically work out the physical connections to the mentioned contents of the practical course with regard to the roles of GSP of the University of Lübeck and of the DFG-guidelines.
- They can use measuring instruments correctly.
- They can display measurement results graphically.
- They can analyze collected data quantitatively.
- They can estimate and evaluate the accuracy of the measurement data and the results of the analysis.
- They can document measurement results correctly.
- They can draw meaningful conclusions from measurement data.
- They can name the principles of occupational health and safety in physical laboratories and comply with them at work.

Grading through:

- certificates and protocols

Responsible for this module:

- Prof. Dr. rer. nat. Christian Hübner

Teacher:

- Institute of Biomedical Optics
- Institute of Physics
- Institute of Medical Engineering

- Prof. Dr. rer. nat. Christian Hübner
- Prof. Dr. rer. nat. Thorsten Buzug
- PD Dr. rer. nat. Hauke Paulsen
- Dr. rer. nat. Norbert Linz
- MitarbeiterInnen des Instituts
- Prof. Dr. rer. nat. Robert Huber
- Dr. rer. nat. Verena Hirschfeld

Literature:

- Giancoli: Physik

Language:

- offered only in German

Notes:

Unmarked certificate (B certificate).

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- Certificates and transcripts

Module Exam(s):
- ME2053-L1: Physics Lab Course, ungraded practical course, 0% of module grade, must be passed

(Share of the Institute for Medical Technology at P is 17.5%)
(Share of the Institute for Physics at P is 45%)
(Share of the Biomedical Optics at P is 37.5%)

MA3300-KP04 - Interdisciplinary Seminar (InterSKP04)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	4

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), Interdisciplinary modules, 5th semester
- Bachelor CLS 2016 (compulsory), Interdisciplinary modules, 5th semester

Classes and lectures:

- Interdisciplinary Seminar (seminar, 2 SWS)

Workload:

- 90 Hours oral presentation (including preparation)
- 30 Hours in-classroom work

Contents of teaching:

- Mathematics in the context of medicine and life sciences
- individual topics in fields as biostatistics, image processing, signal analysis, machine learning, robotic, biochemistry etc.

Qualification-goals/Competencies:

- Students are able to become acquainted with an interdisciplinary scientific topic
- They are able to summarize important contents in written form
- They are able to present complex scientific contents in an intelligible oral presentation
- They are able to discuss scientific problems

Grading through:

- oral presentation
- Written report
- participation in discussions

Responsible for this module:

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Teacher:

- Institute of Medical Biometry and Statistics
- Institute of Mathematics and Image Computing
- Institute for Mathematics

- Prof. Dr. rer. nat. Jan Modersitzki
- Nachfolge von Prof. Dr. rer. nat. Karsten Keller
- Prof. Dr. rer. biol. hum. Inke König

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- Written report, oral presentation, participation in discussions

Module examination(s):
- MA3300-L1: Interdisciplinary Seminar, ungraded seminar, 0% of module grade, must be passed

MA3990-KP13 - Bachelor's thesis in Computational Life Science (BAMMLKP13)

Duration:	Turnus of offer:	Credit points:
1 Semester	each semester	13

Course of study, specific field and term:

- Bachelor CLS 2023 (compulsory), Interdisciplinary modules, 6th semester
- Bachelor CLS 2016 (compulsory), Interdisciplinary modules, 6th semester

Classes and lectures:

- Bachelor's thesis (supervised self studies, 1 SWS)
- Colloquium (presentation (incl. preparation), 1 SWS)

Workload:

- 360 Hours work on an individual topic from a recent field of research and written elaboration
- 30 Hours oral presentation and discussion (including preparation)

Contents of teaching:

- Investigating a given problem in mathematics or its application areas and developing a good solution
- Writing a Bachelor Thesis
- Colloquium to represent the results including a discussion with the referees

Qualification-goals/Competencies:

- Solving a moderately difficult problem with state-of-the-art methods in mathematics
- Being able to write a scientific thesis
- Being able to present own results in a scientific talk

Grading through:

- Written report
- colloquium

Responsible for this module:

- Prof. Dr. rer. nat. Jürgen Prestin

Teacher:

- Institutes of the Department of Computer Science/ Engineering
- Alle prüfungsberechtigten Dozentinnen/Dozenten des Studienganges

Language:

- thesis can be written in German or English

Notes:

Admission requirements for taking the module:
- The basic prerequisite for starting the Bachelor's thesis is the successful completion of 120 credits

Admission requirements for participation in module examination(s):
- Submission of a bachelor's thesis

Module examination(s):
- MA3990-L1: Bachelor's thesis in Computational Life Science, bachelor's thesis and colloquium, 100% of module grade

The Bachelor's thesis is worth 12 credits, the preparation and performance of the colloquium 1 credit.