Leibniz Universität Hannover

Bachelor degree program Physics

Bachelor degree program Meteorology

Master degree program Physics

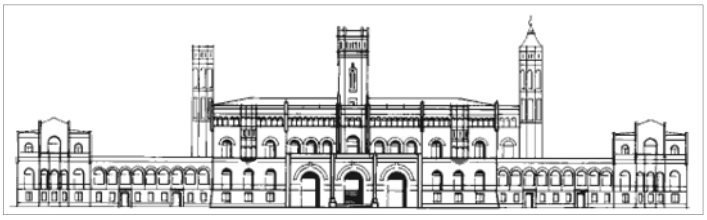
Master degree program Meteorology

Module catalog

Status 24.05.2017

Faculty of Mathematics and Physics

Leibniz University of Hanover



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Preliminary note

The module catalog Physics and Meteorology consists of two parts, the module descriptions and the following with the lecture descriptions (course catalog). Because in the elective modules can be chosen variouse lectures, these are described in more details in the following. In such cases, the contents and frequency of the offer are to be found in the lectures and not in the modules.

Please note that this is a compilation of lectures that are offeres on a regular basis. In particular, further lectures in the course catalog can be assigned tot he elective modules.

The module catalog should also be understood as a supplement to the examination regulation. The current version of our examination regulations can be found here:

Physics :
http://www.uni-hannover.de/de/studium/studiengaenge/physik/ordnungen/index.php

Meteorology :
http://www.uni-hannover.de/de/studium/studiengaenge/meteorologie/ordnungen/index.php

Content

Curriculums

Curriculum BA Meteorology

<table>
<tr><th></th><th>1. semester</th><th>2. semester</th><th>3. semester</th><th>4. semester</th><th>5. semester</th><th>6. semester</th><th>CP</th></tr>
<tr><td rowspan="4">Mathematics</td><td>Linear Algebra A
4 CP, SL, PL</td><td>Linear Algebra B
4 CP, SL, PL</td><td rowspan="2">Numerics A
4 CP, SL, PL</td><td rowspan="4">Applied programm-ing
4 CP, SL</td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4">30</td></tr>
<tr><td colspan="2">Better grade determines final grade</td></tr>
<tr><td>Analysis A
5 CP, SL, PL</td><td>Analysis B
5 CP, SL, PL</td><td rowspan="2">Stochastics A
4 CP, SL, PL</td></tr>
<tr><td colspan="2">Better grade determines final grade</td></tr>
<tr><td rowspan="2">Experimental physics</td><td>Mechanics and relativity
6 CP, SL</td><td>Electricity
12 CP, SL</td><td>Optics, nuclear physics, quantum phenomena
10 CP, SL</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">28</td></tr>
<tr><td colspan="3">PL</td></tr>
<tr><td rowspan="2">Theoretical physics</td><td>Mathema-tical methods of physics
7 CP, SL</td><td>Theoretical electrody-namics
7 CP, SL</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">14</td></tr>
<tr><td colspan="2">PL: one of the exams have to be passed</td></tr>
<tr><td rowspan="4">General and applied meteorology</td><td rowspan="4">Introduc-tion to meteorolo-gy I
4 CP, SL, PL</td><td rowspan="4">Introduc-tion to meteorolo-gy II
4 CP, SL, PL</td><td>Radiation I
4 CP</td><td>Radiation II
4 CP</td><td>Instru-ment intern-ship
6 CP, SL</td><td rowspan="2"></td><td rowspan="4">38</td></tr>
<tr><td colspan="2">SL, PL</td></tr>
<tr><td rowspan="2"></td><td>Cloud physics
4 CP, SL, PL</td><td>Climato-logy
4 CP, SL, PL</td></tr>
<tr><td></td><td>Synopticme teo-rology I
4 CP, SL</td><td>Synoptic meteorolo-gy II
4 CP, SL</td></tr>
<tr><td rowspan="2">Theoretical meteorology</td><td rowspan="2"></td><td rowspan="2"></td><td>Thermodyna mics and statics
4 CP, SL, PL</td><td>Turbulence and diffusion
4 CP, SL, PL</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">12</td></tr>
<tr><td>Kinematics and dynamics
4 CP, SL, PL</td><td></td></tr>
</table>

