Leibniz
Universität
Hannover

Faculty of Mathematics and Physics

Module handbook Physics

Studiengänge:

Bachelor's degree programme Physics

Master's degree programme Physics

Version of 3. July 2024
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1 Preliminary remark

This version of the module catalogue was created by a new technical implementation.We are convinced that this version contains significant improvements compared to previous versions. Although we have put a great deal of effort into correcting errors, this document may and will still contain formal errors. We would be pleased to receive any suggestions for correction.

This document consists of three parts:

- In the first part, central contact persons are introduced and the reader is familiarised with the degree programme.
- The second part is the module catalogue, which presents the modules and courses.
- The third section contains further important information about the degree programme. In particular, the other institutions that are important for the degree programme are listed.

The module catalogue, as the second part, consists of two parts, the module descriptions and the course catalogue. As different lectures can be selected in the elective modules, these are described in more detail in the appendix. In such cases, the information on the content and frequency of the courses offered can be found in the lectures and not in the modules.

Please note that this is a compilation of the lectures that are regularly offered. In particular, further lectures in the course catalogue can be assigned to the compulsory elective modules and the elective modules.

The module catalogue should also be understood as a supplement to the examination regulations. You can find the current version of our examination regulations at

https://www.uni-hannover.de/de/studium/im-studium/pruefungsinfos-fachberatung.

Inhaltsverzeichnis

2 The Faculty at a glance

The Dean heads the faculty. The Dean of Studies is responsible for the courses offered. He is represented by the Vice Dean of Studies.

Dean

Prof. Dr. Alexander Heisterkamp

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Dean of Studies

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Study Programme Coordinator

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2.1 The institutes of the faculty

The Faculty of Mathematics and Physics consists of thirteen institutes. Seven institutes belong to the Department of Physics. Six to the Department of Mathematics and one joint institute for Didactics. For Meteorology there is the Institute of Meteorology and Climatology.

Some of these are further subdivided into departments or can be subdivided thematically into working groups. The Institute of Gravitational Physics works very closely with the Hannover branch of the Max Planck Institute for Gravitational Physics (Albert Einstein Institute) under one roof. In research and teaching, there are close links with the Laser Zentrum Hannover e.V. (LZH) and the Laboratory for Nano and Quantum Engineering (LNQE). The physics institutes are spread across several buildings in the city.

Institut für Algebra, Zahlentheorie und Diskrete Mathematik(english) (IAZD)

www.iazd.uni-hannover.de

Institut für Algebraische Geometrie(english) (IAG)

www.iag.uni-hannover.de

Institut für Analysis(english) (IA)

www.analysis.uni-hannover.de

Institut für Angewandte Mathematik(english) (IfAM)

www.ifam.uni-hannover.de

Institut für Differentialgeometrie(english) (IDG)

www.diffgeo.uni-hannover.de

Institut für Versicherungs- und Finanzmathematik(english) (IVFM)

www.ivfm.uni-hannover.de

Institut für Didaktik der Mathematik und Physik(english) (IDMP)

www.idmp.uni-hannover.de

Institut für Festkörperphysik(english) (FKP)

www.fkp.uni-hannover.de

Institut für Gravitationsphysik(english) (AEI)

www.aei.uni-hannover.de

Institut für Quantenoptik(english) (IQO)

www.iqo.uni-hannover.de

Institut für Radioökologie und Strahlenschutz(english) (IRS)

www.irs.uni-hannover.de

Institut für Theoretische Physik(english) (ITP)

www.itp.uni-hannover.de

Institut für Photonik(english) (IOP)

www.iop.uni-hannover.de

Insttut für Meteorologie und Klimatologie(english) (ImuK)

www.meteo.uni-hannover.de

2.2 Committees of the Faculty

The current members of the following committees can be found on the homepage of the Faculty of Mathematics and Physics. The e-mail addresses of the student representatives can be found on the homepage of the Mathematics and Physics Student Council.

Faculty Council The Faculty Council decides on matters of research and teaching of fundamental importance. It adopts the Faculty's regulations, in particular the examination regulations. The Faculty Council consists of seven professors, two members of academic staff, two students, two representatives of doctoral students (without voting rights) and two members of technical and administrative staff (MTV group); the Dean chairs the Council. Most of the meetings are open to the public and take place approximately once a month on Wednesdays during the lecture period.

Study Commission The Study Commission must be consulted before decisions are made by the Faculty Council in all matters relating to teaching, studies and examinations. The Faculty Council must assess the recommendations. The Study Commission consists of two professors, one research assistant and four students as voting members; the Dean of Studies is the chair. The Study Commission usually meets two weeks before the Faculty Council.

Examination Board The Examination Board ensures that examinations for the Bachelor's and Master's degree courses are conducted. It ensures that the examination regulations are adhered to. The Examination Board also decides in cases of doubt regarding examination questions. A request for the Examination Board is usually addressed directly to the Chair of the Examination Board.

The student council The students of the Faculty of Mathematics and Physics form the joint Mathematics/Physics Student Council. The interests of the student council are represented by the open student council, in which all students can participate. The student council meets every Monday at 6.15 pm during the lecture period in the student council room. The main task of the student council is to represent student interests in the faculty committees. For example, through the student representatives, it is involved in the design of study and examination regulations or the use of tuition fees and can help decide on the appointment of new professors in the appointment committees. It is also involved in cross-faculty committees. Anyone who is interested in actively participating in the planning of teaching and research - i.e. in the committees - is always welcome to join the student council.

3 The study of physics at Leibniz University

3.1 The degree programs

At Leibniz University Hannover, you can study physics as part of several Bachelor's (BA) and Master's (MA) degree programs. The Bachelor's and Master's degree courses in Physics are specialist courses with the aim of working in research or industry. In addition, we also offer degree courses that serve to train teachers in physics. These will not be discussed further below.

What are the aims of the individual degree programs?

The **Bachelor's degree courses in physics** primarily serve to provide a science-oriented basic education. They initially provide a foundation of basic mathematical and physical knowledge. On this basis, the Bachelor's degree course in Physics provides an overview of the entire spectrum of modern physics.

Structure of the subject-specific degree courses

All Bachelor's degree courses lead to an independent professional qualification.

The main objective of the **Master's degree course in Physics**, on the other hand, is to enable students to work efficiently and independently at the forefront of research and in innovative areas of technology and business, as well as in all positions of responsibility in government and society.

This requires both in-depth knowledge of the subject and an introduction to the practice of working independently in academia. The Master's degree course is therefore characterized by a one-year in-depth phase and a one-year research phase.

In the **Master's degree program in Physics**, students first acquire in-depth knowledge in the five basic research areas: Solid State Physics, Quantum Optics, Quantum Field Theory, Gravitation and Radioecology and Radiation Protection. You will then be introduced to basic research in one of these areas.

What career opportunities are there after graduation?

The **Bachelor's degree courses** serve to enable the transition to a subsequent Master's degree course or a qualified change to other disciplines. They can also be independently **professionally qualifying** for certain fields of activity.

Conceivable occupational fields can be found where companies enable career starters to gain further qualifications based on sound basic mathematical and scientific knowledge in line with company requirements (e.g. in special trainee programs). On the other hand, companies may have a need for graduates of the Bachelor's degree program in Physics for fields of activity that require analytical skills and the ability to think abstractly, but for which the comprehensive scientific qualifications of Master's graduates are not sufficient.

The **consecutive Master's degree courses** are research-oriented. A successful Master's degree is also the prerequisite for obtaining a **doctoral degree** in the context of subsequent professional and research activities.

The professional **key competence** of our graduates in the **experimental** field is the ability to design suitable experiments that are as meaningful as possible and then to interpret the observations and measurement results on the basis of comprehensive and versatile knowledge. Characteristic skills of physicists in the theoretical field are the conceptual and mathematical analysis of observed physical properties as well as the development of numerical models and numerical methods at various levels of abstraction.

Due to these diverse fundamental skills, physicists can work in publicly funded or industrial research laboratories on basic and application-oriented issues, but are also sought-after employees outside their immediate field, for example in information technology, management consultancy, banking and insurance. They often work in areas for which they were not directly trained during their studies. They can be found wherever complex problems need to be dealt with in a structured way in a rapidly changing environment and flexible, creative problem solvers are required.

3.2 Structure of the degree programs

Please note that the legally binding wording of all examination regulations is exclusively that published in the university's official gazettes.

Admission requirements:

All **Bachelor's degree programs** at our faculty are admission-free. This means that you only need a university entrance qualification to start a degree course. This is usually provided by the Abitur. In addition to the general higher education entrance qualification, there are other ways to be admitted to a degree course - e.g. the examination for the acquisition of a subject-related higher education entrance qualification after previous professional training. You can find more information about admission to university without an Abitur on the university's homepage

The **Master's degree programs** are admission-restricted. The exact rules (including exceptions) can be found in the relevant admission regulations

The application deadline for admission to a Master's degree program is 15 July for the winter semester (31 May for non-EU citizens) and 15 January for the summer semester (30 November of the previous year for non-EU citizens).

The course of study.

The course content is divided into so-called **modules**. A module is a thematic summary of courses. More than one course can therefore belong to a module. In addition to the lectures, which are usually accompanied by exercises, laboratories and seminars also contribute to the course. In order to successfully complete a degree program, **Studienleistungen** and **Prüfungsleistungen** must be completed in the individual modules.

As a rule, a minimum number of points from exercises is required for coursework. Assessments of coursework are not included in the final grade. Coursework can be repeated as often as required. The content of a module is usually assessed in the form of an oral or written examination during the course of study.

So-called **Leistungspunkte** are assigned to each module according to the expected workload. After completing the required coursework and examinations, students are credited with the credit points allocated to the module.

Credit points according to the European Credit Transfer and Accumulation System (ECTS) describe the effort required to acquire the competence imparted by a module. One credit point (CP) corresponds to an estimated workload of 30 hours. Approximately 30 credit points must be earned per semester.

At least **180 credit points** must be acquired in the **Bachelor's degree programs** and **120 credit points** in the Master's degree programs. The modules extend over one to two semesters. As a rule, they each require students to work between 150 and 300 hours, corresponding to 5 to 10 CP. In particular, the basic modules as well as the Bachelor's project and the modules of the research phase in the Master's degree program require a workload that exceeds this standard scope.

The **final grade** is calculated as the average of the examination grades weighted by the credit points of the modules.

You can find out which modules you have to take in your degree program in the examination regulations for your degree program.

Registration and taking examinations:

You must register for each examination at the Examinations Office within a specified registration period. If you fail an examination, you have the opportunity to retake it twice. This does not apply to Bachelor's and Master's theses. They may be repeated once with a different topic.

The registration and examination dates can be found here, but they are also part of the respective examination regulations.

3.2.1 Bachelor's degree program

preliminary remarks on the study plans

In the following sections you will find, among other things, specific **Study plans** for the physics degree programs at Leibniz Universität Hannover. Please note that these study plans are merely suggestions for organizing your studies. They are by no means compulsory. However, when planning your studies, please bear in mind that some of the basic lectures build on each other and should therefore be taken in the order given. If you have any questions, please do not hesitate to contact the program coordinator or the academic advisors.

	1. Semester	2. Semester	3. Semester	4. Semester	5. Semester	6. Semester	LP
Mathematik	Analysis I 10 LP, SL, PL	Analysis II 10 LP, SL, PL	Mathematik für Physiker I 4 LP, SL	Mathematik für Physiker II 4 LP, SL			38
	Es muss nur eine Klausur bestanden werden		PL				
	Lineare Algebra I 10 LP, SL, PL						
Experimentalphysik	Mechanik und Wärme 6 LP, SL	Elektrizität und Relativität 12 LP, SL	Optik, Atome, Moleküle, Quantenphänomene 10 LP, SL	2 Vorlesungen: Kerne und Teilchen & Festkörperphysik 10 LP, SL			38
	PL						
		Grundpraktikum I: Grundlagen zur Messdatenanalyse	Grundpraktikum II: Physikalische Messmethoden – Elektronische Messtechnik	Grundpraktikum III: Messmethoden – Computergestützte Verfahren			
Theoretische Physik	Mathematische Methoden der Physik 7 LP, SL	Theoretische Elektrodynamik 7LP, SL	Analytische Mechanik und Spezielle Relativitätstheorie 8 LP, SL	Einführung in die Quantentheorie 8 LP, SL	Statistische Physik 8 LP, SL		38
	PL	PL					
Vertiefungsstudium					**2 von 3 Vertiefungsmodulen** - Festkörperphysik II - Atom- und Molekülphysik - Kohärente Optik je 8 LP		16
Physikalischer Wahlbereich					Mind. 12 LP aus dem Lehrangebot der Physik		12
Schlüsselkompetenzen		Seminar oder Vorlesung 4 LP					4
Wahlfach	Betriebswirtschaftslehre, Chemie, Elektrotechnik, Geodäsie und Geoinformatik, Informatik, Maschinenbau, Mathematik, Meteorologie, Philosophie und Volkswirtschaftslehre						16
Präsentation und Projektarbeit				Seminar: Physik präsentieren 3 LP, SL		Bachelorarbeit 15 LP, SL	18

Bachelor thesis:

The Bachelor's thesis should show that you are able to work independently on a problem from the subject using scientific methods within a specified period of time. Talk to the physics lecturers and ask for suitable topics. The Bachelor's thesis module includes a presentation on your completed Bachelor's thesis. Admission requirements: To register for the Bachelor's thesis, you must have completed the module Mathematics for Physicists, Experimental Physics A or B1 and B2 as well as the completed module Classical Fields and Particles.

Elective subject:

In the elective subject, students learn about the tasks and procedures of other disciplines. The total scope is 16 credit points (CP). The elective usually begins in the third semester. However, deviations are possible depending on personal study plans. Standard electives are business administration, chemistry, electrical engineering, geodesy, computer science, mathematics, mechanical engineering, meteorology, philosophy and economics. Students who wish to choose an elective subject not listed here should draw up a study plan with a representative of the subject in question and then submit it to the examination board together with the application for admission to an additional elective subject.

3.2.2 Master of Science in Physics

The Master's degree program in Physics is **research-oriented** and introduces students to modern basic research. Knowledge and skills are imparted in several sub-subjects of physics and students are encouraged to work independently in scientific research. Students must have sufficient knowledge of German or English (at level B2 according to the Common European Framework of Reference for Languages). Lectures are usually held in English. For oral examinations and for the Master's thesis, you can use German or English as you wish.

The **technical specialization and focus phase** serves to acquire the advanced knowledge necessary for independent productive work in physics in the basic research areas represented at the Faculty of Mathematics and Physics: Solid State Physics, Quantum Optics, Quantum Field Physics, Gravitation as well as Radioecology and Radiation Protection. The study options are rounded off and supplemented by an interdisciplinary elective subject.

The central element of the **research phase** is the Master's thesis, which is worth 30 credit points. This is an independent research project on a current issue in modern physics.

	1. Semester	2. Semester	3. Semester	4. Semester	CP
Advanced Specialisation and Specialisation Phase	**2 out of 5 advanced specialisation modules (5 CP each):** - Advanced Solid State Physics - Gravitational Physics - Quantum Optics - Quantum Field Theory - Radioecology and Radiation Protection				10
	either **Courses** in Physics for at least 27 CP *or* **Courses** in Physics for 17 CP and **Industrial Internship** for 10 CP				27
	Seminar for 3 CP				3
Key Comeptencies	Courses offered by Leibniz Language Center (LLC), Leibniz University IT Services (LUIS), ZQS or Faculties				4
Elective Subject	Business Studies („BWL“), Chemistry, Electrical Engineering, Geodesy, Computer Science, Mathematics, Mechanical Engineering, Meteorology, Philosophy, Economics („VWL“) *other subjects are possible on request*				16
Masters thesis				**Masters Thesis** Research internship/ Project planning	60

4 Modules of the study programme's physics

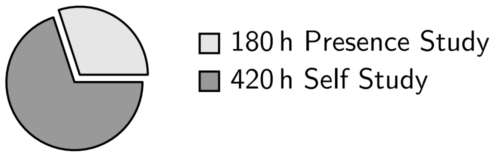
4.1 Bachelor Physics – Core Modules

Analysis I and II
(Analysis I + II)

Semester	Winter and Summer semester
Responsible	Elmar Schrohe, Institute of Analysis
Courses (SWS)	Analysis I (4+2 SWS) Analysis II (4+2 SWS)
Type of Course	Lecture and excercise classes
Perfomance record	Course achievement: Analysis I and II exercise classes (one each) Exam perfomance: Analysis I and II written exams (one each)

Credit Points (ECTS)

20



Competency Aims: Competence in dealing with mathematical language. Basic understanding of the correct solution of mathematical and scientific problems in higher-dimensional spaces with the help of convergence considerations, differentiation and integration. Confident mastery of the relevant methods and mathematical proof techniques. As a result of the exercise, students are familiar with mathematically exact formulations and conclusions in simple contexts and are able to present them.

Contents: Analysis I

- Number ranges, systematic introduction of real and complex numbers
- Sequences and series
- Convergence and continuity
- Differential calculus for functions in one variable
- Integral calculus for functions in one variable
- Sequences of functions, power series

Analysis II

- Basic topological concepts such as metric and normalised spaces, convergence, continuity, completeness, compactness
- Differentiation of functions in several variables, total and partial differentiability, theorem on inverse functions and implicit functions, local extrema with and without constraints
- Vector fields and potentials
- curve integrals
- Ordinary differential equations, existence, uniqueness, elementary solution methods

Basic literature:

- H. Amann & J. Escher: Analysis I, Birkhäuser Verlag, 2002
- O. Forster: Analysis 1, Vieweg+Teubner 2008
- H. Amann & J. Escher: Analysis II, Birkhäuser Verlag, 1999

- O. Forster: Analysis 2, Vieweg+Teubner, 2006

Recommended prior knowledge School knowledge in mathematics (upper secondary school)

Entry requirements none

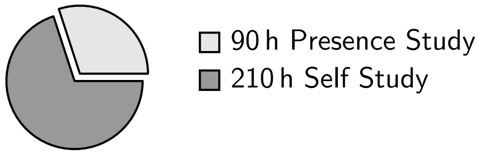
Module applicability Bachelor Physics (Core-module)

Linear Algebra I
(Lineare Algebra I)

Semester	Winter semester
Responsible	Stefan Schreieder, Institute of Algebraic Geometry
Courses (SWS)	Linear Algebra I (4+2 SWS)
Type of Course	Lecture and excercise classes
Perfomance record	Course achievement: exercises Exam performance: Exam

Credit Points (ECTS)

10



Competency Aims: Basic understanding of mathematical thinking and its application to various problems. Confident handling of linear systems of equations and the associated solution methods and sound knowledge of the underlying algebraic structures. Ability to express mathematical arguments and knowledge of the appropriate methods.

Contents: Fundamental properties of vector spaces (basis and dimension)

- linear mappings and matrices
- Determinants
- Linear systems of equations with solution methods (Gauss algorithm)
- Eigenvalues and eigenvectors
- Diagonalization

Basic literature: G. Fischer, Lineare Algebra, Vieweg

Recommended prior knowledge School knowledge in mathematics (upper secondary school)

Entry requirements none

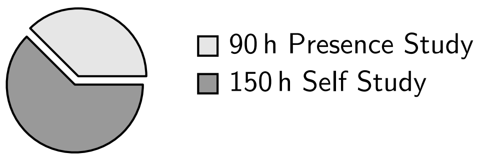
Module applicability Bachelor Physics (Core-module)

Mathematics for Physicists
(Mathematik für Physiker)

Semester Winter and Summer semester
Responsible Elmar Schrohe, Institute of Analysis
Courses (SWS) Mathematics for Physicists I (2+2 SWS)
Mathematics for Physicists II (2+2 SWS)

Type of Course Lecture and excercise classes
Perfomance record Course achievement: exercises for each class (I and II) Exam performance: written or oral exam (lecturer´s choice) (Examination for the entire module is offered every semester)

Credit Points (ECTS)
8



Competency Aims: Students have an in-depth understanding of analytical methods, in particular integration and function theory. They have the ability to work out difficult mathematical arguments independently and to present them independently in the exercise group. Students have understood the mathematical structure of important differential equations in physics and can apply suitable solution strategies.

Contents:

- Lebesgue's function spaces and convergence theorems
- Differential forms and integral theorems
- Fourier analysis
- Linear partial differential equations
- Elements of function theory

Basic literature: Will be specified by the lecturer

Recommended prior knowledge Analysis I+II

Entry requirements none

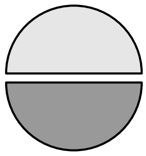
Module applicability Bachelor Physics (Core-module) Bachlor Meteorlogy (Scientific-technical elective area)

Fundamental practical course A
(Grundpraktikum A)

Semester	Summer semester
Responsible	Institutes of Experimental Physics
Courses (SWS)	Fundamental Practical Course I: Fundamentals of Measured Data Analysis
Type of Course	Practical Lab Course
Perfomance record	Course achievement: lab exercises

Credit Points (ECTS)

4



- 60 h Presence Study
- 60 h Self Study

Competency Aims: Students are familiar with the basic principles of experimentation. They know the function and accuracy of various measuring devices and are familiar with computer-aided data acquisition. They are able to present measurement results clearly in tabular and graphical form. Continuous participation is required to achieve the competence goals of the laboratory exercise.

Contents: Mechanics

- Possible practical experiments: energy theorem for pendulums, oscillations, coupled pendulums, gyroscopes, ultrasound, acoustics, Maxwell wheel

Thermodynamics

- Possible practical experiments: temperature, ideal gas, viscosity, specific heat, water vapour, thermal radiation, Stirling engine, critical point, gas pressure fields/specific heat

Electricity

- Possible practical experiments: electrical resistance, oscillating circuits, transistor, operational amplifier, tilt circuit, feedback, membrane model, galvanometer, oscilloscope, noise analysis, storage oscilloscope

Basic literature:

- Demtröder, Experimentalphysik 2, Elektrizität und Optik, Springer Verlag
- Gerthsen, Physik, Springer Verlag
- Tipler, Physik, Spektrum Akademischer Verlag
- Feynman, Lectures on Physics, Band 2; Addison-Wesley Verlag

Recommended prior knowledge Mechanics and Heat, Mathematical Methods of Physics

Entry requirements none

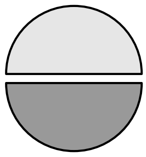
Module applicability Bachelor Physics (Core-module) Bachelor Meteorology (Core-module)

Fundamental practical course B
(Grundpraktikum B)

Semester	Winter and Summer semester
Responsible	Institutes of Experimental Physics
Courses (SWS)	Fundamental Practical Course II: Measurement Methods – Electronic Measurement Technology Fundamental Practical Course III: Measurement Methods – Computer-assited Procedures
Type of Course	Practical Lab Course
Perfomance record	Course achievement: lab exercises

Credit Points (ECTS)

6



☐ 90 h Presence Study
■ 90 h Self Study

Competency Aims: Students know the function and accuracy of various measuring devices and are familiar with the adaptation of functions to measurement data. They can carry out appropriate error estimations and are familiar with the theory of error propagation. Students are proficient in the operation of standard measuring instruments. They are able to record measurement results accurately and completely and to scrutinize them critically. Continuous participation is required to achieve the competence goals of the laboratory exercise.

Contents: possible practical experiments

- Lenses, microscope, Michelson interferometer, Mach-Zehnder interferometer, interference/coherence, diffraction, polarisation, Faraday effect, prism, grating, photo effect, absorption spectroscopy, emission spectroscopy, spectral apparatus, X-rays

Basic literature:

- Demtröder, Experimentalphysik 2, Elektrizität und Optik, Springer Verlag
- Gerthsen, Physik, Springer Verlag
- Tipler, Physik, Spektrum Akademischer Verlag
- Feynman, Lectures on Physics, Band 2; Addison-Wesley Verlag

Recommended prior knowledge Mechanics and Heat, Electricity and Relativity, Mathematical Methods of Physics

Entry requirements none

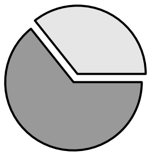
Module applicability Bachelor Physics (Core-module) Bachelor Meteorology (Core-module)

Mathematical Methods of Physics
(Mathematische Methoden der Physik)

Semester	Winter semester
Responsible	L. Santos, Institute of Theoretical Physics
Courses (SWS)	Mathematical Methods of Physics (3+2 SWS)
Type of Course	Lecture and excercise classes
Perfomance record	Course achievement: exercise class Exam performance: written or oral exam (lecturer's choice)

Credit Points (ECTS)

7



☐ 75 h Presence Study
■ 135 h Self Study

Competency Aims: Students know the mathematical quantities used to describe physical theories. They are able to formulate simple physical problems mathematically and solve them using analytical methods and numerical, computer-aided methods

Contents:

- Accelerated coordinate systems: apparent forces, kinematics of the rigid body
- Vectors: scalar and cross product, index notation, determinants
- Space curves: differentiation, chain rule, gradient, Frenet formulae
- Ordinary differential equations: Solution methods
- Newtonian mechanics of a centre of mass, systems of centres of mass
- Tensors: matrices, rotations, principal axis transformation, inertia tensor
- Harmonic oscillations: Normal coordinates, resonance
- Functions: inverse function, power series, Taylor series, complex numbers
- Integration: one- and multi-dimensional, curve and surface integrals
- one-dimensional motion: Solution with energy theorem
- Curvilinear coordinates: measure of integration, substitution, delta distribution
- Programming simple numerical methods for solving and visualising physical problems

Basic literature:

- Feynman, Lectures on Physics, Band 1+2, Addison-Wesley Verlag
- Großmann, Mathematischer Einführungskurs für die Physik, Teubner 2000
- Nolting, Grundkurs Theoretische Physik 1 - Klassische Mechanik, Springer

Recommended prior knowledge School knowledge in mathematics (upper secondary school)

Entry requirements none

Module applicability Bachelor Physics (Core-module) Bachelor Meteorology (Core-module)

Classical Fields and Particles
(Klassische Felder und Teilchen)

Semester	Winter and Summer semester
Responsible	H. Frahm, Institute of Theoretical Physics
Courses (SWS)	Theoretical Electrodynamics (3+2 SWS) Analytical Mechanics and Special Theory of Relativity (4+2 SWS)
Type of Course	Lecture and excercise classes
Perfomance record	Course achievement: exercises or written exam per lecture Exam performance: oral exam

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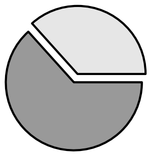
Credit Points (ECTS)

15



- 165 h Presence Study
- 285 h Self Study

Competency Aims: Students know the mathematical quantities used to describe physical theories. They are able to formulate simple physical problems mathematically and solve them using analytical methods and numerical, computer-aided methods. Students understand the logical structure of electrodynamics, classical mechanics and special relativity and are familiar with the mathematical formulation of the laws. They know prominent examples from these fields and can derive them from the basic equations. Students are able to find analytical solutions for selected problems and make suitable mathematical and physical approximations for the solution.

Contents:

- Vector fields: Vector analysis, integral theorems, Laplace operator
- Maxwell's equations: Integral form, initial and boundary values, interfaces
- Potentials, gauge-free, vacuum solution, solution with sources, retardation
- Linear partial differential equations: Separation, Green's function
- Fourier analysis: function spaces, Fourier series, Fourier transformation
- electrostatics: boundary value problems, potential theory, multipole development
- Magnetostatics: filamentary current distributions, field energy
- moving point charges, Lienard-Wiechert potential theory, multipole development
- Electromagnetic waves: in a vacuum, influence of sources, radiation
- Electrodynamics in media
- Programming simple numerical methods for solving and visualising physical problems
- Lagrange mechanics: Constraints, multipliers, Lorentz force
- Calculus of variations: functional derivation, extrema with constraints
- Principle of action, Noether's theorem, conservation laws
- Dynamics of rigid bodies: Euler's equations, gyroscopes, precession, nutation
- Hamiltonian mechanics: Legendre transformation, canonical equations, conservation laws
- canonical transformations: Phase portrait, symplectic structure, invariants
- covariant formulation of Maxwell & Lorentz, Lagrange density, conservation laws

- special relativity: kinematics, dynamics of mass points, quadratic notation

Basic literature:

- Landau-Lifschitz, Lehrbuch der Theoretischen Physik, Band I+II, Harri
- J.D. Jackson, Klassische Elektrodynamik, Gruyter, Walter de GmbH
- Römer & Forger, Elementare Feldtheorie, Wiley
- Nolting, Grundkurs Theoretische Physik 3 - Elektrodynamik, Springer
- H. Goldstein, Poole & Safko, Classical Mechanics, Wiley-VCH Verlag GmbH & Co
- L.N. Hand and J. D. Finch, Analytical Mechanics, Cambridge University Press
- Arnold, Classical Mechanics, Springer

Recommended prior knowledge Mathematical methods of physics

Entry requirements none

Module applicability Bachelor Physics (Core-module)

Quantum Theorie and Statistical Physics

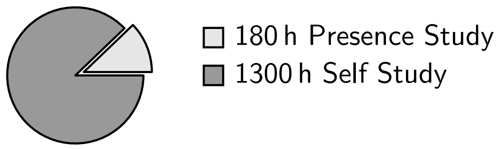
(Quantentheorie und Statistische Physik)

Semester Winter and Summer semester
Responsible Institute of Theoretical Physics
Courses (SWS) Introduction to Quantum Theory (4+2 SWS)
Statistical Physisc (4+2 SWS)

Type of Course Lecture and excercise classes
Perfomance record Course achievement: exercises or written exam per lecture
Exam performance: oral exam

Credit Points (ECTS)

16



Competency Aims: Die Studierenden haben einen Überblick über die Gebiete der Quantenmechanik und Statistische Physik. Sie verstehen diese Gebiete als Teilgebiete eines umfassenden physikalischen Theoriengebäudes. Die Studierenden beherrschen den mathematischen Apparat der Quantentheorie. Sie verstehen die physikalischen Konsequenzen der Quantentheorie und kennen den Zusammenhang zur klassischen Physik. Sie sind in der Lage den mathematischen Formalismus der Quantentheorie auf ausgewählte Probleme eigenständig anzuwenden. Sie sind mit störungstheoretischen Konzepten vertraut. Die Studierenden beherrschen die mathematische Beschreibung der Hauptsätze der Thermodynamik und der statistischen Physik. Sie sind in der Lage die Konzepte der Statistischen Physik auf die Gebiete der klassischen Physik wie auch der Quantentheorie anzuwenden. Sie kennen prominente Beispiele und können diverse mathematisch behandeln. They are able to use the mathematical apply the mathematical formalism of quantum theory to selected problems independently.

Contents: Quantum theory

- Photons as simple quantum systems, motion of particles, Schrödinger equation
- Hamiltonian formalism: postulates, transformations, time evolution pictures
- Simple systems: oscillator, potential threshold, potential well, periodic potential
- Angular momentum: symmetries, angular momentum algebra, representation, addition of angular momentum, spin
- Central potential: separation of the Schrödinger equation, Coulumb potential
- Approximation methods: time-independent and time-dependent perturbation theory, variational methods, semiclassics, applications
- Multi-particle systems: identical particles, Fock space, Hartree-Fock, molecules, quantum field

Statistical physics

- Fundamental concepts in statistical mechanics: Probability theory, statistical ensembles, state sums, density matrices, entropy
- Ideal gases: polyatomic gases, Fermi gas, Bose gas, non-interacting spins, quasiparticles
- Phenomenological theory (thermodynamics): Main laws of thermodynamics. Heat machines, irreversible processes, thermodynamic potentials and relations Interacting systems: molecular field theory, Monte Carlo simulations, Ising model, percolation, real gases, phase transitions

- Non-equilibrium statistics: fluctuations, Brownian motion, kinetic equations, transport

Basic literature:

- F. Schwabl, Quantenmechanik, Springer
- J.J. Sakurai, Modern Quantum Mechanics, Pearson
- Peres, Quantum Theory: Concepts and Methods, Springer
- L.D. Landau, E.M. Lifshitz, Theoretische Physik, Bd V+VI , Harri
- L.P. Kadanoff, Statistical Physics: Statics, Dynamics and Renormalization, World Scientific Pub Co
- C. Kittel, H. Krömer, Thermodynamik, Oldenbourg
- F. Schwabl, Statistische Physik, Springer

Recommended prior knowledge Mathematical Methods of Physics, Theoretical Electrodynamics, Analytical Mechanics and Special Theory of Relativity

Entry requirements none

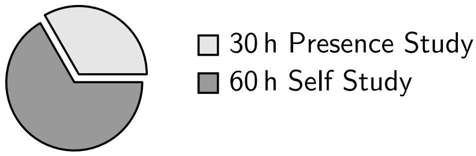
Module applicability Bachelor Physics (Core-module)

Presenting Physics
(Physik präsentieren)

Semester	Winter and Summer semester
Responsible	Deanery of Studies
Courses (SWS)	Proseminar (2 SWS)
Type of Course	Lecture and excercise classes
Perfomance record	Course achievement: seminar performance

Credit Points (ECTS)

3



Competency Aims: Students are able to familiarize themselves with a given topic under supervision. They can independently research literature and structure and give a presentation.They are familiar with common presentation and visualization techniques.Students are proficient in German technical language in free speech. Continuous participation is required to achieve the competency goals.

Contents:

- Physical topics (selection from a topic field specified by the lecturer)
- Preparation of a presentation
- Success factors of an understandable presentation
- Using visualization media effectively
- Dealing with stage fright
- Scientific discussion

Basic literature: Will be specified for the respective topic

Recommended prior knowledge In consultation with the lecturers

Entry requirements none

Module applicability Bachelor Physics (Core-module)

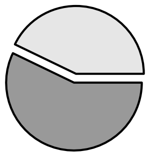
4.2 Bachelor Physics – Elective Area Experimental Physics

Experimental Physics
(Experimentalphysik)

Semester	Winter or Summer semester
Responsible	Dean of Studies Physics
Courses (SWS)	Mechanics and Heat (4+2 SWS) Electricity and Relativity (4+2 SWS) Optics, Atomic Physics, Quantum Phenomena (4+2 SWS) Nuclei and Particles (2+2 SWS) Solid-State Physics (2+2 SWS)
Type of Course	Lecture and excercise classes
Perfomance record	Course achievement: exercise classes for all course Exam performance oral exam on courses

Credit Points (ECTS)

28



360 h Presence Study
480 h Self Study

Competency Aims: Students have an overview of the fundamental areas of experimental physics. They have recognized parallels and cross-connections between the individual areas and can present these in a scientific discussion. Students have an idea of physics as a whole and its different manifestations on different length and energy scales.They have mastered the independent acquisition of knowledge from specialist books, some of which are in English.

Contents: Depending on the course

Basic literature: Depending on the course

Recommended prior knowledge School knowledge in mathematics and physics (upper secondary school)

Entry requirements none

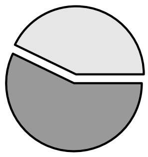
Module applicability Bachelor Physics Interdisciplinary Bachelor Physics Bachelor Nanotechnology

Experimental Physics Part 1
(Experimentalphysik Teil 1)

Semester	Winter or Summer semester
Responsible	Dean of Studies Physics
Courses (SWS)	Mechanics and Heat (4+2 SWS) Electricity and Relativity (4+2 SWS)
Type of Course	Lecture and excercise classes
Perfomance record	Course achievement: exercise classes for all course Exam performance oral exam on courses

Credit Points (ECTS)

14



180 h Presence Study
240 h Self Study

Competency Aims: Students have an overview of the fundamental areas of mechanics, thermodynamics, electrodynamics and relativity theory in experimental physics. They have recognized parallels and cross-connections between these areas and can present them in a scientific discussion.

Contents: Depending on the course

Basic literature: Depending on the course

Recommended prior knowledge School knowledge in mathematics and physics (upper secondary school)

Entry requirements none

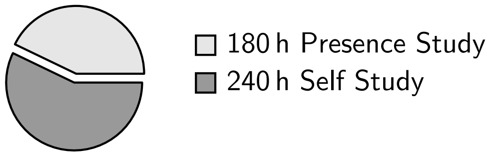
Module applicability Bachelor Physics Interdisciplinary Bachelor Physics Bachelor Nanotechnology

Experimental Physics Part 2
(Experimentalphysik Teil 2)

Semester	Winter or Summer semester
Responsible	Dean of Studies Physics
Courses (SWS)	Optics, Atomic Physics, Quantum Phenomena (4+2 SWS) Nuclei and Particles (2+2 SWS) Solid-State Physics (2+2 SWS)
Type of Course	Lecture and excercise classes
Perfomance record	Course achievement: exercise classes for all course Exam performance oral exam on courses

Credit Points (ECTS)

14



Competency Aims: Students have an overview of the fundamental areas of experimental physics. They have recognized parallels and cross-connections between the individual areas and can present these in a scientific discussion. Students have an idea of physics as a whole and its different manifestations on different length and energy scales. They have mastered the independent acquisition of knowledge from specialist books, some of which are in English.

Contents: Depending on the course

Basic literature: Depending on the course

Recommended prior knowledge Module: Experimental Physics Part 1

Entry requirements Module: Experimental Physics Part 1

Module applicability Bachelor Physics Interdisciplinary Bachelor Physics Bachelor Nanotechnology

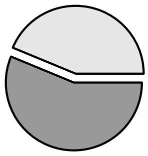
4.3 Bachelor Physics – Experimental Physics Specialization

Specialization Area Experimental Physics
(Vertiefungsbereich Experimentalphysik)

Semester	Winter or Summer semester
Responsible	Dean of Studies
Courses (SWS)	Solid-State Physics II (3+3+2 SWS) Atomic and Molecular Physics (3SWS + 3SWS + 2SWS) Coherent Optics (3+1+3 SWS)
Type of Course	Practical Lab Course and Lecture and excercise classes
Perfomance record	Course achievement: exercise classes and practical lab courses (choose two courses) Exam performance: oral exam on the two chosen courses

Credit Points (ECTS)

16



☐ 210 h Presence Study
☐ 270 h Self Study

Competency Aims: Students understand the basic concepts of two advanced areas of physics. They know the the relationships between the fields and are able to demonstrate the effects of new findings in one field on the other. the other.

Contents: Depending on the course

Basic literature: Depending on the course

Recommended prior knowledge

Entry requirements Completed module Experimental Physics or Experimental Physics Part 1 and Experimental Physics Part 2

Module applicability Bachelor Physics

Modern Aspects of Physics
(Moderne Aspekte der Physik)

Semester	Winter and Summer semester
Responsible	Dean of Studies
Courses (SWS)	Selection of Courses in total of 12 CP according to course catalog
Type of Course	Lecture and excercise classes
Perfomance record	Course achievement: according to the Prüfungsordnung (exam regulations) Exam performance: oral exam

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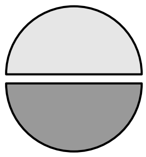
Credit Points (ECTS)

12



☐ 240 h Presence Study
■ 240 h Self Study

Competency Aims: Students have in-depth knowledge in selected specialist areas of physics. They are able to integrate newly acquired knowledge into the logical structure of physics. Students are able to understand specialist literature in English.

Contents:

- Further courses in physics of the student's choice.
- The examination covers courses of at least 4 CP of the student's choice.

Basic literature: Will be specified by the lecturer

Recommended prior knowledge Basic lectures in physics

Entry requirements none

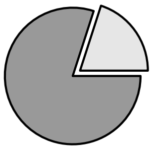
Module applicability Bachelor Physics (elective module)

Key Skills (Bachelor)
(Schlüsselkompetenzen (Bachelor))

Semester	Winter and Summer semester
Responsible	Dean of Studies
Courses (SWS)	Courses at the Leibniz Language Center or the ZQS/Key Competencies or other key skill courses offered by the faculties (e.g. computer courses)
Type of Course	Lecture and excercise classes
Perfomance record	Course achievement: according to the Prüfungsordnung (exam regulations) Exam performance: oral exam

Credit Points (ECTS)

4



30 h Presence Study
120 h Self Study

Competency Aims: They learn and master exemplary key competencies in the field of the selected course

Contents: Contents depending on the selected course

Basic literature: Will be specified by the lecturer

Recommended prior knowledge none

Entry requirements none

Module applicability Bachelor Physics

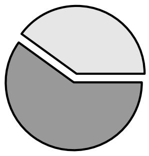
4.4 Master Physics – Advanced Specialization

Advanced Solid-State Physics
(Fortgeschrittene Festkörperphysik)

Semester	Winter semester
Responsible	Management of the Institute of Solid State Physics
Courses (SWS)	Advanced Solid-State Physics
Type of Course	Lecture and excercise classes
Perfomance record	Course achievement: short exams and/or exercises Exam performance: oral or written exam (lecturer's choice)

Credit Points (ECTS)

5



60 h Presence Study
90 h Self Study

Competency Aims: Students have in-depth knowledge of models and experimental findings in the field of solid state physics. They can independently classify selected phenomena and develop suitable models to explain them. They are familiar with significant developments in the field over the last few decades and have an idea of the current unresolved issues. Students know the advantages and disadvantages of individual experimental techniques and know how the different techniques complement each other.

Contents:

- Superconductivity
- Dia- and paramagnetism
- Ferro- and antiferromagnetism
- Magnetic resonance
- Finite solids
- Physics in one and two dimensions, at surfaces and interfaces
- Disorder in solids

Basic literature:

- Ashcroft, Mermin, Festkörperphysik, Oldenbourg Verlag
- Ch. Kittel, Einführung in die Festkörperphysik, Oldenbourg Verlag

Recommended prior knowledge Solid-State Physics I, Solid-State Physics II

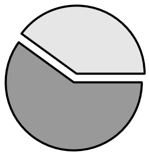
Entry requirements none

Module applicability Master Physics (Advanced Specialization)

Gravitational Physics
(Gravitationsphysik)

Semester	Summer semester
Responsible	B. Willke, Institute of Gravitational Physics
Courses (SWS)	Gravitational Physics
Type of Course	Lecture and excercise classes
Perfomance record	Course achievement: exercises Exam performance: oral or written exam (lecturer's choice)

Credit Points (ECTS)
5



- 60 h Presence Study
- 90 h Self Study

Competency Aims: Students understand the basic concepts of advanced gravitational physics and can apply them independently to selected problems. They are familiar with advanced experimental methods in the field and can apply them under supervision.

Contents:

- General theory of relativity
- Equivalence principle, Lense-Thirring effect
- Cosmology
- Astrophysics
- Sources and propagation of gravitational waves
- Basics of laser interferometric gravitational wave detection
- Noise sources in laser interferometers
- Seismic isolation
- Mechanical quality and thermal noise
- Quantum noise in interferometers
- Interferometer recycling techniques

Basic literature: Will be specified by the lecturer

Recommended prior knowledge Special Theory of Relativity (Basics), Coherent Optics

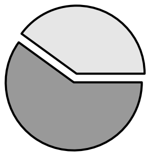
Entry requirements none

Module applicability Master Physics (Advanced Specialization)

Quantum Field Theory
(Quantenfeldtheorie)

Semester	Winter or Summer semester
Responsible	Olaf Lechtenfeld, Institut of Theoretical Physics
Courses (SWS)	Quantum Field Theory
Type of Course	Lecture and excercise classes
Perfomance record	Course achievement: exercises Exam performance: oral or written exam (lecturer's choice)

Credit Points (ECTS)
5



60 h Presence Study
90 h Self Study

Competency Aims: Students have an in-depth, formal understanding of quantum field theory and can independently apply its mathematical-quantitative description methods. They are able to derive the physical content of mathematical models and place them in the context of known theories. Students are familiar with mathematical techniques and know analytical and numerical methods that can be used to solve problems in the field.

Contents:

- Classical field theory
- Canonical field quantization (scalar field, Dirac field, vector field)
- Perturbation calculus and Feynman rules
- Path integral quantization (quantum mechanics, scalar field, coherent states)
- Renormalization (regularization, renormalization, effective action)
- Quantization of gauge fields (QED, Yang-Mills)
- Finite temperatures & statistical mechanics

Basic literature:

- M.E. Peskin & D.V. Schroeder, An Introduction to Quantum Field Theory, Westview Press
- L. H. Ryder, Quantum Field Theory, Cambridge University Press
- S. Weinberg, The Quantum Theory of Fields, Vols. I&II, Cambridge University Press
- D.J. Amit, Field Theory, the Renormalization Group and Critical Phenomena, World Scientific Publishing Company
- J. Cardy, Scaling and Renormalization in Statistical Physics, Cambridge University Press
- J. Zinn-Justin, Quantum Field Theory and Critical Phenomena, Oxford University Press

Recommended prior knowledge Advanced Quantum Theorie

Entry requirements none

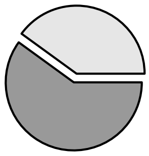
Module applicability Master Physics (Advanced Specialization)

Quantum Optics
(Quantenoptik)

Semester	Winter semester
Responsible	Piet Schmidt, Tanja Mehlstäubler
Courses (SWS)	Quantum Optics
Type of Course	Lecture and excercise classes
Perfomance record	Course achievement: exercises Exam performance: oral or written exam (lecturer's choice)

Credit Points (ECTS)

5



☐ 60 h Presence Study

■ 90 h Self Study

Competency Aims: Students understand the basic concepts of quantum optics and can apply these independently to selected problems. They are familiar with advanced experimental methods in the field and can apply them under supervision.

Contents:

- Quantisation of the EM field & coherent and Fock states, quadrature operators
- Spontaneous emission, Lamb shift, Casimir effect
- Heisenberg uncertainty relation, photon statistics, quantum noise
- Non-classical light: beam splitters, interferometry, generation and characterisation
- Applications: Quantum sensor technology with light, optical tests of quantum mechanics, quantum communication
- Atom-field interaction with coherent fields, Rabi model, optical Bloch equations, Jaynes-Cummings model
- Resonance fluorescence, laser cooling, optical traps, coherent manipulation of atoms
- Experiments in modern quantum optics

Basic literature:

- Gerry/Knight, Introductory Quantum Optics, Cambridge University Press
- Mandel/Wolf, Optical Coherence and Quantum Optics, Cambridge University Press
- Bachor/Ralph, A Guide to experiments in Quantum Optics, Wiley-VCH
- Schleich, Quantum Optics in Phase space, Wiley-VCH

Recommended prior knowledge Coherent Optics, Introduction to Quantum Theory

Entry requirements

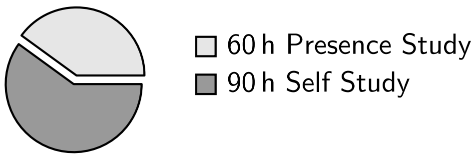
Module applicability Master Physics – Advanced Specialization module

Radiation Protection and Radioecology
(Strahlenschutz und Radioökologie)

Semester	Winter semester
Responsible	Clemens Walther, Institute of Radioecology and Radiation Protection
Courses (SWS)	Radiation Protection and Radioecology Seminar Radiation Protection and Radioecology
Type of Course	Lecture and excercise classes, Seminar
Perfomance record	Course achievement: to be provided during seminar Exam performance: oral exam

Credit Points (ECTS)

5



Competency Aims: Students understand the basic concepts of radiation physics, radiation protection and radioecology and are able to apply these independently to selected problems.

Contents: The lecture deals with ionizing radiation, radioactive decay, the interaction of radiation with matter, radiation measurement methods, dosimetry, biological effects of radiation, effects of radioactive substances and ionizing radiation on humans, exposure pathways, radioecological modelling, the pathways of radioactive substances to humans, natural radiation exposure, civilization-related radiation exposure, estimation of radiation risks, radiation dose and radiation risk, dose-effect relationships, the concept of collective dose, radiation protection principles, non-ionizing radiation and radiation protection in flying and space travel

The seminar covers selected topics on the spread of radionuclides in the environment, radioecological issues, radiation protection, the use of radiation in medicine and radionuclide production. In order to take the Master module Radiation Protection and Radioecology you have to

a). Take part in the Thursday seminar (hyperref[veranstaltung:Seminar Radiation Protection and Radioecology]Seminar Radiation Protection and Radioecology

b). **AND** attend **one of the following** lectures

a. Strahlenschutz und Radioökologie; Clemens Walther (Mo 10:15) (Radiation Protection and Radioecology

b. Chemistry and physical analysis of radionuclides; Sergiy Dubchak (Tue 16:00)

For SL you have to attend the seminar and one of the lectures. For PL you have to give one talk in the seminar and answer questions after the talk (oral exam) combining topics of the seminar and the lecture.

Basic literature: Will be specified by the lecturer

Recommended prior knowledge Nuclei and Particles

Entry requirements

Module applicability Master Physics – Advanced Specialization module

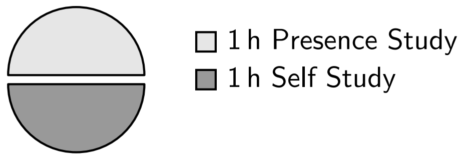
4.5 Master Physics – Specialization Phase

Selected Topics in Modern Physics A
(Ausgewählte Themen moderner Physik A)

Semester	Winter or Summer semester
Responsible	Dean of Studies
Courses (SWS)	Courses in total of 27 CP according to course catalog
Type of Course	Lecture and excercise classes
Perfomance record	Course achievement: according to the Prüfungsordnung (exam regulations) Exam performance: oral exam

Credit Points (ECTS)

27



Competency Aims: Students have a broad overview of the range of topics in modern physics and can integrate this knowledge into the overall structure of physics. They will have familiarized themselves with a selected specialist area of physics and will be able to build on this to start working in a research group in this area.

Contents:

- Advanced physics courses of the student's choice
- The examination covers thematically related courses amounting to at least 12 CP.

Basic literature: Will be specified by the lecturer

Recommended prior knowledge according to course catalog

Entry requirements none

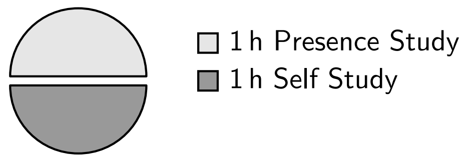
Module applicability Master Physics (Specialization)

Selected Topics in Modern Physics B
(Ausgewählte Themen moderner Physik B)

Semester	Winter or Summer semester
Responsible	Dean of Studies
Courses (SWS)	Courses in total of 17 CP according to course catalog
Type of Course	Lecture and excercise classes
Perfomance record	Course achievement: according to the Prüfungsordnung (exam regulations) Exam performance: oral exam

Credit Points (ECTS)

17



Competency Aims: Students have a broad overview of the range of topics in modern physics and can integrate this knowledge into the overall structure of physics. They will have familiarized themselves with a selected specialist area of physics and will be able to build on this to start working in a research group in this area.

Contents:

- Advanced physics courses of the student's choice
- The examination covers thematically related courses amounting to at least 12 CP.

Basic literature: Will be specified by the lecturer

Recommended prior knowledge according to course catalog

Entry requirements Must be chosen together with the Industrial Internship module

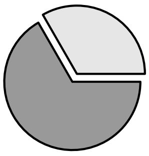
Module applicability Master Physics (Specialization)

Seminar

Semester	Winter or Summer semester
Responsible	Dean of Studies
Courses (SWS)	Seminar
Type of Course	Seminar
Perfomance record	Exam performance: seminar performance

Credit Points (ECTS)

3



- 30 h Presence Study
- 60 h Self Study

Competency Aims: Students are able to independently research literature on a given, current topic from modern physics, some of which is still the subject of research. Students are able to work independently on a current field of knowledge. Students can structure and deliver a lecture on a complex topic in modern physics in such a way that an audience with an education in physics can follow the lecture well. They can also interest the audience in a complex special topic through the design of the lecture. Students are able to create an appealing presentation. (PowerPoint or similar). Students are able to lead a scientific discussion (on their own topic as well as on the topics of other seminar participants). Students are proficient in German and English technical language in free speech.

Continuous participation is required to achieve the competence goals.

Contents: Advanced topics in physics

Basic literature: Will be specified by the lecturer

Recommended prior knowledge

Entry requirements none

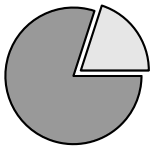
Module applicability Master Physics (Specialization)

Key Skills (Master)
(Schlüsselkompetenzen (Master))

Semester	Winter and Summer semester
Responsible	Dean of Studies
Courses (SWS)	Courses at the Leibniz Language Center or the ZQS/Key Competencies or other key skill courses offered by the faculties (e.g. computer courses)
Type of Course	Miscellaneous
Perfomance record	Course achievement: according to the Prüfungsordnung (exam regulations)

Credit Points (ECTS)

4



30 h Presence Study
120 h Self Study

Competency Aims: They learn and master exemplary key competencies in the field of the selected course

Contents: Contents depending on the selected course

Basic literature: Will be specified by the lecturer

Recommended prior knowledge none

Entry requirements none

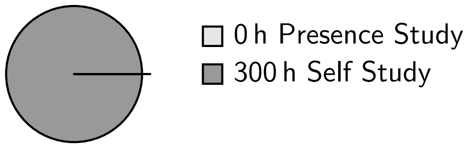
Module applicability Master Physics Students of the English branch of the MA Physics complete language courses in German of up to 16 CP in this module, depending on the result of the compulsory consultation. For all other students, this module comprises 4 CP

Industrial Internship
(Industriepraktikum)

Semester Winter or Summer semester
Responsible Intership / Practical Course Coordinator
Courses (SWS) -

Type of Course Internship
Perfomance record Course achievement: Internship report

Credit Points (ECTS)
10



Competency Aims: Students will be familiar with typical areas of responsibility and fields of activity of physics graduates in professional practice. They can integrate themselves into a working environment with scientists and engineers from related disciplines and actively contribute to the team. They are familiar with examples of the implementation of scientific findings in an industrial process and understand the tasks involved.

Contents:

- Internship in an industrial company. University institutes are excluded; in exceptional cases, the internship can also take place in a non-university research institution.
- The internship should be completed in a typical professional field of a physicist.
- If possible, a defined (small) project should be completed as part of the internship.
- The duration is at least eight weeks

Basic literature: Will be specified by the lecturer

Recommended prior knowledge

Entry requirements The internship must be approved in advance by the Chairperson of the Examination Board.

Module applicability Master Physics (Module: Selected Topics in Modern Physics B)

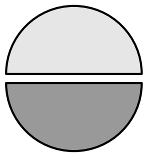
4.6 Thesis and Research Phase

Bachelor Project
(Bachelorprojekt)

Semester	Start all year round possible
Responsible	Dean of Studies
Courses (SWS)	Projekt: Bachelorthesis Workgroup seminar
Type of Course	Seminar and Thesis
Perfomance record	Exam performance: bachelor thesis Course achievement: seminar performance

Credit Points (ECTS)

15



- 450 h Presence Study
- 450 h Self Study

Competency Aims: Students have the ability to familiarize themselves independently with a research topic. They can independently acquire knowledge from books and specialist journals, some of which are in English. They are able to realistically plan, schedule and carry out a scientific project using scientific methods under supervision. You will be able to write a text according to scientific standards. They can present a scientific topic using suitable media and are able to discuss their own work with fellow students and lecturers. They are proficient in written and spoken German and some English technical language. Examination procedure

Contents:

- Introduction to scientific work
- Independent project work under supervision
- Scientific writing
- Presentation techniques
- Scientific presentation
- Leading a discussion

Basic literature:

- Current literature on the topic of the Bachelor thesis
- Stickel-Wolf, Wolf, Wissenschaftliches Arbeiten und Lerntechniken, 2004, ISBN: 3-409-31826-7
- Walter Krämer, Wie schreibe ich eine Seminar- oder Examensarbeit?, 1999, ISBN: 3-593-36268-6, Gruppe: Studienratgeber, Reihe: campus concret, Band: 47
- Abacus communications, The language of presentations, CDROM Lehr- und Trainingsmaterial
- Alley, The Craft of Scientific Presentation, Springer
- Day, How to write & publish a scientific paper. Cambridge University Press.

Recommended prior knowledge The respective core-module of Bachelor's degree program

Entry requirements Completed module Mathematics for Physicists and completed module Experimental Physics or Part 1 and Part 2 as well as completed module Classical Fields and Particles.

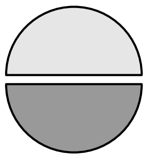
Module applicability Bachelor Physics (Module: Bachelor's Thesis)

Research internship / Project Planning
(Forschungspraktikum /Projektplanung)

Semester	Winter and Summer semester
Responsible	Dean of Studies
Courses (SWS)	Research Internship Project Planning: Masterthesis Workgroup seminar
Type of Course	Seminar
Perfomance record	Course achievement: seminar performance Exam performance: Presentation/Talk

Credit Points (ECTS)

30



Competency Aims: Students are able to familiarize themselves with the measurement methods or theoretical concepts of a research area. They are able to gain an overview of the specialist literature on a research project. Students are able to work in an (international) team and communicate easily in German and English. Students have acquired social skills that enable them to integrate themselves into a research or development team. They can work independently in a scientific manner and plan complex projects. Students can conduct independent research and gain an overview of the specialist literature on a research project, some of which is in English. Students can gain an overview of the specialist literature on a research project. They are able to give a scientific presentation and present their own research project in the context of the current state of science.

Contents:

- Literature research
- Familiarization with theoretical methods and experimental procedures
- Discussion of problems of current research in the working group seminar
- Definition of a scientific problem
- Methods of project management
- Preparation, presentation and discussion of a project plan

Basic literature:

- Current literature on the respective research area
- Abacus communications, The language of presentations, CDROM Lehr- und Trainingsmaterial
- Alley, The Craft of Scientific Presentation, Springer
- Stickel-Wolf, Wolf, Wissenschaftliches Arbeiten und Lerntechniken, ISBN: 3-409-31826-7, Gabler Verlag
- Steinle, Bruch, Lawa, (Hrsg.), Projektmanagement: Instrument moderner Dienstleistung, 1995, ISBN 3-929368-27-7, FAZ
- Little, (Hrsg.), Management der Hochleistungsorganisation, Gabler Verlag, Wiesbaden, 1990

Recommended prior knowledge The respective advanced specialization modules of Master's degree program

Entry requirements none

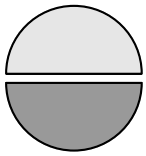
Module applicability Master Physics (Research Phase modules)

Master Thesis
(Masterarbeit)

Semester	Winter and Summer semester
Responsible	Dean of Studies
Courses (SWS)	
Type of Course	Thesis
Perfomance record	Exam performance: master thesis

Credit Points (ECTS)

30



900 h Presence Study
900 h Self Study

Competency Aims: Students can independently familiarize themselves with a research project. They are able to structure, prepare and carry out scientific projects under supervision. They gain an overview of current literature and analyze and solve complex problems. Students are able to hold critical discussions about their own and others' research results and deal constructively with questions and criticism. Students are proficient in German and English technical language. They are able to give a scientific presentation and present their own results in the context of the current state of science. Examination procedure

Contents:

- Independent work on a current scientific problem in an international research environment
- Written documentation and oral presentation of the research project and the results
- Scientific discussion of the results

Basic literature:

- Current literature on the respective scientific problem
- Day, How to write & publish a scientific paper. Cambridge University Press
- Walter Krämer, Wie schreibe ich eine Seminar- oder Examensarbeit?, 1999, ISBN: 3-593-36268-6, Gruppe: Studienratgeber, Reihe: campus concret, Band: 47.

Recommended prior knowledge

Entry requirements at least 40 CP

Module applicability Master Physics

5 Courses

Mechanics and Heat
(Mechanik und Wärme)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	7	**SWS:**	4+2
Cycle:	Winter semester		

Contents:

- Mechanics of a center of mass
- Newton's axioms
- Work, energy and potential
- Harmonic oscillator
- Systems of mass points, collisions, conservation of momentum
- Rotational motion, dynamics of rigid, extended bodies
- Reference systems, apparent forces
- The $1/r^2$ law, gravitation, Kepler's laws
- Mechanical oscillations and waves
- Real solid and liquid bodies, surface tension, friction
- Flowing liquids and gases, Bernoulli's equation
- Temperature, ideal gas, heat capacity, degrees of freedom
- Transport processes, diffusion, heat conduction
- Conversion of energy, fundamental laws, changes of state, cyclic processes, heat engines, entropy

Basic literature:

- Demtröder, Experimentalphysik 1, Mechanik und Wärme, Springer Verlag
- Feynman, Lectures on Physics, Band 1; Addison-Wesley Verlag
- Tipler, Physik, Spektrum Akademischer Verlag
- Gerthsen, Physik, Springer Verlag

Recommended prior knowledge:

Assigned modules: Experimental Physics (Bachelor Physics), Experimental Physics Part 1 (Bachelor Physics).

Responsible: Institutes of Experimental Physics

Electricity and Relativity
(Elektrizität und Relativität)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	7	**SWS:**	4+2
Cycle:	Summer semester		

Contents:

- Electrostatics, Coulomb's law, multipoles, Gauss theorem, capacitors
- Electric current, Ohm's law, Kirchhoff's rules, Stokes' theorem, conservation of charge
- Static magnetic fields, Biot-Savart law, permanent magnets, Lorentz force, stationary Maxmell equations, Hall effect
- Time-varying fields, induction, Lenz's rule, alternating current, dynamic Maxwell's equations
- Magnetic and electrical properties of matter, Maxwell's equations in matter
- Electromagnetic oscillations and the formation of electromagnetic waves, energy of the e.m. field, oscillating circuits, Hertz's dipole
- Electromagnetic waves
- Waves in a vacuum, wave equation, speed of light
- Electromagnetic waves in matter, refractive index, absorption, dispersion
- Moving reference systems, special theory of relativity, Michelson-Morley, Lorentz transformation, Doppler effect, addition of velocities

Basic literature:

- Demtröder, Experimentalphysik 2, Mechanik und Wärme, Springer Verlag
- Feynman, Lectures on Physics, Band 2; Addison-Wesley Verlag
- Tipler, Physik, Spektrum Akademischer Verlag
- Gerthsen, Physik, Springer Verlag

Recommended prior knowledge: Mechanics and Heat, Mathematical Methods of Physics

Assigned modules: Experimental Physics (Bachelor Physics), Experimental Physics Part 1 (Bachelor Physics).

Responsible: Institutes of Experimental Physics

Optics, Atomic Physics, Quantum Phenomena

(Optik, Atome, Moleküle, Quantenphänomene)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	7	**SWS:**	4+2
Cycle:	Winter semester		

Contents:

- Geometrical optics
- Complex refractive index
- Optics at interfaces
- Lenses and simple optical instruments, photometry
- Polarization, birefringence, optical activity Interference, diffraction, scattering
- Gaussian optics, resonators, lasers
- Blackbody radiation, photoelectric effect, Compton effect, wave-particle duality
- Wave function in the box potential, matter waves, Schrödinger equation, tunnel effect, hydrogen atom
- The structure of atoms, Bohr's atomic model, quantum numbers, Pauli principle, spin, Zeeman effect, fine structure, spin-orbit coupling
- Selection rules, X-ray spectra, atomic units
- Atoms with several electrons, structure of the periodic table
- Molecules: chemical bonding, molecular potential, molecular orbitals, vibration, rotation, Franck-Condon principle

Basic literature:

- Demtröder Experimentalphysik 2 und 3, Springer Verlag
- Berkeley Physikkurs
- Bergmann/Schäfer
- Haken, Wolf, Atom- und Quantenphysik, Springer Verlag

Recommended prior knowledge: Mechanics and Heat, Electricity and Relativity

Assigned modules: Experimental Physics (Bachelor Physics), Experimental Physics Part 2 (Bachelor Physics).

Responsible: Institutes of Experimental Physics

Nuclei and Particles
(Kerne und Teilchen)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	3.5	**SWS:**	2+1
Cycle:	Summer semester		

Contents:

- Terms energies in nuclei, cross section, Schrödinger equation, Heisenberg
- Radioactive decay, nuclide map, nuclear properties Particle properties
- Strong KK, binding energy, droplet model
- alpha decay incl. Gamov
- Nuclear forces, shell model
- gamma decay incl. transitions
- weak WW
- beta decay incl. Fermi theory
- Neutrons, moderation, fission
- Nuclear reactions, collective excitations, compound nucleus
- nuclear fusion
- The standard model: hadrons, leptons, bosons

Basic literature:

- Wolfgang Demtröder Experimentalphysik 4: Kern-, Teilchen- und Astrophysik, Springer Verlag
- T. Mayer-Kuckuk, Kernphysik, Teubner Studienbücher Physik
- Bergmann/Schäfer
- J.V. Kratz, K.H. Lieser, Nuclear and Radiochemistry, WileyVCH, Weinheim, 2013
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Recommended prior knowledge:

Assigned modules: Experimental Physics (Bachelor Physics), Experimental Physics Part 2 (Bachelor Physics).

Responsible: Institutes of Experimental Physics

Solid-State Physics I
(Festkörperphysik I)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	3.5	**SWS:**	2+1
Cycle:	Summer semester		

Contents:

- Many-body systems: Identical particles, Fock space, field quantization
- Open quantum systems: Density matrix, measurement process, Bell's inequality
- Information and thermodynamics: sums of states, entropy, thermodynamic equilibrium
- Semiclassical approximation: Bohr-Sommer field, tunnel effect, path integral
- Relativistic quantum mechanics: Space-time symmetries, Dirac equation
- Scattering theory

Basic literature:

- R. Gross und A. Marx, „Festkörperphysik", De Gruyter
- K. Kopitzki und P Herzog, „Einführung in die Festkörperphysik", SpringerSpektrum
- N. W. Ashcroft and N. D. Mermin, „Solid State Physics", Oldenbourg
- C. Kittel, "Introduction to Solid State Physics", Wiley

Recommended prior knowledge: Mechanics and Heat, Electricity and Relativity, Optics, Atomic Physics, Quantum Phenomena

Assigned modules: Experimental Physics (Bachelor Physics), Experimental Physics Part 2 (Bachelor Physics).

Responsible: Institute of Solid State Physics

Solid-State Physics II
(Festkörperphysik II)

Coursetype:	Lecture and Exercise class and Practical Lab	**Language:**	not specified
Credit Points: (ECTS)		**SWS:**	3+2+3
Cycle:	Winter semester		

Contents:

- Electrical transport
- Energy bands
- Dynamics and crystal electrons
- Semiconductors
- Dielectric properties

Basic literature:

- R. Gross und A. Marx, „Festkörperphysik", De Gruyter
- K. Kopitzki und P Herzog, „Einführung in die Festkörperphysik", SpringerSpektrum
- N. W. Ashcroft and N. D. Mermin, „Solid State Physics", Oldenbourg
- C. Kittel, "Introduction to Solid State Physics", Wiley

Recommended prior knowledge: Mechanics and Heat, Electricity and Relativity, Optics, Atoms, Molecules Quantum Phenomena, Solid-State Physics I

Assigned modules: Specialization Area Experimental Physics.

Responsible: Michael Oestreich, Institute of Solid State Physics

Atomic and Molecular Physics
(Atom- und Molekülphysik)

Coursetype:	Lecture and Exercise class and Practical Lab	**Language:**	not specified
Credit Points: (ECTS)		**SWS:**	3 + 1 + 2
Cycle:	Winter semester		

Contents:

- Summary H atom
- Atoms in static electric and magnetic fields
- Fine/hyperfine structures of atomic states
- Interaction with the EM radiation field
- Multi-electron systems
- Atomic spectra/spectroscopy
- Vibration and rotation of molecules
- Dissociation and ionisation of molecules
- Selected experiments in modern atomic and molecular physics

Basic literature:

- T. Mayer-Kuckuck, Atomphysik, Teubner, 1994
- B. Bransden, C. Joachain, Physics of Atoms and Molecules, Longman 1983
- H. Haken, H. Wolf, Atom- und Quantenphysik sowie Molekühlphysik und Quantenchemier, Springer
- R. Loudon, The Quantum Theory of Light, OUP, 1973
- W. Demtröder, Molekülphysik, Oldenbourg, 2003 ISBN: 3486249746

Recommended prior knowledge: Introduction to Quantum Theory, Theoretical Physics C, Mechanics and Heat, Electricity and Relativity, Optics, Atoms, Molecules Quantum Phenomena, Nuclei and Particles

Assigned modules: Specialization Area Experimental Physics.

Responsible: Christian Ospelkaus, Institute of Quantum Optics

Coherent Optics
(Kohärente Optik)

Coursetype:	Lecture and Exercise class and Practical Lab	**Language:**	not specified
Credit Points: (ECTS)		**SWS:**	3+1+3
Cycle:	Summer semester		

Contents:

- Maxwell equations and EM waves
- Wave optics, matrix optics (ABCD, Jones, Müller, scattering, transfer...)
- Diffraction theory, Fourier optics
- Resonators, modes
- Light-matter interaction (classical / semi-classical, Bloch model)
- Rate equations, laser dynamics
- Laser types, laser components, laser applications
- Mode-locked lasers
- Single-mode lasers
- Laser noise/stabilisation
- Laser interferometry
- Modulation fields and homodyne detection

Basic literature:

- Meschede, Optik, Licht und Laser, Teubner Verlag
- Menzel, Photonik, Springer
- Born/Wolf Principles of Optics, Pergamon Press
- Kneubühl/Sigrist, Laser Teubner
- Reider, Photonik, Springer
- Yariv, Hecht, Siegmann
- Original Literature

Recommended prior knowledge: Mechanics and Heat, Electricity and Relativity, Optics, Atoms, Molecules, Quantum Phenomena, Nuclei and Particles

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Assigned modules: Specialization Area Experimental Physics.

Responsible: Piet Schmidt, Ernst Maria Rasel, Institute of Quantum Optics

5.2 Courses of Institute of Theoretical Physics

Advanced Quantum Theory

(Fortgeschrittene Quantentheorie)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	5	**SWS:**	3+1
Cycle:	Summer semester		

Contents:

- Many-body systems: Identical particles, Fock space, field quantization
- Open quantum systems: Density matrix, measurement process, Bell's inequality
- Information and thermodynamics: sums of states, entropy, thermodynamic equilibrium
- Semiclassical approximation: Bohr-Sommer field, tunnel effect, path integral
- Relativistic quantum mechanics: Space-time symmetries, Dirac equation
- Scattering theory

Basic literature:

- W. Greiner and J. Reinhardt, Theoretische Physik 7 (Quantenelektrodynamik) und 7a (Feldquantisierung), Springer
- R.H. Landau, Quantum Mechanics II, A Second Course in Quantum Theory, Wiley-VCH
- A. Peres, Quantum Theory: Concepts and Methods, Springer
- M.E. Peskin & D.V. Schroeder, An Introduction to Quantum Field Theory, Westview Press
- J.J. Sakurai, Modern Quantum Mechanics, Addison Wesley
- F. Schwabl, Quantenmechanik für Fortgeschrittene, Springer

Recommended prior knowledge: Mathematics for Physicists, Introduction to Quantum Theory

Assigned modules: Modern Aspects of Physics (Bachelor Physics), Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Theoretical Physics

Seminar: Advanced Quantum Theory

(Seminar zu Fortgeschrittene Quantentheorie)

Coursetype:	Seminar	**Language:**	not specified
Credit Points: (ECTS)	3	**SWS:**	2
Cycle:	Summer semester		

Contents:

- By arrangement with the lecturers.
- The seminar (Master Physics) must be taken in conjunction with the lecture Advanced Quantum Theory.

Basic literature:

- W. Greiner and J. Reinhardt, Theoretische Physik 7 (Quantenelektrodynamik) und 7a (Feldquantisierung), Springer
- R.H. Landau, Quantum Mechanics II, A Second Course in Quantum Theory, , Wiley-VCH
- A. Peres, Quantum Theory: Concepts and Methods, Springer
- M.E. Peskin & D.V. Schroeder, An Introduction to Quantum Field Theory, Westview Press
- J.J. Sakurai, Modern Quantum Mechanics, Addison Wesley
- F. Schwabl, Quantenmechanik für Fortgeschrittene, Springer

Recommended prior knowledge: Mathematics for Physicists, Introduction to Quantum Theory

Assigned modules: Modern Aspects of Physics (Bachelor Physics), Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Theoretical Physics

Theoretical Quantum Optics and Quantum Dynamics
(Theoretische Quantenoptik und Quantendynamik)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	5	**SWS:**	3+1
Cycle:	Winter or Summer semester		

Contents:

- Field quantization, Casimir effect
- Fock states, thermal states, coherent states
- Phase space distributions (P-function, Husimi function, Wigner function)
- Non-classical light
- Atom-field interaction (perturbation theory, Rabi oscillations, Jaynes-Cummings model, Floquet theory, fluorescence, spontaneous emission)
- Stochastic methods (master equation, Fokker-Planck equation), parametric amplification
- Atomic optics, cavity QED, strong laser fields

Basic literature:

- C. Gerry und P. Knight, Introductory Quantum Optics, Cambridge University Press
- S. Barnett, Methods in theoretical quantum optics, Clarendon Press
- D. Walls und G. Milburn, Quantum Optics, Springer
- H.-J. Kull, Laserphysik, Oldenbourg
- W. Schleich, Quantum optics in phase space, Wiley-VCH
- C. Joachain, N. Kylstra und R. Potvliege, Atoms in intense laser fields, Cambridge University Press
- R. Loudon, The Quantum Theory of Light, Oxford Science Publications

Recommended prior knowledge: Theoretical Electrodynamics, Introduction to Quantum Theory

Assigned modules: Modern Aspects of Physics (Bachelor Physics), Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Theoretical Physics

Computational Physics
(Computerphysik)

Coursetype:	Lecture and Exercise class	**Language:**	german
Credit Points: (ECTS)	6	**SWS:**	2+2
Cycle:	Summer semester		

Contents:

- Basic numerical methods (differentiation, integration, interpolation, solution of a non-linear equation, systems of linear algebraic equations, Monte Carlo methods)
- Numerical solution of common problems in physics (differential equations, eigenvalue problems, optimization, integration and sums of many variables)
- Applications from mechanics, electrodynamics, thermodynamics and quantum mechanics
- Data analysis (statistical analysis, adjustment calculation, extrapolation, spectral analysis)
- Visualization (graphical representation of data)
- Introduction to the simulation of physical systems (dynamic systems, simple molecular dynamics)

Basic literature:

- Wolfgang Kinzel und Georg Reents, „Physik per Computer“, Spektrum Akademischer Verlag
- S.E. Koonin and D.C. Meredith, „Computational Physics“, Addison-Wesley
- W.H. Press, S.A. Teukolsky, W.T. Vetterling, B.P. Flannery, „Numerical Recipes in C++“, Cambridge University Press
- J.M. Thijssen, „Computational Physics“, Cambridge University Press
- Tao Pang, „An Introduction to Computational Physics“, Cambridge University Press
- R.H. Landau, M.J. Paez, and C.C. Bordeianu, Computational Physics, Wiley-VCH, 2007
- O. Natt, Physik mit Python, 2. Auflage, Springer, 2022. Webseite: `https://pyph.de`
- R.H. Landau, M.J. Páez, and C.C. Bordeianu, Computational Physics – Problem Solving with Python, Wiley-VCH, 2015.
- Mark Newman, Computational Physics, 2013.
- A. Gezerlis, Numerical Methods in Physics with Python, Cambridge University Press, 2020. Website: `https://numphyspy.org/`

Recommended prior knowledge: Experience with computers and basic programming., Analysis I and II, Theoretical Electrodynamics, Analytical Mechanics and Special Theory of Relativity, Introduction to Quantum Theory

Assigned modules: Modern Aspects of Physics (Bachelor Physics), Selected Topics in Modern Physics (Master Physics).

Responsible: Eric Jeckelmann, Institute of Theoretical Physics

Theoretical Solid-State Physics
(Theoretische Festkörperphysik)

Coursetype:	Lecture and Exercise class	**Language:**	english
Credit Points: (ECTS)	5	**SWS:**	3+1

Cycle: Winter or Summer semester (alternating with Statistical Field Theory)

Contents:

- Transport phenomena
- Electronic correlations
- low-dimensional systems
- magnetism
- superconductivity
- Disorder and impurities
- Mesoscopic systems

Basic literature: P.G. deGennes, Superconductivity of Metals and Alloys, Perseus Publishing, 1999, Westview Press C. Kittel: Quantum Theory of Solids, Wiley W. Nolting: Quantentheorie des Magnetismus, Band I + II, Teubner Verlag J.M. Ziman, Electrons and Phonons, Oxford University Press, 2000 H. Bruus and K. Flensberg, Many Body Quantum Theory in Condensed Matter Physics (Oxford University Press, 2004) Jenö Sólyom, Fundamentals of Physics of Solids, * Volume 1 - Structure and Dynamics (Springer, Berlin, 2007), * Volume 2 – Electronic Properties (Springer, Berlin, 2009), * Volume 3 - Normal, Broken-Symmetry, and Correlated Systems (Springer, Berlin, 2010)

Recommended prior knowledge: Advanced Quantum Theory, Quantum Field Theory

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Eric Jeckelmann, Institute of Theoretical Physics

Statistical Field Theory
(Statistische Feldtheorie)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	5	**SWS:**	3+1
Cycle:	Winter or Summer semester (alternating with Theoretical Solid-State Physics		

Contents:

- State sum as path integral
- critical phenomena
- condensed matter in two dimensions
- quantum spin chains
- non-equilibrium phenomena

Basic literature: C. Kittel: Quantum Theory of Solids, Wiley

Recommended prior knowledge: Advanced Quantum Theory, Quantum Field Theory

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Theoretical Physics

Seminar Condensed Matter Theory

(Seminar zur Theorie der kondensierten Materie)

Coursetype:	Seminar	**Language:**	german, englisch
Credit Points: (ECTS)	3	**SWS:**	2
Cycle:	Winter and Summer semester		

Contents:

- By arrangement with the lecturers.
- The seminar (Master Physics) must be taken in conjunction with the lecture Theoretical Solid State Physics or Statistical Field Theory.

Basic literature: W. Nolting: Quantentheorie des Magnetismus, Band I + II, Teubner Verlag

Recommended prior knowledge: Advanced Quantum Theory, Quantum Field Theory

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Eric Jeckelmann, Holger Frahm, Institute of Theoretical Physics

Advanced Computational Physics

(Fortgeschrittene Computerphysik)

Coursetype:	Lecture and Exercise class	**Language:**	english
Credit Points: (ECTS)	8	**SWS:**	4+2
Cycle:	Winter or Summer semester		

Contents:

- Exact diagonalization
- Monte Carlo simulations
- numerical renormalization group
- density functional theory
- molecular dynamics
- quantum dynamics
- Artificial intelligence and machine learning
- Quantum computing

Basic literature: J.M. Ziman, Electrons and Phonons, Oxford University Press, 2000

Recommended prior knowledge: Introduction to Quantum Theory, Statistical Physics, Computational Physics

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Assigned modules: Selected Topics in Modern Physics (Master Physics), Modern Aspects of Physics (Bachelor Physics).

Responsible: Eric Jeckelmann, Institute of Theoretical Physics

Current problems in Condensed Matter Theory

(Aktuelle Probleme der Theorie der kondensierten Materie)

Coursetype:	Lecture and Exercise class	**Language:**	german, english
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Winter or Summer semester		

Contents: Current topic of the lecturer's choice, e.g.

- Theory of magnetism
- Theory of superconductivity
- Theory of the quantum Hall effect
- Theory of strongly correlated electrons
- Integrable quantum systems
- Systems outside the equilibrium

Basic literature: H. Bruus and K. Flensberg, Many Body Quantum Theory in Condensed Matter Physics (Oxford University Press, 2004)

Recommended prior knowledge: Advanced Quantum Theory, Advanced Solid-State Physics

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Eric Jeckelmann, Holger Frahm, Institute of Theoretical Physics

Theory of Fundamental Interactions
(Theorie der fundamentalen Wechselwirkungen)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	5	**SWS:**	3+1
Cycle:	Winter or Summer semester		

Contents:

- The standard model of particle physics
- A heuristic representation of the theory and applications
- Lagrangian densities in field theory
- Gauge invariance, non-Abelian gauge theory
- Dirac fermions
- The electroweak theory
- Masses and the Higgs mechanism
- QCD, quark confinement, jets, glueballs
- Flavor physics, SU(3), heavy quarks
- cross sections, decay widths, lifetimes
- Tests of the standard model
- Further topics

Basic literature: Jenö Sólyom, Fundamentals of Physics of Solids, * Volume 1 - Structure and Dynamics (Springer, Berlin, 2007), * Volume 2 – Electronic Properties (Springer, Berlin, 2009), * Volume 3 - Normal, Broken-Symmetry, and Correlated Systems (Springer, Berlin, 2010)

Recommended prior knowledge: Advanced Quantum Theory

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Theoretical Physics

Seminar: Theory of Fundamental Interactions

(Seminar zu Theorie der fundamentalen Wechselwirkungen)

Coursetype:	Seminar	**Language:**	not specified
Credit Points: (ECTS)	3	**SWS:**	2
Cycle:	Winter or Summer semester		

Contents:

- By arrangement with the lecturers.
- The seminar (Master Physics) must be taken in conjunction with the lecture Theory of Fundamental Interactions

Basic literature:

- Peskin, Schröder, Quantum Field Theory, Westview Press
- Wess, Bagger, Supersymmetry and Supergravity, Princeton University Press
- Galperin, Ivanov, Ogievetsky, Sokatchev, Harmonic Superspace, Cambridge University Press
- Green, Schwarz, Witten, Superstring Theory, Cambridge University Press
- Aktuelle Forschungspublikationen

Recommended prior knowledge: Advanced Quantum Theory

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Theoretical Physics

Advamced topics in classical physics

(Ergänzungen zur klassischen Physik)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	5	**SWS:**	3+1
Cycle:	Winter or Summer semester		

Contents: Selected areas of classical physics of the lecturer's choice, e.g.

- Theory of relativity: Minkowski space, Lorentz group, representations of the Lorentz group, relativistic particles, coupling of the electromagnetic field, Liénard-Wiechert potentials, Schwarzschild metrics, tests of general relativity in the solar system, Thirring-Lense effect, light deflection, Einstein-Hilbert effect, covariant conservation of energy-momentum, gravitational waves: Generation and detection, cosmology
- gauge theories: Parallel shift, covariant derivative, field strengths, holonomy group, Bianchi identities, principle of action, Noether identities, algebraic Poincaré lemma, standard model of fundamental interactions, monopoles, spontaneous symmetry breaking, BRS symmetry, anomalies
- Integrable and chaotic motion: Hamiltonian equations of motion, canonical transformations, Poincaré's integral invariants, action-angle variable, perturbation theory, Kolmogorov-Arnol'd-Moser theorem, Poincaré's recurrence mapping, Birkhoff's fixed point theorem, self-similar Hamiltonian flow

Basic literature:

- B. F. Schutz, A first course in general relativity, Cambridge University Press
- W. Rindler, Relativity, Oxford University Press
- V. Mukhanov, Physical Foundations of Cosmology, Cambridge University Press
- L. O'Raifeartaigh, Group Structure of Gauge Theories, Cambridge University Press
- V. Arnol'd, Mathematical Methods of Classical Mechanics, Springer
- A. J. Lichtenberg and M. A. Liebermann, Regular and Stochastic Motion, Springer
- J. Moser, Stable and Random Motion in Dynamical Systems, Princeton University Press

Recommended prior knowledge: Analytical Mechanics and Special Theory of Relativity

Assigned modules: Modern Aspects of Physics (Bachelor Physics), Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Theoretical Physics

Introduction to Particle Physics
(Einführung in die Teilchenphysik)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	5	**SWS:**	3+1
Cycle:	Summer semester		

Contents:

- Fundamental particles and their interactions
- Symmetries and conservation laws
- Hadrons, quarks, partons
- QCD
- Electromagnetic and weak interactions and their unification
- Standard model of particle physics
- Accelerators and detectors
- Neutrino physics
- Open questions and future projects in particle physics

Basic literature:

- F. Halzen und A.D. Martin, Quarks and Leptons, Wiley
- D.H. Perkins, Introduction to High Energy Physics, Cambridge University Press
- B.R. Martin and G. Shaw, Particle Physics, Wiley
- E. Lohrmann, Hochenergiephysik, Teubner Verlag
- C. Berger, Elementarteilchenphysik, Springer

Recommended prior knowledge:

Assigned modules: Modern Aspects of Physics (Bachelor Physics), Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Theoretical Physics

Introduction to the general Theory of Relativity
(Einführung in die Allgemeine Relativitätstheorie)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	8	**SWS:**	4+2
Cycle:	Summer semester		

Contents:

- Understanding of the basic concepts and acquisition of the mathematical methods of general relativity
- Application of the formalism to simple physical problems of gravitational physics on Earth, the solar system, astrophysics of compact objects and cosmology
- Discussion of relevant solutions; both linearized and exact Einstein equations - including in particular gravitational waves and their generation/detection, and black holes and their detection.

Basic literature:

- Norbert Straumann: General Relativity (second edition). Springer Verlag.
- Michael Ruhrländer: Allgemeine Relativitätstheorie Schritt für Schritt: Eine Einführung mit Details, Beispielen und Aufgaben, Springer Spektrum
- Tosten Fließbach: Allgemeine Relatitvitätstheorie. Springer Spektrum

Recommended prior knowledge: Theoretical Electrodynamics, Analytical Mechanics and Special Theory of Relativity

Assigned modules: Modern Aspects of Physics (Bachelor Physics), Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Theoretical Physics

Fundamentals of Semiconductor Physics

(Grundlagen der Halbleiterphysik)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Winter semester		

Contents:

- Ribbon theory
- Intrinsic and impurity conduction
- Defects in semiconductors
- p-n junctions
- Recombination processes
- Charge carrier transport
- Heterojunctions
- Metal-semiconductor contacts
- Semiconductor devices (diodes, transistors, photodiodes)

Basic literature:

- P.Y. Yu, M. Cardona, Fundamentals of Semiconductors, Springer
- S.M. Sze, Semiconductor devices, Physics and Technology, Wiley, New York

Recommended prior knowledge: Introduction to Solid-State Physics

Assigned modules: Modern Aspects of Physics (Bachelor Physics), Selected Topics in Nanoelectronics, Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Solid State Physics

Semiconductor Physics in Python

(Halbleiterphysik mit Python)

Coursetype: Lecture and Exercise class
Language: not specified
Credit Points: (ECTS) 4
SWS: 2+1

Cycle: Winter and Summer semester

Contents: Competences covered in the lecture/ course: Physics:

- Fundamental principles of semiconductor optics and transport.
- Microscopic working principles of semiconductor devices like light emitting diodes, laser diodes, and photodetectors.

Computer skills:

- Fundamental (and advanced) subjects of programming with python.
- Data science: Working with jupyter notebooks.
- Web based software exchange (version and source control).

Basic literature:

- Rosencher, Vinter, „Optoelectroncis", Cambridge
- Klein, „Numerisches Python ; Arbeiten mit NumPy, Matplotlib und Pandas", Hauser Verlag

Recommended prior knowledge: Introduction to Solid-State Physics (Basics are required:. I.e., crystal structure and phonons, carrier statistics, energy bands, optical processes, basic quantum mechanical concepts of solid-state physics.)

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Solid State Physics

Characterization of Semiconductors and Solar Cells

(Charakterisierung von Halbleitern und Solarzellen)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Summer semester		

Contents: The first part of this lecture deals with the basics of semiconductor physics in connection with characterization methods for semiconductor materials. One focus is on methods for characterizing defects in semiconductors and their effect on the electrical properties of the semiconductor. In the second part of the lecture, methods for the characterization of solar cells are presented, covering both integral methods such as spectral responsivity and spatially resolved methods such as camera-based photoluminescence.

Basic literature: will be specified by the lecturer

Recommended prior knowledge: Introduction to Solid-State Physics

Assigned modules: Modern Aspects of Physics (Bachelor Physics), Selected Topics in Nanoelectronics, Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Solid State Physics

Quantum Devices
(Quantenstrukturbauelemente)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	5	**SWS:**	3+1
Cycle:	Summer semester		

Contents:

- Quantum effects in semiconductor structures
- Physics of two-dimensional electron gases
- Quantum wires
- Quantum dots
- Coherence and interaction effects
- Single electron tunnel transistor
- Quantum computing

Basic literature:

- C. Weisbuch, B. Vinter, Quantum Semiconductor Structures, Academic Pr Inc
- S.M. Sze, Semiconductor Devices: Physics and Technology, Wiley
- M.J. Kelly, Low-Dimensional Semiconductors: Materials, Physics, Technology, Devices, Oxford University Press

Recommended prior knowledge: Introduction to Solid-State Physics, Advanced Solid State Physics

Assigned modules: Selected Topics in Nanoelectronics, Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Solid State Physics

Physics of Solar Cells
(Physik der Solarzelle)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	5	**SWS:**	2+2
Cycle:	Summer semester		

Contents:

- Semiconductor basics
- Optical properties of semiconductors
- Transport of electrons and holes
- Mechanisms of charge carrier recombination
- Manufacturing processes for solar cells
- Characterization methods for solar cells
- Possibilities and limits of efficiency improvement

Basic literature:

- P. Würfel, „Physik der Solarzellen“ (Spektrum Akademischer Verlag, 2000).
- A. Goetzberger, B. Voß, J. Knobloch, „Sonnenenergie: Photovoltaik“ (Teubner 1994).

Recommended prior knowledge: Solid-State Physics I

Assigned modules: Modern Aspects of Physics (Bachelor Physics), Selected Topics in Modern Physics (Master Physics), Selected Topics in Nanoelectronics, Elective Area Master Nanotechnology.

Responsible: Head of Institute of Solid State Physics

Seminar: Solid State Quantum Technology, Quantum Information, and Single Photon Emitter

Coursetype:	Seminar	**Language:**	not specified
Credit Points: (ECTS)	3	**SWS:**	2
Cycle:	Winter and Summer semester		

Contents:

- Quantum technology and quantum information Solid state physics and optics
- Experimental concepts of quantum entanglement and quantum sensors
- Quantum entanglement in future semiconductor devices
- Challenges of quantum imaging
- Quantum dots for single-photon cryptography

Basic literature: will be specified by the lecturer

Recommended prior knowledge: Solid-State Physics I, Solid-State Physics II

Assigned modules: Selected Topics in Modern Physics (Master Physics), Seminar (Master Physik).

Responsible: Head of Institute of Solid State Physics

Energy Storage Materials and Devices

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	5	**SWS:**	3 + 2
Cycle:	Winter semester		

Contents:

- Introduction (energy crisis, different types of energy storage devices)
- Review of Introduction to Nanophysics (basic knowledge about materials characterization an device fabrication)
- Pumped hydro, thermal, gravity, solar energy
- Batteries and capacitors
- Introduction to electrochemical energy storage devices
- Lithium ion battery
- Lithium sulphur battery
- Lithium air battery
- Other emerging technologies
- Super-capacitor
- Outlook (micro-batteries, on-chip integration, etc)
- For practical training, the students are encouraged to visit the laboratory courses in close relation to the topics covered by the lecture

Basic literature: Important literatures will be announced at the beginning of the lecture

Recommended prior knowledge: Introduction to Nanophysics

Assigned modules: Selected Topics in Modern Physics (Master Physics), Selected Topics in Nanoelectronics.

Responsible: Head of Institute of Solid State Physics

Physics of 2D materials
(Physik der 2D Materialien)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	4	**SWS:**	2+1
Cycle:	Winter semester		

Contents:

- Overview of the different 2D materials
- Fabrication methods and nanofabrication of 2D materials
- Differences in the electronic, optical and mechanical properties of single layers, multilayers and heterostructures of selected 2D materials

Basic literature:

- P. Avouris, T. F. Heinz, and T. Low, 2D Materials: Properties and Devices, Cambridge University Press
- R. Gross and A. Marx, Festkörperphysik, De Gruyter Oldenbourg

Recommended prior knowledge: Quantum Devices

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Solid State Physics

Introduction to Nanophysics

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	10	**SWS:**	4+2
Cycle:	Summer semester		

Contents:

- Characterization at the nanoscale
- Fabrication at the nanoscale
- Energy storage with nano materials
- Semiconductors nanomaterials and devices
- Optics at the nanoscale: Semiconductor nano- and quantum photonics
- For practical training, the students are encouraged to visit three laboratory courses in close relation to the topics covered by the lecture

Basic literature: will be specified by the lecturer

Recommended prior knowledge:

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Solid State Physics

Lab course: Growth and Characterization of Nanostructures

(Laborpraktikum Growth and Characterization of Nanostructures)

Coursetype:	Practical Laboratory Course	**Language:**	not specified
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Winter and Summer semester		

Contents:

- Introduction in molecular beam epitaxy (MBE): Facility and growth process
- Wafer material handling prior to processing
- Substrate preparation steps and in-situ analysis
- MBE growth training
- Ex-situ layer thickness characterization by means of surface analysis techniques .

Basic literature: will be specified by the lecturer

Recommended prior knowledge:

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Solid State Physics

Lab course: Characterization of Nanostructures

(Laborpraktikum Optical Characterization of Nanostructures)

Coursetype:	Practical Laboratory Course	**Language:**	not specified
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Winter and Summer semester		

Contents:

- Basic sample preparation and optical setup alignment
- Photoluminescence characterization of Semiconductor quantum dots and bulk material
- Introduction in semiconductor quantum dot statistics characterization

Basic literature: will be specified by the lecturer

Recommended prior knowledge: Course: Introduction to Nanophysics

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Solid State Physics

Lab course: Nanomaterials in Energy Storage Devices

(Laborpraktikum Nanomaterials in Energy Storage Devices)

Coursetype:	Practical Laboratory Course	**Language:**	not specified
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Winter and Summer semester		

Contents:

- Preparation of a slurry consisting of binder, additives and active material.
- Making electrodes.
- Using these electrodes and assembling batteries.
- Electrochemical tests of the batteries (CV, long-term charge / discharge, EIS).

Basic literature: will be specified by the lecturer

Recommended prior knowledge:

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Solid State Physics

5.4 Courses of Institute of Quantum Optics

Nonlinear Optics
(Nichtlineare Optik)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	5	**SWS:**	3+1
Cycle:	Summer semester		

Contents:

- Nonlinear optical susceptibility
- Crystal optics, tensor optics
- Wave equation with non-linear source terms
- Frequency doubling, sum and difference frequency generation
- Optical parametric amplifier, oscillator
- Phase matching schemes, quasi-phase matching
- Electro-optical effect
- Electro-acoustic modulator
- Frequency tripling, Kerr effect, self-phase modulation, self-focusing
- Raman, Brillouin scattering, four-wave mixing
- Non-linear propagation, solitons

Basic literature:

- Agrawal, Nonlinear Fiber optics, Academic Press
- Boyd, Nonlinear Optics, Academic Press
- Shen, Nonlinear Optics, Wiley-Interscience
- Dmitriev, Handbook of nonlinear crystals, Springer
- Originalliteratur

Recommended prior knowledge: Atomic and molecular physics

Assigned modules: Selected Topics in Modern Physics (Master Physics), Selected Topics in Photonics.

Responsible: Head of Institute of Quantum Optics

Advanced Nonlinear Optics

Coursetype: Lecture and Exercise class
Language: english
Credit Points: (ECTS) 4
SWS: 2

Cycle: Winter semester

Contents:

- Overview of light-atom interactions
- The photoelectric effect and beyond
- Overview of perturbative nonlinear optics
- The breakdown of the perturbative picture
- Above-treshold ionisation
- Multi-photon absorption vs. Electron tunneling
- Atoms interacting with high-energy photons
- Light-driven electronics in matter
- Photo-driven electronic-nucleus interactions in nuclear transitions

Basic literature:

- Boyd, Nonlinear Optics, Academic Press
- J. C. Diels, W. Rudolph: Ultrashort Laser Pulse Phenomena 2 Ed. (Elsevier, 2006)
- Thomas Brabec „Strong Field Laser Physics“, Springer Series in optical sciences (2008)
- Published research papers will be suggested during the course

Recommended prior knowledge: Basic knowledge of optics, laser physics, atomic physics., Nonlinear Optics

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Quantum Optics

Photonics
(Photonik)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	4	**SWS:**	2+1
Cycle:	Winter semester		

Contents:

- Waves in matter
- Dielectric waveguides (planar, glass fiber), integrated waveguides
- Photonic crystals
- Waveguides - Modes
- Nonlinear fiber optics
- Fiber optic components (circulators, AWG, fiber Bragg gratings, modulators)
- Fiber lasers
- Laser diodes, photodetectors
- Optical communication technology (RZ, NRZ, WDM/TDM)
- Networks

Basic literature:

- Reider, Photonik, Springer
- Menzel, Photonik, Springer
- Agrawal, Nonlinear Fiber optics, Academic Press
- Originalliteratur

Recommended prior knowledge: Coherent Optics, Nonlinear Optics

Assigned modules: Selected Topics in Modern Physics (Master Physics), Selected Topics in Photonics.

Responsible: Head of Institute of Quantum Optics

Seminar: Photonics

(Seminar zu Photonik)

Coursetype:	Seminar	**Language:**	not specified
Credit Points: (ECTS)	3	**SWS:**	2
Cycle:	Winter semester		

Contents:

- By arrangement with the lecturers.
- The seminar (Master Physics) must be taken in conjunction with the lecture Photonics.

Basic literature:

- Reider, Photonik, Springer
- Menzel, Photonik, Springer
- Agrawal, Nonlinear Fiber optics, Academic Press
- Originalliteratur

Recommended prior knowledge: Coherent Optics, Nonlinear Optics

Assigned modules: Selected Topics in Modern Physics (Master Physics), Selected Topics in Photonics, Seminar (Master Physics).

Responsible: Head of Institute of Quantum Optics

Atom Optics
(Atomoptik)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	4	**SWS:**	2+1
Cycle:	Summer semester		

Contents:

- Atom-light interaction
- Radiation pressure forces
- Atom and ion traps
- Cooling by evaporation
- Bose-Einstein condensation
- Ultracold Fermi gases
- Experiments with ultracold and degenerate quantum gases
- Atoms in optical periodic lattices
- Atomic interferometry and frequency standards

Basic literature:

- B. Bransden, C. Joachain, Physics of Atoms and Molecules, Longman 1983
- R. Loudon, The Quantum Theory of Light, OUP, 1973
- Aktuelle Publikationen

Recommended prior knowledge: Atomic and Molecular Physics, Quantum Optics

Assigned modules: Selected Topics in Modern Physics (Master Physics), Selected Topics in Photonics.

Responsible: Head of Institute of Quantum Optics

Solid-State Lasers
(Festkörperlaser)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Summer semester		

Contents:

- Solid-state laser media
- Optical resonators
- Operating regimes of lasers
- Diode-pumped solid-state lasers
- Types of construction: Fiber, rod, disk
- Tunable lasers
- Single-frequency lasers
- Ultra-short pulse lasers
- Frequency conversion

Basic literature:

- W. Koechner: Solid-State Laser Engineering
- A.E. Siegman: Lasers
- O. Svelto: Principles of Lasers

Recommended prior knowledge: Coherent Optics, Nonlinear Optics

Assigned modules: Selected Topics in Modern Physics (Master Physics), Selected Topics in Photonics.

Responsible: Head of Institute of Quantum Optics

Optical Coatings
(Optische Schichten)

Coursetype:	Lecture and Exercise class	**Language:**	english
Credit Points: (ECTS)	4-5	**SWS:**	2 + 1
Cycle:	Winter semester		

Contents:

- Significance, functional principle and application areas of optical coatings, current quality level of coating systems for laser technology)
- Theoretical basics (collection of known formulas and phenomena, calculation of coating systems)
- Production of optical components (substrates, coating materials, coating processes, control of coating processes)
- Characterization of optics (measurements of transmission behavior: losses: total scattering, optical absorption, damage thresholds of optical laser components, non-optical properties)

The following modalities of the course are possible to acquire either 4 or 5 CP:

- Course 1 »Theory and practice of optical coatings«, 5 CP For physics major (both BA and MA elective modules), to be fulfilled for 5 CP: Lecture (identical for all courses) Either SL and PL (counts as SL), or SL and laboratory (4 +12 hours practical course at the LZH, limited number of places, only admission after successful pre-test (the reduced written exam)) The entry for this course would be an SL and 5 points
- Course 2 »Optical Layers«, 4 CP For physics studies (both BA and MA elective modules), to be fulfilled for 4 CP: Lecture (identical for all courses) SL or PL (equivalent to an SL) The entry for this course would be an SL and 4 points

Basic literature:

- Wird in der Vorlesung bekannt gegeben, zur Einführung in das Thema:
- Macleod, H.A.: Thin Film Optical Filters, Fourth Edition, CRC Press 2010

Recommended prior knowledge: Course: Coherent Optics or Nonlinear Optics

Assigned modules: Selected Topics in Modern Physics (Master Physics), Modern Aspects of Physics (Bachelor Physics).

Responsible: Head of Institute of Quantum Optics

Introduction to Biophysics
(Einführung in die Biophysik)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	3	**SWS:**	2
Cycle:	Winter semester		

Contents:

- What is life? - Units, time scales, organisms
- The cell and its biology
- Central molecules of life DNA, RNA and proteins
- Crystal structure analysis to understand the central molecules of life
- Physical principles of crystal structure analysis
- "Biophysical traffic: membranes and channels
- How do you measure "biophysical traffic"?
- Cell forces and cell movement
- Experimental techniques for analyzing cell movement and contraction
- How nanotechnology complements our understanding of biology
- How quantum physics complements our understanding of biology

The lecture introduces basic biophysical and biological concepts. The focus is on a detailed presentation of cell biology, the central molecules of life and the physical principles of their interaction. As an example, the structure of mammalian cells is analyzed and cellular processes such as replication, transcription and translation are discussed. Furthermore, experimental techniques will be discussed that have been used historically and are still used today to obtain information about the central molecules of life, cellular homeostasis, cell movement, or the development of forces in a cell. At the end of the course, new fields of research, such as nanotechnology or quantum physics, will be integrated into the context of biophysics.

Basic literature:

- Molecular Biology of the Cell (Garland Science)
- Biophysics: An Introduction (Springer)
- Campbell Biology
- Originalliteratur

Recommended prior knowledge: Experimental Physics

Assigned modules: Selected Topics in Modern Physics (Master Physics), Modern Aspects of Physics (Bachelor Physics).

Responsible: : Alexander Heisterkamp, Stefan Kalies;

Laser Medicine and Biomedical Optics
(Lasermedizin und Biomedizinischen Optik)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	4	**SWS:**	2
Cycle:	Winter semester		

Contents:

- Laser systems for use in medicine and biology
- Beam delivery systems and optical medical devices
- Optical properties of tissue
- Thermal properties of tissue
- Photochemical interaction
- Vaporization/coagulation
- Photoablation, optoacoustics
- Photodisruption, nonlinear optics
- Applications in ophthalmology, refractive surgery
- Laser-based diagnostics, optical biopsy
- Optical coherence tomography, theragnostics
- Clinical application examples
- Students are introduced to the basics of laser-tissue interaction and learn how to apply these to clinically relevant application examples. In tutorials and in the block seminar (Master Physics) (at the end of the semester), current original articles are compiled and discussed.
- At the end of the course there will be an excursion to the research laboratories of the LZH and the Rowiak company.

Basic literature:

- Eichler, Seiler: Lasertechnik in der Medizin. Springer-Verlag
- Berlien: Applied Laser Medicine
- Bille, Schlegel: Medizinische Physik. Bd. 2: Medizinische Strahlphysik, Springer
- Welch, van Gemert: Optical-Thermal Response of Laser-Irradiated Tissue. Plenum Press
- Originalliteratur

Recommended prior knowledge: Coherent Optics, Optics, Atoms and Molecules, Laser Physics

Assigned modules: Selected Topics in Modern Physics (Master Physics), Modern Aspects of Physics (Bachelor Physics).

Responsible: Alexander Heisterkamp, Laser Medicine

Biophotonics - imaging and manipulation of biological cells

(Biophotonik - Bildgebung und Manipulation von biologischen Zellen)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	4	**SWS:**	2
Cycle:	Summer semester		

Contents:

- Introduction to biophotonics
- Tissue optics
- Basics of microscopy
- Laser scanning microscopy
- Laser-based nanosurgery
- Light sheet microscopy
- Superresolution / molecular microscopy
- Optogenetics and fusion proteins
- Tomography and optoacoustic microscopy
- Optical markers and plasmonics
- Optical chips, sensors and optofluidics
- Optical tweezers

The lecture provides insights into biophotonics, a field of research between biology and physics. Microscopic procedures, three-dimensional imaging, the manipulation of cells and biological tissues with the aid of laser-based systems are explained in more detail. Students learn basic optical aspects and the interaction of light with tissues and cells. Modern and current laser-based microscopy techniques are presented based on current publications. Furthermore, optical techniques for cell manipulation are explained, such as switching cell activity on and off, measuring very small forces in living cells, cutting and ablating subcellular structures and future applications in regenerative medicine and more generally in biotechnology are discussed. The lecture can enable students to later independently identify suitable biophotonic tools to answer relevant biological questions.

Basic literature:

- Spector, D.; Goldman, R.: Basic Methods in Microscopy 2006;
- Atala, Lanza, Thomsom, Nerem: Principles of Regenerative Medicine, Academic Press
- Handbook of Biological Confocal Microscopy, Pawley, Springer.

Recommended prior knowledge: Coherent Optics, Optics, Atoms and Molecules, Laser Physics

Assigned modules: Selected Topics in Modern Physics (Master Physics), Modern Aspects of Physics (Bachelor Physics).

Responsible: Alexander Heisterkamp

Physics of Life

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Summer semester		

Contents: The lecture is aimed at all students who are interested in the interface between physics, biology and medicine. The classical disciplines (physics, chemistry) are increasingly being combined with the life sciences through interdisciplinary research. This makes it necessary to think outside the box of the individual disciplines. This special lecture offers an insight into the physics of living matter and presents existing and future interdisciplinary research goals.

Basic literature: will be specified by the lecturer

Recommended prior knowledge: Experimental Physics

Assigned modules: Selected Topics in Modern Physics (Master Physics), Modern Aspects of Physics (Bachelor Physics).

Responsible: Head of Institute of Quantum Optics

Ultrashort Laser Pulses

(Ultrakurze Laserpulse)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Summer semester		

Contents: not specified

Basic literature:

- J.C. Diels, W. Rudolph: Ultrashort Laser Pulse Phenomena, 2 Ed. (Elsevier, 2006)
- A.M. Weiner: Ultrafast Optics (Wiley, 2009)
- G.P. Agrawal: Nonlinear Fiber Optics 5 rd Ed. (Academic, 2013)
- Zenghu Chang, Fundamentals of Attosecond Optics, (CRC Press, 2016)

Recommended prior knowledge: Basic knowledge in Optics, Laser Physics and Atomic Physics

Assigned modules: Modern Aspects of Physics (Bachelor Physics).

Responsible: Head of Institute of Quantum Optics

Fundamentals of Optical Fibers

(Grundlagen optischer Fasern)

Coursetype:	Lecture and Exercise class	**Language:**	german
Credit Points: (ECTS)	4	**SWS:**	2 + 1
Cycle:	Summer semester		

Contents: Today, optical fibers are among the key components of modern photonics. It is impossible to imagine many areas of our everyday lives without them: in complex medical applications, optical fibers are used in endoscopy, for example. In laser material processing, optical fibers are also established technologies in beam guidance or as beam sources in modern industrial production. More and more concepts based on optical fibers are also being developed in sensor technology. Today, however, the term optical fiber is mainly associated with modern optical data transmission via fiber optic cables and their enormous capacity, which spans the entire globe in the age of high-speed Internet. By doping the fiber core with rare earths, such as ytterbium, it is possible to amplify light to the point of laser activity. Modern fiber laser systems have a power level of over 100 kW and are used in a wide range of industrial production technologies. In addition to these application aspects, the lecture "Fundamentals of Optical Fibers" focuses on the physical fundamentals and also provides an overview of the technological aspects of characterizing and manufacturing fibers. The lecture contains a lot of practical information on optical fibers, which can be useful for further studies and future careers. Key chapters of the lecture include:

- Compilation of the essential quality characteristics and measurement methods
- Production of optical fibers
- Components and devices in fiber technology
- Non-linear effects in optical fibers
- Fiber laser systems
- Selected application areas (communication technology, sensor technology, etc.)

Exercise and examination:

- Exercises: 3 exercise sheets, discussion in the exercise hours,
- Practical part: visit to the fiber manufacturing laboratories in the HiTEC building
- Examination: by arrangement

Further details will be announced in the lecture, NN

Basic literature:

- will be specified by the lecturer
- As an Introduction: Fedor Mitschke, Glasfasern, Elsevier Heidelberg, 2005

Recommended prior knowledge: Basic knowledge in fundamentals of Optics and Physics

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Assigned modules: Selected Topics in Modern Physics (Master Physics), Modern Aspects of Physics (Bachelor Physics), Selected Topics in Photonics.

Responsible: Institut für Photonik, Detlev Ristau

Seminar: Optical Speciality Fibers: Fabrication, Function Priciples and Applications

(Seminar Optische Spezialglasfasern: Herstellung, Funktionsprinzipien und Anwendungen)

Coursetype:	Seminar	**Language:**	english
Credit Points: (ECTS)	3	**SWS:**	2
Cycle:	Summer semester		

Contents: The Hannover Institute of Technology has state-of-the-art facilities for the production of optical glass fibers - an extremely exciting and topical field of research at the interface of physics, chemistry and engineering. During the seminar, interested students will gain an in-depth insight into theoretical and practical aspects of the production, functional principles and applications of special glass fibers. The results compiled on a selected topic will be presented in lectures. The lecturers will provide technical advice. The subsequent technical discussion will be of particular importance. In addition, the way in which the presentations are organized will be discussed together during the event in order to identify ways of improving them. Possible technical topics include:

- From step-index fibers to photonic bandgap fibers and hollow-core fibers
- Linear and non-linear effects
- Glasses for fiber production:
- From molecular glass structure to macroscopic properties
- The typical dopants for quartz glass fibers and their properties
- Radiation effects
- How a glass fiber is produced:
- The modified chemical vapor deposition (MCVD) process for the production of preforms: Basics, functionality and limitations
- Production of a fiber from a preform: Basics, functionality and limitations of a fiber drawing tower
- Applications of special glass fibers: Medical technology, data transmission and fiber lasers in science and industry
- Passive components (e.g. wavelength division multiplexers (WDMs)) for fiber-based systems: Functionality and manufacturing
- The lecturers will be happy to provide further details at any time. The course will be included in the e-learning (Stud-IP) program, which will then enable an exchange within the closed audience.

Basic literature: will be specified by the lecturer

Recommended prior knowledge:

Assigned modules: Selected Topics in Modern Physics (Master Physics), Modern Aspects of Physics (Bachelor Physics), Seminar (Master Physics).

Responsible: Michael Steinke, Matthias Liessmann, Detlev Ristau

Experimental Methods in Atomic Physics

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	4	**SWS:**	2 ?
Cycle:	Winter semester		

Contents:

- After successful completion of the module, students are able to recognize experimental methods of atomic physics and quantum sensor technology
- recognize them in original literature,
- describe them on a theoretical basis,
- as well as to understand and plan their practical implementation in current experiments.

Basic literature: will be specified by the lecturer

Recommended prior knowledge: Atomic and molecular physics, Coherent optics

Assigned modules: Selected Topics in Modern Physics (Master Physics), Modern Aspects of Physics (Bachelor Physics).

Responsible: Head of Institute of Quantum Optics

Physics of Medicine

(Physik der Medizin)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Summer semester		

Contents: The lecture provides insights into the areas of physics that are fundamental to understanding medical processes, diagnostics and therapy. This ranges from mechanics in the area of bones and joints to flow dynamics in the cardiovascular system and electronics in nerves and muscles. The use of radioactive radiation in imaging and radiotherapy as well as light and lasers in various fields such as dermatology and surgery are also considered. The lecture offers students insights into areas of application of physics in medicine and provides them with tools to answer relevant questions in medical physics. Contents:

- Introduction and review of Biophysics I
- Mechanics and orthopaedics
- Fluid dynamics and myocardial infarction
- Introduction to electrophysiology
- Electrophysiological examples: ECG, NLG
- Introduction to medical imaging: ultrasound
- Radiology and radiation protection: X-ray
- Further radiological applications: CT, MRI, stereotaxy
- Nuclear medicine + radiotherapy: scintigraphy, PET, SPECT
- Light in diagnostics: (fluorescence) microscopy in endoscopy
- Light therapy: PDT, etc.
- Laser surgery

Basic literature:

- Hobbie, KH und Roth, BJ Intermediate Physics for Medicine and Biology 5th Edition 2015, Springer
- Verlag
- Harten, U Physik in der Medizin 15. Auflage 2017, Springer Verlag)
- Schlegel, W, Karger, CP, Jäkel, O (Hrsg.) Medizinische Physik 2018, Springer Verlag

Recommended prior knowledge: Optic, atoms and molecules

Assigned modules: Selected Topics in Modern Physics (Master Physics), Modern Aspects of Physics (Bachelor Physics).

Responsible: Alexander Heisterkamp

Seminar: Biophysics

(Seminar: Biophysik)

Coursetype: Seminar
Credit Points: (ECTS) 3
Language: not specified
SWS: 2

Cycle: Summer semester

Contents:

- The biophysics seminar builds on the lecture "Introductory Biophysics for Physicists". Students will prepare posters on novel biophysical methods and scientific results. These are to be presented, discussed and evaluated by the students in a style similar to a scientific conference as part of a block event with a short presentation.
- The topics are chosen at the beginning of the semester and each student is assigned a supervisor who assists with the preparation. In the first hour of the course, the lecturer introduces the topic and gives tips and advice on preparing and giving a presentation in the seminar (Master's Physics).

Basic literature: will be specified by the lecturer

Recommended prior knowledge: Introductory Biophysics for Physicists

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Assigned modules: Seminar (Master Physics), Presenting Physics (Bachelor Physics) ?.

Responsible: : Alexander Heisterkamp, Stefan Kalies;

5.5 Courses of Institute of Photonics

Fracture of Materials and Fracture Mechanics

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	6	**SWS:**	2 + 2
Cycle:	Summer semester		

Contents: The following aspects of fractur emechanics:

- Introduciton: Review of the history of materials failure and fracture mechanics including historial cases and state of the art
- Fractue modes and characteristics: mode I, II and III cracks
- Brittle and ductile fractures in different materials
- Characterization of fracture toughness
- Solution of elastic stress around the crack tip: Kolosov-Muskhelishvili formulus and Westergaard solution
- Stress intensity factor in 2D and 3D problems and crack handbook
- Computation of Stress intensity factor: J-integral and a general Eshelby's energy momentum tensor for crack enegy release
- Introduction and overview of Computational methods for fractue modelling: meshless methods, XFEM and peridynamics and commercial software for fracture modelling
- Introduction and overview of multiscale approach for fracture modelling
- Students are also guided by practical exercises in the computer lab, assigning also specific projects to be solved through the implementation of numerical codes. The codes will be written in Mathematical/Matlab language at the continuum level and in Mathematica/FEAP language when FE discretization are needed. An introduction and examples to using commerical software ABAQUS for crack modelling will be demonstrated.

Basic literature: Subject specific recommendation of textbooks and journal articles

Recommended prior knowledge:

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Head of Institute of Photonics

Introduction to Multiscale and Multiphysics Modelling

Coursetype: Lecture and Exercise class
Language: not specified
Credit Points: (ECTS) 6
SWS: 2 + 2

Cycle: Winter semester

Contents:

- Introduction: Review of the classification of multiscale and multiphysics problems and state-of-the-art
- Multiscale modelling theory and analytical approaches
- Concept of representative volume element
- Computationl hierachical multiscale method
- Computationl concurrent/semi-concurrent multiscale methods
- Multiphysics model and some types of governing equations
- Multiphysics modelling commercial software with testing examples e.g. COMSOL
- Solvers for multifields problems
- Particial issues in multiscale and multiphysics modelling
- Students are also guided by practical exercises in the computer lab, assigning also specific projects to be solved through the implementation of numerical codes. The codes will be written in both LAMMPS for atomistic model, Mathematical/Matlab language at the continuum level or abaqus software when FE.

Basic literature: Subject specific recommendation of textbooks and journal articles

Recommended prior knowledge:

Assigned modules: Selected Topics in Modern Physics (Master Physics), Modern Aspects of Physics (Bachelor Physics).

Responsible: Head of Institute of Photonics

Foundations of Probability

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	every semester		

Contents:

- probabilistic models
- conditional probability
- independence
- Bayes' rule
- counting
- discrete and continuous random variables
- multiple random variables
- functions of random variables
- covariance and correlation
- Chebyschev inequality
- convergence in probability
- the weak law of large numbers
- The central limit theorem

Basic literature: "Introduction to Probability" by D. P. Bertsekas et al

Recommended prior knowledge: Analysis I+II

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Maria Alessandra Papa, Institute of Gravitational Physics

Lab course: Data Analysis
(Laborpraktikum Data Analysis)

Coursetype:	Practical Laboratory Course	**Language:**	not specified
Credit Points: (ECTS)	4	**SWS:**	4
Cycle:	Winter and Summer semester		

Contents:

- Introduction to version control and python: git, python, jupiter notebooks, google Colaboratory, numpy e scipy libraries.
- Monte Carlo simulations: hands-on approach
- Plausible reasoning: simple bayesian inference
- Combinatorics: calculate chances in a card game
- Random Variables and associated concepts
- Random number generation: the inverse transform method
- Poisson processes: maximise the profit of a business
- Numerical integration: calculate the value of pi using the Buffon's needle experiment
- Hypothesis testing basics: false alarm rate, false negative, roc curves.
- Hypothesis testing hands-on: distinguish noise+signal data from noise only data.
- Two random variables: covariance.

Basic literature: will be specified by the lecturer

Recommended prior knowledge: Experience with Linux

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Maria Alessandra Papa, Institute of Gravitational Physics

Neutron Stars and Black Holes

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Summer semester		

Contents:

- Sources and propagation of gravitational waves
- Neutron stars and black holes

Basic literature: will be specified by the lecturer

Recommended prior knowledge: Fundamentals of Special Theory of Relativity, Coherent Optics

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: NN, Institute of Gravitational Physics

Seminar: Gravitational Waves

(Seminar Gravitationswellen)

Coursetype:	Seminar	**Language:**	not specified
Credit Points: (ECTS)	3	**SWS:**	2
Cycle:	Summer semester		

Contents: By arrangement with the lecturers.

Basic literature: will be specified by the lecturer

Recommended prior knowledge: Fundamentals of Special Theory of Relativity, Coherent Optics

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Karsten Danzmann, Institute of Gravitational Physics

Seminar: Gravitational Physics
(Seminar Gravitationsphysik)

Coursetype:	Seminar	**Language:**	not specified
Credit Points: (ECTS)	3	**SWS:**	3
Cycle:	Winter and Summer semester		

Contents:

- General theory of relativity
- Sources of gravitational waves
- Gravitational wave detectors
- Astrophysics and cosmology

Basic literature: will be specified by the lecturer

Recommended prior knowledge: Gravitational Physics

Assigned modules: Selected Topics in Modern Physics (Master Physics), Seminar (Master Physik).

Responsible: Karsten Danzmann, Institute of Gravitational Physics

Laser Interferometry
(Laserinterferometrie)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	3	**SWS:**	3
Cycle:	Summer semester (annually)		

Contents:

- Applications of laser interferometry for gravitational waves and earth observation
- Description of light fields, interference and beam splitters
- Modulation techniques and modulators
- Michelson, Mach-Zehnder, homodyne and heterodyne interferometers
- Readout by internal, external or Schnupp modulation
- Fabry-Perot resonators (»cavities«) and Pound-Drever-Hall method
- Description of Gaussian beams and higher modes
- ABCD matrices and transformation of Gaussian beams
- Mechanical qualities of suspended optics
- Applications for measuring gravitational waves and the Earth's gravitational field
- Description of Gaussian beams and higher modes
- Polarization transfer functions and control loops

Basic literature:

- Saulson, Fundamentals of Interferometric GW detectors, World Scientific Pub Co Inc
- Siegman: Lasers
- Yariv: Quantum Electronics r

Recommended prior knowledge: Optics, Complex linear algebra

Assigned modules: Selected Topics in Modern Physics (Master Physics), Selected Topics in Photonics.

Responsible: Gerhard Heinzel, Institute of Gravitational Physics

Lab course: Laser Interferometry
(Laborpraktikum Laserinterferometrie)

Coursetype:	Practical Laboratory Course	**Language:**	not specified
Credit Points: (ECTS)	4	**SWS:**	4
Cycle:	Summer semester or Winter semester (irregular)		

Contents:

- Michelson, Mach-Zehnder, Sagnac, polarization interferometer,
- Power and signal recycling, Resonant sideband extraction, Delay lines
- Modulation fields, sniff modulation, external modulation
- Homodyne and heterodyne detection
- Spectral noise density
- Interferometer noise and sensitivity (quantum, thermal noise, ...)
- Mechanical qualities of suspended optics

Basic literature:

- Saulson, Fundamentals of Interferometric GW detectors, World Scientific Pub Co Inc
- Originalliteratur

Recommended prior knowledge: Coherent Optics, Nonlinear Optics

Assigned modules: Selected Topics in Modern Physics (Master Physics), Selected Topics in Photonics.

Responsible: Harald Lück, Institute of Gravitational Physics

Laser Stabilization and Control of Optical Experiments

(Laserstabilisierung und Kontrolle optischer Experimente)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Summer semester or Winter semester (irregular)		

Contents:

- Lasers and the cause of power, frequency and beam position fluctuations
- Fundamentals of control engineering
- Length control of interferometers and optical resonators
- Detection of frequency fluctuations and their suppression
- Detection of power fluctuations and their suppression
- Beam position control

Basic literature:

- Siegman, Lasers, University Science Books
- Yarif, Optical Elektronics in Modern Communications, Oxford University Press
- Abramovici, Chapsky, Feedback Control Systems

Recommended prior knowledge: Coherent Optics

Assigned modules: Selected Topics in Modern Physics (Master Physics), Modern Aspects of Phyics (Bachlor Physics), Selected Topics in Photonics.

Responsible: Benno Willke, Institute of Gravitational Physics

Non-classical Light
(Nichtklassisches Licht)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Winter semester (irregular)		

Contents:

- Classical and non-classical states of light
- Criteria for non-classicality
- Detection and generation of Fock states
- Detection and generation of squeezed light
- Quantum state tomography
- EPR-entangled (two-mode squeezed) light
- Optical test of non-locality

Basic literature:

- C.C. Gerry und P.L. Knight, Introductory Quantum Optics, University Press, Cambridge (2005).
- H.-A. Bachor und T.C. Ralph, A guide to experiments in quantum optics, Wiley, 2nd edition (2003).

Recommended prior knowledge: Coherent Optics, Quantum Optics, Nonlinear Optics

Assigned modules: Selected Topics in Modern Physics (Master Physics), Selected Topics in Photonics.

Responsible: Michèle Heurs, Institute of Gravitational Physics

Non-classical Laser Interferometry

(Nichtklassische Laserinterferometrie)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Summer semester (irregular)		

Contents:

- Shot noise and radiation pressure noise in the interferometer
- Square operators and input-output relations of interferometers
- The standard quantum limit of position measurement
- Quantum nondemolition techniques
- Interferometers with squeezed light and other non-classical states of light
- Opto-mechanical coupling and optical springs
- Quantum states of mechanical oscillators
- Cooling mechanical oscillators to their quantum mechanical ground state
- Entanglement of mirrors and light

Basic literature:

- Saulson, Fundamentals of Interferometric GW detectors, World Scientific Pub Co Inc
- Originalliteratur

Recommended prior knowledge: Coherent Optics, Nonlinear Optics, Non-classical Light, Quantum Optics,

Assigned modules: Selected Topics in Modern Physics (Master Physics), Selected Topics in Photonics.

Responsible: Michèle Heurs, Institute of Gravitational Physics

Electronic Metrology in the Optics Lab
(Elektronische Metrologie im Optiklabor)

Coursetype:	Lecture and Exercise class	**Language:**	not specified
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Summer semester or Winter semester (irregular)		

Contents:

- Electronics basics: Kirchhoff's rules, impedance, phasor diagrams
- Operational amplifiers: mode of operation and basic circuits
- Resonant circuits and filters (active / passive)
- Spectrum analyzer and network analyzer
- Measurement and interpretation of transfer functions
- Fundamentals of control engineering
- Photodetection
- Sensors and actuators in optical experiments
- Noise measurements

Basic literature:

- Horowitz & Hill, The Art of Electronics, Cambridge University Press
- Abramovici & Chapsky, Feedback Control Systems, Kluwer Academic Publishers
- Yariv, Quantum Electronics, Wiley
- Originalliteratur

Recommended prior knowledge: Coherent Optics

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Michèle Heurs, Institute of Gravitational Physics

Seminar: Non-classical Light

(Seminar Nichtklassisches Licht)

Coursetype:	Seminar	**Language:**	not specified
Credit Points: (ECTS)	3	**SWS:**	2
Cycle:	every semester		

Contents:

- Non-classical states of light (e.g. Fock states, squeezed states).
- Generation of non-classical states via non-linear optical processes.
- Detection of non-classical states.
- State-of-the-art squeezed states and applications.

Basic literature: will be specified by the lecturer

Recommended prior knowledge: Non-classical light, Quantum optics, Non-linear optics, Coherent optics.

Assigned modules: Seminar (Master Physics).

Responsible: Michèle Heurs, Institute of Gravitational Physics

5.7 Courses of Institute of Radioecology and Radiation Protection

Nuclear Energy and Fuel Cycle, Technical Aspects and Public Discourse

(Kernenergie und Brennstoffkreislauf, technische Aspekte und gesellschaftlicher Diskurs)

Coursetype:	Lecture and Exercise class	**Language:**	german
Credit Points: (ECTS)	2/Semester	**SWS:**	4
Cycle:	Winter Semester (part 1) and Summer semester (part 2)		

Contents:

- Despite or precisely because of the phase-out of nuclear energy in Germany, this topic continues to be the subject of social debate. In addition to 3 lecturers from LUH, 10 lecturers from other German universities and ETH Zurich are taking part in this lecture series. It extends over 2 semesters of 2 SWS each and ranges from the technical basics to the ethical, socio-ecological, economic, legal and political implications of radioactive waste disposal.
- In the winter semester, the focus is on the technical fundamentals. The energy situation is considered globally and the technical fundamentals of nuclear energy use, from uranium extraction to the functioning of current and future reactors and the disposal of spent nuclear fuel, are discussed. In addition to the technical aspects, the problems are explained from a social science/ethical and legal point of view.
- In the following summer semester, the focus will be on the problem of finding a final storage site on a very broad multidisciplinary basis and from different scientific perspectives. There is plenty of room for discussion (your own opinion is welcome!)

Basic literature:

- Streffer, Radioactive Waste, Springer
- Michaelis, Handbuch Kernenergie
- Heinloth, Die Energiefrage, Vieweg
- Weitere Literatur wird in der Veranstaltung bekannt gegeben

Recommended prior knowledge: Nuclei and Particles, Radiation Protection and Radioecology (optional)

Assigned modules: Modern Aspects of Phyics (Bachlor Physics), Selected Topics in Modern Physics (Master Physics).

Responsible: Clemens Walther

Radioactive Contaminations in the Environment and Risk to Human Health

(Radioaktivität in der Umwelt und Strahlengefährdung des Menschen)

Coursetype:	Lecture and Exercise class	**Language:**	german
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Summer semester		

Contents: The lecture deals with the occurrence of natural and artificial radionuclides in the environment, describes the pathways of radioactive substances through the environment to humans and gives an assessment of the resulting radiation exposure and the associated risks. The following topics are covered in detail: Radiation exposure due to the nuclear weapons explosions at Hiroshima and Nagasaki and the subsequent decades of nuclear weapons testing, in nuclear accidents: Windscale, Three Mile Island, Chernobyl, Fukushima, Kystym, criticality accidents, lost sources (Goiania) . Consequences of uranium mining for workers and the environment. Exposure of patients to radium and radon therapy.

Basic literature:

- Richard Rhodes, The making of the Atomic Bomb
- Warner, Kirchmann Nuclear Test Explosions
- Mosey, Reactor Accidents Nuclear Engineering International Special Publications (2006)
- Shaw Radioactivity in the terrestrial environment, Elsevier, Amsterdam (2007)
- Eisenbud, Environmental Radioactivity
- David Atwood, Radionuclides in the Environment, Wiley and Sons, 2010
- Weitere Literatur in der Vorlesung (Originalveröffentlichungen und web links)

Recommended prior knowledge: Nuclei and Particles, Radiation Protection and Radioecology

Assigned modules: Modern Aspects of Phyics (Bachlor Physics), Selected Topics in Modern Physics (Master Physics).

Responsible: Clemens Walther

Radiation Protection and Radioecology

(Strahlenschutz und Radioökologie)

Coursetype: Lecture and Exercise class
Language: german
Credit Points: (ECTS) 2
SWS: 2
Cycle: Winter semester

Contents: The lecture deals with ionizing radiation, radioactive decay, the interaction of radiation with matter, natural radioactivity, biological radiation effects, consequences for dose-risk relationships, effects of radioactive substances and ionizing radiation on humans, epidemiology, exposure pathways, radioecological modelling of the pathways of radioactive substances to humans, Estimation of radiation risks, radiation dose and radiation risk, dose-effect relationships, concept of collective dose, radiation protection principles, determination of dose values, radiation protection measures, statutory radiation protection regulations, EURATOM basic standards, fundamental issues of radiation protection (with the possibility of acquiring specialist knowledge (for SSB S 4. 1) for handling open radioactive substances in accordance with StrlSchV).

Basic literature:

- Vogt, Grundzüge des praktischen Strahlenschutzes 7. überarbeitete Auflage, Hanser Verlag, 2019. (https://doi.org/10.3139/9783446459823)
- Siehl, Umweltradioaktivität, Ernst & Sohn Verlag Berlin (1996)
- Ahrens, Pigeot Handbook of Epidemiology, Springer Berlin Heidelberg New York (2205)
- Strahlenschutzverordnung vom 29. November 2018 (BGBl. I Nr 41; 2018 I S. 2034)', (2018).
- Gesetz zum Schutz vor der schädlichen Wirkung ionisierender Strahlung Vom 27. Juni 2017 (BGBl. I Nr. 42, S. 1966) , (2017).
- Allgemeine Verwaltungsvorschrift zu § 47 Strahlenschutzverordnung: Ermittlung der Strahlenexposition durch die Ableitung radioaktiver Stoffe aus Anlagen oder Einrichtungen, Drucksache 88/12 15.02.12
- Weitere Literatur wird in der Veranstaltung bekannt gegeben

Recommended prior knowledge: Nuclei and Particles

Assigned modules: Modern Aspects of Phyics (Bachlor Physics), Selected Topics in Modern Physics (Master Physics), Teaching Profession Physics (Interdisciplinary Bachelor or Master of Education).

Responsible: Clemens Walther

Nuclear Physics Applications in the Environmental Sciences

(Kernphysikalische Anwendungen in der Umweltphysik)

Coursetype:	Lecture and Exercise class	**Language:**	german
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Winter semester		

Contents: The nuclear physics principles of stellar nucleosynthesis and the formation of elements in stellar burning processes and supernova explosions (r- and s-process) are discussed. The concept of isotopy is introduced and physical and chemical isotope effects are discussed. Both natural isotope effects and their technical application in isotope separation are discussed. In general, stable and radioactive isotopes are discussed as tracers and clocks in the geosphere, atmosphere, hydrosphere, pedosphere and biosphere. Primary, radiogenic, cosmogenic and nucleogenic anomalies of isotope abundances are presented with regard to age determinations, e.g. the age of chemical elements, the formation of the solar system and the collision history of small bodies in the solar system. The cycles of elements in the environment are treated with compartment models and applied to the behavior of special nuclides such as H-3, Be-10, C-14, Cl-36 and I-129 in the environment. The physical principles of the production of cosmogenic nuclides in the atmosphere and their in-situ production in the Earth's surface are presented. Stable and radioactive isotopes in the different environmental archives allow the study of the evolution of general environmental conditions and anthropogenic changes.

Basic literature:

- Davis, Meteorites, Comets and Planets
- Siehl, Umweltradioaktivität, Ernst & Sohn Verlag Berlin (1996)
- Oberhummer, Kerne und Sterne, Barth Verlagsgesellschaft, Leipzig (1993)
- Choppin, Rydberg, Liljenzin, Radiochemistry and Nuclear Chemistry, Butterworth Heinemann, Oxford, 1995
- Marmier, Sheldon, Physics of Nuclei and Particles, 2 vol., Academic Press, New York, 1970
- T. Mayer-Kuckuk, Kernphysik (6. Aufl.) Teubner, Stuttgart, 1994
- G.F. Knoll, Radiation detection and measurement, J. Wiley & Sons, New York, 2000
- Http://www.nucleonica.com/ : Karlsruhe Chart of Nuclides

Recommended prior knowledge: Optics, Atomic Physics, Quantum Phenomena, Nuclei and Particles, Radiation Protection and Radioecology

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Assigned modules: Modern Aspects of Phyics (Bachlor Physics), Selected Topics in Modern Physics (Master Physics).

Responsible: Clemens Walther

Chemistry and physical analysis of radionuclides

(Chemie und physikalische Analyse von Radionukliden)

Coursetype:	Lecture and Exercise class	**Language:**	english
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Winter semester		

Contents: The aim of this lecture is to impart knowledge of the chemical and physical properties of natural and artificial radionuclides. Essential pathways of the formation/production of radionuclides will be discussed as well as their occurrence and risk potential in the animate and inanimate environment up to application-oriented aspects such as nuclear forensics. Measurement of radiation fields, interaction radiation / matter, solid body nuclear track detector, alpha, beta and gamma detection, neutron detection, neutron activation analysis, nuclear reactions, cross section, natural radionuclides, natural decay series, nuclear reactions, radionuclide production, extraction chromatography, Szilard Chalmers effect, nuclear fission, tritium, potassium-40, radiocesium, radiostrontium, radium, technetium, radioiodine, radioxenon, CTBT verification, uranium, plutonium.

Basic literature:

- David Atwood, Radionuclides in the Environment, Wiley and Sons, 2010
- Lehto, Hou, Chemistry and Analysis of Radionuclides, Wiley-VCH 2011
- K.H. Lieser, Nuclear and Radiochemistry, Wiley-VCH, 2001
- J.V. Kratz, K.H. Lieser, Nuclear and Radiochemistry, Wiley- VCH, 2013

Recommended prior knowledge: Fundamentals of Chemistry, Nuclei and Particles

Assigned modules: Modern Aspects of Phyics (Bachlor Physics), Selected Topics in Modern Physics (Master Physics).

Responsible: Dubchak/Walther

Introduction to Mass Spectrometry

(Einführung in die Massenspektrometrie)

Coursetype:	Lecture and Exercise class	**Language:**	german
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	irregular (starting 2026)		

Contents: After the introduction of basic mass spectrometric concepts, various ionization, mass selection and detection methods as well as vacuum technology aspects are explained. Common mass spectrometric methods with a focus on element and isotope ratio analysis, determination of solution species and imaging MS methods are covered. Finally, high-precision mass measurements of extremely short-lived radionuclides and antimatter are presented, as well as the use of mass spectrometric methods in space travel. Techniques: ICP-MS, AMS, IRMS, TIMS, RIMS, SIMS, ESI MS, Schottky MS, Isochronous MS, Penning-trap MS.

Basic literature:

- Gross, Mass Spectrometry, Springer Berlin (2004)
- Becker, Inorganic mass spectrometry : principles and applications, Wiley (2007)
- Hoffmann, Stroobant, Mass spectrometry : principles and applications, Wiley (2007)

Recommended prior knowledge: Mechanics, Electrodynamics, Optics, Atomic Physics, Quantum Phenomena

Assigned modules: Selected Topics in Modern Physics (Master Physics).

Responsible: Institut of Radioecology and Radiation Protection

Practical course: Radiation Proctection and Radioecology

(Praktikum Strahlenschutz und Radioökologie)

Coursetype:	Practical Course	**Language:**	german
Credit Points: (ECTS)	6	**SWS:**	6
Cycle:	Winter and Summer semester		

Contents: By arrangement with the lecturers.

Basic literature: Literature for the individual lectures will be handed out during the course

Recommended prior knowledge: Radiation Protection and Radioecology (optional), Nuclei and Particles

Assigned modules: Modern Aspects of Phyics (Bachlor Physics), Selected Topics in Modern Physics (Master Physics), Teaching Profession Physics (Interdisciplinary Bachelor or Master of Education).

Responsible: Walther

Seminar: Radiation Proctection and Radioecology

(Seminar Strahlenschutz und Radioökologie)

Coursetype:	Seminar	**Language:**	german
Credit Points: (ECTS)	3	**SWS:**	3
Cycle:	Winter and Summer semester		

Contents: By arrangement with the lecturers.

Basic literature: Literature for the individual lectures will be handed out during the course

Recommended prior knowledge: Radiation Protection and Radioecology (optional), Nuclei and Particles

Assigned modules: Modern Aspects of Phyics (Bachlor Physics), Selected Topics in Modern Physics (Master Physics), Teaching Profession Physics (Interdisciplinary Bachelor or Master of Education), Chemistry Master: Analytics.

Responsible: Riebe / Walther

Knowledge in Radiation Protection

(Fachkunde im Strahlenschutz)

Coursetype:	Lecture and Exercise class	**Language:**	german
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Winter and Summer semester		

Contents: The IRS offers radiation protection courses to obtain specialist knowledge in radiation protection in accordance with the Radiation Protection Act and the Radiation Protection Ordinance. Contents include physical principles, dose concepts, biological radiation effects as well as technical and organizational radiation protection concepts and regulations.

Depending on their interests, students can choose a radiation protection course from the IRS course program (www.strahlenschutzkurse.de). The scope of the radiation protection courses is between 2 SWS and 6 SWS. As an additional qualification, participation in this course entitles the student to apply to the competent authority (Trade Supervisory Office) for »Fachkunde im Strahlenschutz« (Specialist knowledge in radiation protection). Therefore, in principle, 2 credit points are awarded for attending the course, even if the duration of the course exceeds 2 SWS.

Basic literature:

- Vahlbruch, Vogt: Grundzüge des praktischen Strahlenschutzes, 7. überarbeitete Auflage, Carl Hanser Verlag München 2019 (https://doi.org/10.3139/9783446459823)
- Vahlbruch, Vogt: Fit für den technischen Strahlenschutz : 200 Aufgaben zum sicheren Umgang mit Quellen ionisierender Strahlung, Carl Hanser Verlag München 2019 (https://doi.org/10.3139/9783446459830)
- Http://www.nucleonica.com/ : Karlsruhe Chart of Nuclides
- Strahlenschutzverordnung vom 29. November 2018 (BGBl. I Nr 41; 2018 I S. 2034), (2018)
- Gesetz zum Schutz vor der schädlichen Wirkung ionisierender Strahlung vom 27. Juni 2017 (BGBl. I Nr. 42, S. 1966), (2017).

Recommended prior knowledge: Mechanics and Heat, Electricty and Relativity, Optics, Atomic Physics, Quantum Phenomena, Nuclei and Particles

Assigned modules: Modern Aspects of Phyics (Bachlor Physics), Selected Topics in Modern Physics (Master Physics).

Responsible: Vahlbruch / Walther

Migration Pathways of Radionuclides in the Biosphere

Coursetype:	Lecture and Exercise class	**Language:**	english
Credit Points: (ECTS)	2	**SWS:**	2
Cycle:	Summer semester		

Contents: The course treats environmental properties of selected radionuclides with a focus on interactions with the biosphere including microbes. Basic aspects of nuclear forensics are presented.

Basic literature:

- David Atwood, Radionuclides in the Environment, Wiley and Sons, 2010
- Lehto, Hou, Chemistry and Analysis of Radionuclides, Wiley-VCH 2011
- K.H. Lieser, Nuclear and Radiochemistry, Wiley-VCH, 2001
- J.V. Kratz, K.H. Lieser, Nuclear and Radiochemistry, Wiley- VCH, 2013

Recommended prior knowledge: Nuclei and Particles, Radiation Protection and Radioecology

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Assigned modules: Modern Aspects of Phyics (Bachlor Physics), Selected Topics in Modern Physics (Master Physics).

Responsible: Dubchak / Walther

Introduction to Nanophotonics

Coursetype:	Lecture and Exercise class	**Language:**	english
Credit Points: (ECTS)	5	**SWS:**	3
Cycle:	Winter Semester		

Contents: Nanophotonics studies light-matter interactions at the nanoscale, and how to engineer the properties of light by exploiting its interaction with nanostructured materials. The course will focus on the theoretical foundations of nanophotonic systems, such as plasmonic nanoantennas, dielectric resonators, metasurfaces, metamaterials, and photonic crystals. The course is enriched with the use of simulation software for nanophotonics, such as Ansys Lumerical and Comsol Multiphysics. Optical properties of matter: dispersive media, and fundamentals of plasmonics (surface plasmon polaritons)

- Light scattering by metallic and dielectric nanostructures: Rayleigh approximation, plasmonic resonances, Mie theory, Mie-type resonances, and multipole decomposition
- Theory of periodic systems: diffraction, beam steering, and photonic bandgaps
- Engineering of light properties (amplitude, polarization, phase, propagation direction, spectrum) through arrays of nanostructures: metasurfaces, metamaterials, and photonic crystals
- Numerical techniques: finite-difference time-domain (FDTD) method
- Software for the simulation of nanophotonic systems: Ansys Lumerical and Comsol Multiphysics
- Selected topics of current research.

Basic literature:

- Novotny, L., & Hecht, B. (2012). Principles of Nano-Optics (2nd ed.). Cambridge: Cambridge University Press
- Gaponenko, S. (2010). Introduction to Nanophotonics. Cambridge: Cambridge University Press
- Maier, S. (2007). Plasmonics: Fundamentals and Applications. Springer, New York

Recommended prior knowledge: Knowledge of electromagnetic theory (Maxwell's equations, wave propagation, etc)

Assigned modules: Selected Topics in Modern Physics (Master Physics), M. Sc. in Optical Technologies, M. Sc. in Nanotechnology.

Responsible: Antonio Calà Lesina

Introduction to Computational Optics

Coursetype:	Lecture and Exercise class	**Language:**	english
Credit Points: (ECTS)	5	**SWS:**	3
Cycle:	Summer semester		

Contents: Some optical problems can be solved analytically, but some involve complex geometries and must be solved numerically. In both cases, translating equations into code that can be executed on a computer allows us to find solutions and post-process the data. This course introduces one of the main programming languages for scientific computing, Python, which is then used to solve many relevant optics problems.

The content of the course is as follows:

- Intro to the Python programming language
- Intro to Python libraries NumPy, SciPy and Matplotlib: arrays and matrices, numerical differentiation, integration, root finding, minimization/maximization, eigenvalue problems, discrete Fourier transform, differential equations, generation of figures, movies, read/write of files
- Selected examples from theoretical optics
- Intro to numerical methods: FDTD (finite-difference time-domain) for light propagation in media; FDFD (finite-difference frequency-domain) for mode analysis and propagation in waveguides

Basic literature: Literature for lectures will be handed out during the course

Recommended prior knowledge: Knowledge of electromagnetic theory (Maxwell's equations, wave propagation, etc)

Assigned modules: Modern Aspects of Phyics (Bachlor Physics), Selected Topics in Modern Physics (Master Physics), B. Sc. in Optical Technologies, M. Sc. in Optical Technologies, B. Sc. in Nanotechnology, M. Sc. in Nanotechnology.

Responsible: Antonio Calà Lesina

Simulations in Photonics

Coursetype:	Lecture and Exercise class	**Language:**	english
Credit Points: (ECTS)	5	**SWS:**	3
Cycle:	Summer semester		

Contents: A project will be assigned. This requires simulations on a given topic with a final presentation and discussion.

This course is the advanced version of the B.Sc. course ´Programming and Software for Optics´. It aims to present current software solutions for the simulation and design of photonic devices based on wave optics. Simulation tools from the commercial packages Ansys Lumerical (FDTD, FDFD, EME, varFDTD, CHARGE, DGTD, FEEM, HEAT, LumOpt, Interconnect) and Comsol Multiphysics (wave optics module) will be demonstrated for applications in integrated optics, nanophotonics, optical fibers and waveguides, including multiphysics scenarios and optimization techniques. Integration with Matlab/Python will also be demonstrated, as well as solutions for pre-/post-processing.

Basic literature: Literature for lectures will be handed out during the course

Recommended prior knowledge: Knowledge of electromagnetic theory (Maxwell's equations, wave propagation, etc)

Assigned modules: Selected Topics in Modern Physics (Master Physics), M. Sc. in Optical Technologies, M. Sc. Nanotechnology.

Responsible: Antonio Calà Lesina

6 Contact for study information and counselling and others services

Many questions about the degree programme should be clarified by reading this module catalogue. However, there are also questions that are better answered in a counselling interview. The following persons and institutions are available to you for this purpose. This chapter also introduces other institutions and facilities that provide services for students at Leibniz University Hannover.

6.1 Contacts within the faculty

Organisation of studies Information on the organisation of studies can be found in this brochure, in the current examination regulations and at www.maphy.uni-hannover.de/de/studium. If you have individual questions or problems, you can contact the degree programme advisor. The degree programme advisory is the central contact point for study matters. It acts as a communicative and organisational interface between students and the teaching staff. The degree programme advisory is thus responsible in particular for advising students.

Degree programme advisory

Study Programme Coordinator

Dipl.-Ing. Axel Köhler, Dr. Katrin Radatz, Dipl.-Soz.Wiss. Miriam Redlich

Gebäude 3403, A121, 30167 Hannover

0511 762 5450

sgk@maphy.uni-hannover.de

Course advice Individual course advice is generally offered by all professors. Subject-related course advice should be taken advantage of especially in the following cases:

- before choosing a major, examination subjects and the field of work for the Bachelor's or Master's thesis
- after failed examinations
- when changing subject, degree programme or university
- when planning a study visit abroad

The current office hours of the subject advisors can usually be found on the internet or can be requested by telephone or e-mail.

Subject-Specific Study Counselling Mathematics

Prof. Dr. Marc Steinbach

Gebäude 1101, Raum E336, 30167 Hannover

0511 762 3988

mcs@ifam.uni-hannover.de

Subject-Specific Study Counselling Physics

Prof. Dr. Tobias J. Osborne

Gebäude 3702, Raum 022, 30167 Hannover

0511 762 17502

tobias.osborne@itp.uni-hannover.de

Subject-Specific Study Counselling Mathematics Teaching Degree

Prof. Dr, Reinhardt Hochmuth

Gebäude 1101, Raum B401, 30167 Hannover

0511 762 4752

hochmuth@idmp.uni-hannover.de

Subject-Specific Study Counselling Physics Teaching Degree

Dr. Dirk Brockmann-Behnsen

Gebäude 1109, Raum 108, 30167 Hannover

0511 762 17296

brockmann-behnsen@idmp.uni-hannover.de

BAföG coordinator If you receive BAföG, you must submit a certificate from the faculty after the 3rd or 4th semester stating that you are studying in regular time. Please contact the BAföG coordinator for this.

BaföG-Officer Mathematics

PD Dr. Lutz Habermann

Gebäude 1101, C420, 30167 Hannover

0511 762 5534

habermann@math.uni-hannover.de

BaföG-Officer Physics

Prof. Dr. Eric Jeckelmann

Gebäude 3701, 225, 30167 Hannover

0511 762 3661

eric.jeckelmann@itp.uni-hannover.de

BaföG-Officer Meteorology

Prof. Dr. Björn Maronga

Gebäude 4105, F126, 30419 Hannover

0511 762 4101

maronga@meteo.uni-hannover.de

BaföG-Officer Nano Technology

Dr. Fritz Schulze-Wischeler

Gebäude 3430, Raum 006, 30167 Hannover

0511 762 16014

schulze-wischeler@lnqe.uni-hannover.de

Student body council of Mathematics and Physics www.fsr-maphy.uni-hannover.de Experience shows that students get a lot of information most quickly from fellow students from the same or higher semesters. The student body council offers contact options for contact persons who can, in most cases, clarify many questions or refer students to the relevant counselling office - especially due to their own study experience. The current contact persons can be found on the internet. The main task of the student body council is to represent student interests in the faculty's committees. For example, through the student representatives, it has a say in the design of examination regulations and can have a say in the appointment of new professors to the appointment committees. It also participates in inter-faculty committees. In addition, the student council also offers the following:

- Orientation sessions and communal breakfast for all first-year students in the first week before the start of the winter semester
- Get-to-know-you weekend for first-semester students
- Advice on the mathematics, physics and meteorology degree programmes
- Help with problems during studies / with lecturers / lecture structure
- Study rooms with a small textbook collection
- a collection of exams and exam protocols of the last years
- the student council newspaper Phÿsemathenten
- A barbecue every two years
- so called Zahlendre3her parties
- First semester party to get to know each other during the OE week
- Regular game evenings as well as a large game collection of the student body council

Contact Students Council Mathematics/Physics

Students Council MathematicsPhysics

Gebäude 1101, Raum D414, 30167 Hannover

0511 762 7405

info@fsr-maphy.uni-hannover.de

Anyone who would like to become a contact person is cordially invited by the student council to simply attend a meeting of the student council. The meetings are always on Mondays at 6.15 p.m. in the student council room during the semester. Since the student council is an open council, every student of the faculty is entitled to vote at the meetings. This applies to all votes that do not deal with finances or changes to the rules of procedure.

Examination Board The course of studies, in particular the performances to be achieved, is regulated by the respective examination regulations (see appendix). The examination board ensures that the provisions of the examination regulations are observed. It decides on questions of recognition of coursework and assessment works as well as in appeal procedures. As a rule, any concerns for the examination board are addressed directly to the chairperson of the examination board.

Examination Board Mathematics

Prof. Dr. Knut Smoczyk

Gebäude 1101, A415, 30167 Hannover

0511 762 4253

pa-mathe@maphy.uni-hannover.de

Examination Board Physics

Prof. Dr. Christian Ospelkaus

Gebäude 1101, D123, 30167 Hannover

0511 762 17644

Pa-physik@maphy.uni-hannover.de

Examination Board Meteorology

Prof. Dr. Björn Maronga

Gebäude 4105, F126, 30419 Hannover

0511 762 4101

maronga@meteo.uni-hannover.de

Examination Board Nano Technology

Prof. Dr. Dr. h. c. Franz Renz

Gebäude 2501, 191, 30167 Hannover

0511 762 4541

franz.renz@acd.uni-hannover.de

Decisions on the teacher training courses are the responsibility of separate examination boards, which are supervised by the Leibniz School of Education.

Central Contacts Service Center www.uni-hannover.de/servicecenter The Service Centre at Leibniz University Hannover is the central contact point for students and prospective students. With staff from various central institutions work here to answer questions about studying and to help students find their way around Leibniz Universität Hannover. During opening hours, staff from the following departments are available for advice:

- Examination office
- BAFöG-coordinator
- International Office
- Admissions Office
- Psychological Counselling for Students
- Student Advisory Services

Service Center

Reception

Gebäude 1101, F101, 30167 Hannover

0511 762 2020

studium@uni-hannover.de

Student Advisory Services (ZSB) www.zsb.uni-hannover.de

The Student Advisory Services is the contact point for all students at Hannover's universities. There are different forms of counselling:

- Open Office Hours: Individual counselling in a confidential atmosphere without prior appointment; registration at the Infothek in the ServiceCenter (Thur. 2:30pm-5pm)
- By appointment: Individual counselling in a confidential atmosphere Appointment via the Leibniz University Hannover Service Hotline (0511-762-2020)
- Brief counselling: Short initial information talks (duration: up to 10 minutes) in the information desk of the ServiceCenter in the main building. (Mo.- Fr. 10am to 2pm)

Counselling is provided on all questions and problems that are closely or widely related to the study programme; for example:

- Change of study programme
- Change of university
- Examination problems
- Career perspectives after Graduation

Student Advisory Services

ZSB

Gebäude 1101, F101, 30167 Hannover

0511 762 5580

studienberatung@uni-hannover.de

Studying with Handicap and/or a chronic illness Studying with a health impairment or, for example, dyslexia can bring difficulties and raise some questions, this applies to students in the first semester as well as to students shortly before graduation. The LUH offers various services to support students, such as borrowing aids, compensating for disadvantages in exams and personal counselling for a wide range of questions and problems, for example:

- How can I get along better at the university?
- Organisation of studies
- Compensation for disadvantages/examination problems
- What happens after graduation?
- ... and whatever is bothering you personally ....

The representative for students with a handicap/chronic illness will be happy to help you.

Representative for Students with Disabilities

Christiane Stolz

Gebäude 1101, C306, 30167 Hannover

0511 762 3217

christiane.stolz@zuv.uni-hannover.de

Examination Office www.uni-hannover.de/pruefungsamt The examinations are organised in the central Academic Examinations Office of the University in cooperation with the Dean of Studies or the respective responsible examination board. The examination office is responsible for the following tasks in particular:

- Examination registrations / admission
- Examination withdrawals (e.g. due to illness)
- Central recording of examination results
- Issuing certificates, e.g. for child benefits
- Compiling grade reports for applications or when changing subject or university
- Issuing certificates and diplomas

The staff at the Academic Examinations Office will be happy to advise you on all examination matters. Please contact the following addresses:

Service Center

Reception

Gebäude 1101, F101, 30167 Hannover

0511 762 2020

studium@uni-hannover.de

Within the Examinations Office, there is currently the following responsibility:

Academic Examination Office

Thorsten Flenner

Gebäude 3403, A108, 30167 Hannover

0511 762 2020

thorsten.flenner@zuv.uni-hannover.de

Study abroad The Leibniz University Hannover offers numerous opportunities to complete part of your studies abroad. The Faculty's International Coordinator and the International Office can advise you on these opportunities.

Study Abroad

Dr. Ing. Axel Köhler

Gebäude 3403, A121, 30167 Hannover

0511 762 5450

sgk@maphy.uni-hannover.de

International Office The International Office provides information and services on study and research opportunities abroad. It oversees the exchange programmes at Leibniz University Hannover and advises on scholarships and funding opportunities. At the University Service Centre, with-workers from the International Office are available to answer further questions about studying abroad. The Erasmus programme is currently the main programme used at the faculty. In the course of the EU's Erasmus programme, numerous universities throughout Europe have entered into partnerships for mutual student exchange. Achievements are mutually recognised. No tuition fees have to be paid at the partner university.

Ombudsperson of university www.zqs.uni-hannover.de/ombudsbuero.html The office of the ombudsperson for ensuring good study conditions serves as a contact point for students who have general or individual problems, complaints or suggestions for improvement regarding their studies and teaching. Contact via:

Ombudsperson

Prof. Dr.-Ing. Stephan Kabelac

Gebäude 8143, 120, 30823 Garbsen

0511 762 2277

ombudsperson@studium.uni-hannover.de

Coaching-Service and Psychological Counselling for Students (ptb) Sometimes the joy and enthusiasm about one's own studies wane over time. Due to the increasing demands that both studying and the new independence bring, the stress can become too much. Without realising it, you can no longer cope with the situation. With the help of the counselling service of the Psychological Counselling for Students(ptb), which is specially tailored to you, you can learn to find your ways to a solution.

Psychological Counselling for Students

PTB

Gebäude 1139, Eingang, 30167 Hannover

0511 762 3799

info@ptb.uni-hannover.de

6.2 Further Services

Libraries www.tib.eu In Hanover, the German National Library of Science and Technology (TIB) - Leibniz Information Centre for Technology and Natural Sciences and University Library is located right next to the main university building. The TIB is the German National Library of Science and Technology for technology/engineering and its basic sciences, in particular chemistry, computer science, mathematics and physics. This means that no location in Germany is better equipped in terms of literature stock for studying these subjects. There are also institute libraries. With the free HOBSY library card, all students can borrow books not only at TIB but also at the city library locations.

Leibniz University IT Services (LUIS)

www.luis.uni-hannover.de Courses on how to deal with programming languages and operating systems (e.g. Linux, WINDOWS, C, JAVA, etc.) are regularly offered here. Furthermore, a series of manuals is also published at Time for self-study (RRZN manuals for state universities).

Leibniz Language Centre

https://www.llc.uni-hannover.de The Subject Language Centre offers free language courses for students. For students of mathematics, a good knowledge of English is not only irreplaceable for their future careers, but is already important during their studies, as many basic textbooks are published in English. English for physics and mathematics, for example, is suitable for building on existing English skills for studies. Furthermore, grammar courses, preparatory courses for stays abroad and work as well as courses for scientific communication and argumentation are offered. Of course, there are also courses for various other languages.

ZQS/Key Competencies: Building blocks for success in studies and career In order to be successful in studies, internships and professional life, other competences are required in addition to specialised knowledge. These include learning strategies and working techniques, strong communication and presentation skills, a confident approach to conflicts in a team or intercultural skills. Clear career goals, practical experience, contacts with employers and a convincing application are also crucial for starting a career. The ZQS/Key Competences supports you with:

- Seminars on key competences with credit points

- Counselling and workshops on learning and working techniques as well as on academic writing of term papers and theses
- Real-life practical projects in companies and the basics of project management
- Counselling and workshops on job applications, internships and career entry
- Job shadowing - a day of sniffing around in a company
- Mentoring - support for career entry
- Company contact fair Career Dates
- Internship and job exchange Job ticket

Further Information: www.sk.uni-hannover.de

6.3 Study and live in Hannover

This section is intended to list a few aspects of student life. More detailed information can be found on the websites of the University of Hannover and the Studentenwerk Hannover. www.uni-hannover.de www.studentenwerk-hannover.de

Living Whether it's your own flat, a shared flat or a place in a hall of residence - for many, the search for a place to live is the first step towards studying. All the helpful links are collected in this section.

Own apartment/establishment of a flat-sharing community If you are looking for a flat for yourself or for a flat to start a new flat-sharing community, there is no getting around the classic sites such as immoscout. Some (subsidised) flats require a so-called *Wohnungsberechtigungsschein* (B certificate), but you shouldn't be put off by this. As a student, it is usually no problem to get one. Especially if you are setting up a new flat share, it is advisable to ask around at the so-called housing or building cooperatives. Here you have to pay a share in the cooperative when you join - comparable to a deposit - which you get back when you leave the cooperative. But you can also find offers for this on sites such as WG-Gesucht.

Search for a WG room Searching for a room in a shared flat The WG-gesucht website is the place to go for both those offering and those looking for a room in a shared flat. Particularly in the run-up to the start of the semester, it is important to be quick and write to suitable flat-shares as soon as possible after placing the ad. It's normal not to get any replies here, as the advertisers are flooded with enquiries, especially at the beginning of the semester. On the notice boards of the university (e.g. in the refectories or in the atrium in the main building of the university or online on stud.ip) you can sometimes still find offers. The Schwesternhaus (see below) is also a good place to look for a room in a shared flat.

Dormitory The student residence halls are usually inexpensive rooms for students provided by the Studentenwerk. The total duration of residence is limited to 3 years. Flats are allocated via a waiting list, but it can be helpful to call to find out what is currently available. These can be single apartments, shared flats or so-called corridor communities. In shared flats, you have your own room, but the bathroom and kitchen are shared by the entire hall. Another option is the 'sisters' house'(Schwesternhaus). The sisters' house is self-managed. The student tenants take care of all the maintenance, upkeep and mornings in the house themselves. Everyone contributes something: the water sisters take care of the water pipes, the renovation sisters take care of the building, the garden sisters take care of the garden, and so on. The sisters' house is open to all genders and fields of study. Temporary accommodation/emergency shelter If you didn't find a flat at the start of the semester or were extremely late in getting a place, e.g. in a lottery, there are still bridging options for the first few months of your studies. First of all, we would like to mention the WG forums, where people are often looking for (spontaneous) interim tenants. The sisters' house also offers emergency accommodation. Another option is the youth hostel, which offers special weekly and monthly rates for students at the start of the semester. The AStA offers a dormitory exchange, where those offering or looking for a place to sleep can register. Warnhinweis Achtet bitte bei der Suche nach Wohnungen -insbesondere über Foren or Angebotsseiten - auf die Seriosität der Angebote. Teilweise sind dort Betrüger unterwegs. Überweist nie Geld ohne die Wohnung gesehen und einen Vertrag unterschrieben zu haben. Helpful Links https://www.wg-gesucht.de/ (WG room) https://schwesternhaus.de/ (WG room, dormitory, emergency accommodation) https://www.studentenwerk-hannover.de/wohnen/uebersicht (WG room, flat, dormitory) https://www.immobilienscout24.de/ (flat) https://baugenossenschaft.info/baugenossenschaften-niedersachsen/wohnungsgenossenschaften-hannover/ (Overview Housing/building cooperatives Hanover) https://www.jugendherberge.de/lvb-hannover/long-stay-miete-fuer-studierende/ (emergency accommodation) https://www.asta-hannover.de/service/soziales/schlafplatzborse/ (emergency accommodation)

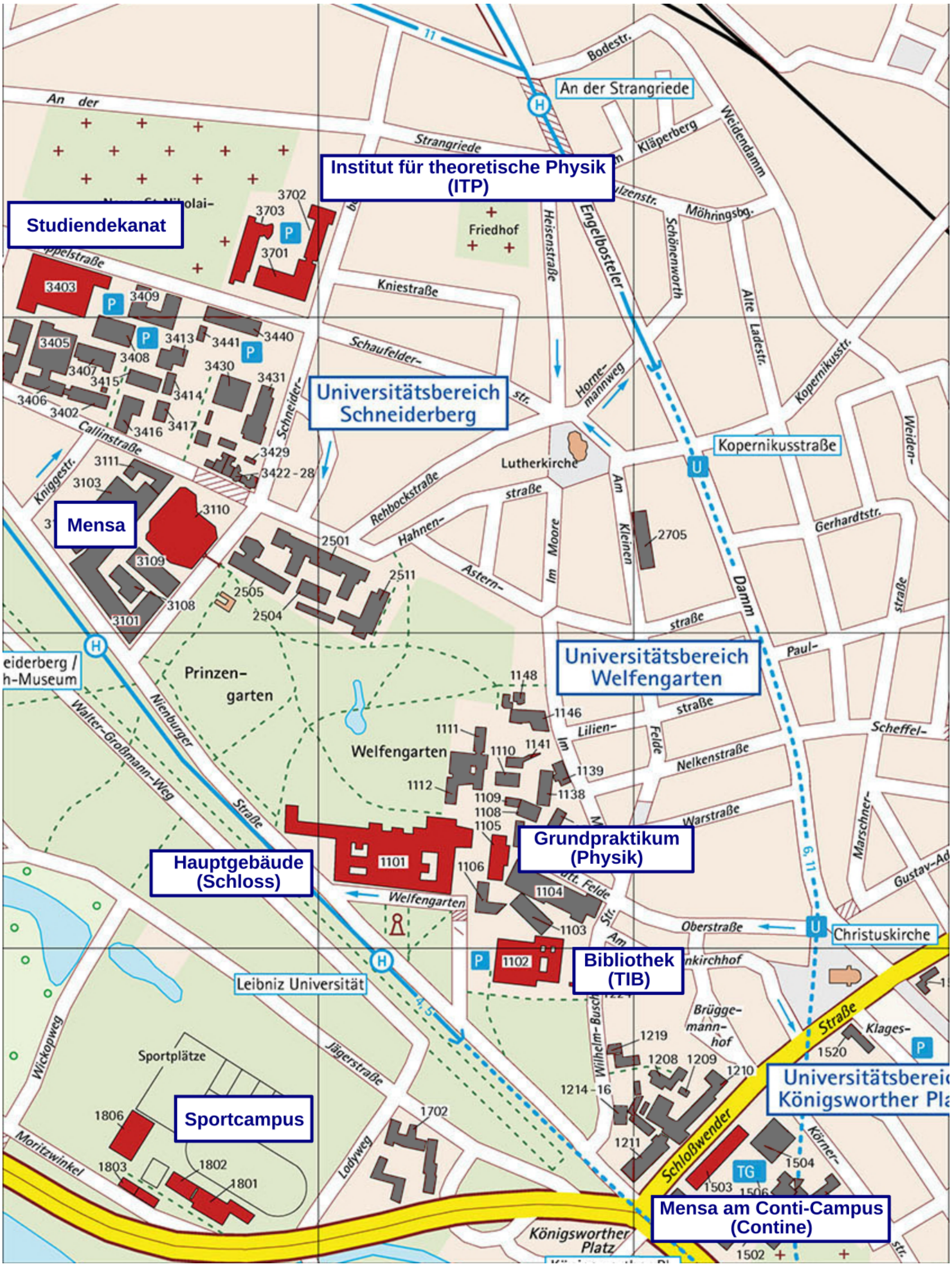
Food and drink In the main canteen, you can choose from a selection of up to 10 dishes. In various surveys, the main canteen has repeatedly been ranked among the best canteens in Germany in terms of quality, price and selection. In addition, there are eight cafeterias at the various university locations for those with a small appetite. The *Sprengelstube* cafeteria in the main building is also a great place to stop off between lectures. www.studentenwerk-hannover.de/essen.html

transport With the semester ticket, students can use public transport in the Hannover Region and almost all local trains in Lower Saxony. As most of the cycle paths are in good condition, many students come to university by bike. The semester fee includes a small contribution which is used for the bicycle workshops where bicycles can be repaired free of charge. Further information on the semester ticket and bicycle repair shops can be obtained from the AStA. www.asta-hannover.de

University sports University sport is an opportunity for all students to do sport together, get some exercise and recover from the stress of university. The various courses, from Aikido to basketball and athletics to yoga, are mostly free for students or significantly cheaper than in most sports clubs. At the beginning of each semester, the sports program is published, from which you can choose courses. Courses are also offered during the semester break. The sports program is available from the sports center as a brochure, but also on the Internet. www.hochschulsport-hannover.de

Financial and social matters Every semester, all students have to pay a semester fee. This is mainly paid for the semester ticket, the administration fee and the student union If the course lasts longer than the standard period of study plus an additional four semesters, so-called long-term study fees must be paid each semester, although there are exceptions in some cases. The amount increases with the length of your studies. The Enrolment Office will provide information on this. Advice on BAFöG is available from the BAFöG department of the Studentenwerk Hannover and the BAFöG and social counseling service at the AStA. https://www.studentenwerk-hannover.de/geld/bafoeg-antrag www.asta-hannover.de

HiWi jobs and work opportunities The best way not only to earn money, but also to gain experience for your future career and repeat course content is to work as a student assistant at the university. Here it is possible to work in research and administration at the institutes or in teaching. If you are interested, it is advisable to contact the lecturers and academic staff directly. They will be happy to advise you. As an important industrial and commercial city, Hannover also offers various opportunities for students to earn money in companies, administration and services as well as at trade fairs (e.g. Hannover Industrial Fair).



7 Misc

This course is also applicable for a module of a differente study programme. The according module is to be found in the regarding module handbook of the programme.