<table>
<tr><td rowspan="2">Study and job</td><td>Introduc-
tion to the
study of
meteorolo-
gy</td><td></td><td></td><td colspan="3" rowspan="2"></td><td>5</td></tr>
<tr><td colspan="3">Professional internship
SL</td></tr>
<tr><td rowspan="3">Advanced studies</td><td colspan="3" rowspan="3"></td><td colspan="3">Meteorological excursion I
2 CP, SL</td><td rowspan="3">34</td></tr>
<tr><td colspan="3">Elective module meteorology
Selection from corresponding assigned courses of at least 20 CP
20 CP, (SL), PL</td></tr>
<tr><td colspan="3">Natural scientific technical electoral area at least 12 CP from courses of the faculties named in the examination regulation
12 CP, (SL)</td></tr>
<tr><td>Key competen-
cies</td><td colspan="4">A course from the offer of the language center (Fachsprachenzentrums) or center for key competencies (Zentrum für Schlüsselkompetenzen) or the corresponding offers of the faculty
2 CP</td><td>writing
2 CP</td><td></td><td>4</td></tr>
<tr><td>Presentation and project work</td><td></td><td></td><td></td><td></td><td></td><td>Bachelor project</td><td>15</td></tr>
<tr><td>Credit points/ Examina-
tions</td><td>28/4</td><td>32/4</td><td>30/5</td><td colspan="3">Depending on individual planning.</td><td>180</td></tr>
</table>

Curriculum BA Physics

<table>
<tr><th></th><th>1. semester</th><th>2. semester</th><th>3. semester</th><th>4. semester</th><th>5. semester</th><th>6. semester</th><th>CP</th></tr>
<tr><td rowspan="3">Mathematics</td><td>Analysis I
10 CP, SL, PL</td><td>Analysis II
10 CP, SL, PL</td><td>Mathema-tics for physicists I
4 CP, SL</td><td>Mathema-tics for physicists II
4 CP, SL</td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3">38</td></tr>
<tr><td colspan="2">Only one exam has to be passed</td><td colspan="2">PL</td></tr>
<tr><td>Linear Algebra I
10 CP, SL, PL</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Experimental physics</td><td>Mechanics and relativity
6 CP, SL</td><td>Electricity
12 CP, SL</td><td>Optics, nuclear physics, quantum phenomena
10 CP, SL</td><td>Molecules, cores, particles, solids
10 CP, SL</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">38</td></tr>
<tr><td colspan="4">PL</td></tr>
<tr><td rowspan="2">Theoretical physics</td><td>Mathema-tical methods of physics
7 CP, SL,</td><td>Theoretical electrodyna mics
7 CP, SL</td><td>Analytical mechanics and special relativity theory
4 CP, SL</td><td>Introduc-tion to the quantum theory
8 CP, SL</td><td>Statistical theory
8 CP, SL</td><td rowspan="2"></td><td rowspan="2">38</td></tr>
<tr><td colspan="2">PL</td><td>PL</td><td>PL</td><td colspan="2"></td></tr>
<tr><td>Advanced studies</td><td></td><td></td><td></td><td></td><td colspan="2">2 of 3 specialization modules each V3+Ü1+P3 each 8 CP
- solid state physics
- nuclear and molecular physics
- coherent optics</td><td>16</td></tr>
<tr><td>Physical electoral area</td><td></td><td></td><td></td><td></td><td colspan="2">At least 12 CP from the courses of physics</td><td>12</td></tr>
<tr><td>Key compe-tencies</td><td></td><td colspan="3">Seminar or lecture
4 CP</td><td></td><td>4</td></tr>
<tr><td>Choosing compul-sory subjects</td><td colspan="6">Business administration, chemistry, electrical engineering, geodesy and geoinformatics, informatics, mechanical engineering, mathematics, meteorology, philosophy and political economy.</td><td>16</td></tr>
</table>

Presentation and project work				Physics presenta-tion seminar 3 CP, SL		Bachelor thesis 12 CP	18
						Lecture 3 CP	
Credits	33/2	29/1	Depending on individual planning.				180

Bachelor Physics – Basic modules

Analysis I + II			0211
Semester	Winter and summer semester		
Responsibility	Institut for Analysis and Institut for Differential geometry		
Courses	Lecture "Analysis I" Exercises to "Analysis I" Lecture "Analysis II" Exercises to "Analysis II"		
Assessement of credit points	**Study achievment:** In each case the practice for Analysis I and Analysis II **Exam achievement:** One exam to Analysis I or to Analysis II		
Note compound	doesn't enter the bachelor note		
Credit points (ECTS): 20	**Attendance study (h):** 180	**Self study (h):** 420	

Competence:
Competence in dealing with mathematical language. Basic understanding of the correct solution of mathematical problems by means of one-dimensional convergence considerations, differential and integral calculus. As a result of the exercise sessions, the students are familiar with mathematically exact formulations and conclusions in simple contexts and are able to present them.

Contents:

Analysis I:
- Number systems; systematic introduction of real numbers
- Sequences and series
- Convergence and continuity
- Differential calculus for functions of one variable
- Integral calculus for functions of one variable.

Analysis II:
- Topological concepts such as metric and normed spaces, convergence, continuity, completeness, compactness;
- Differentiation of functions of several variables, total and partial differentiability, theorems on inverse functions and implicit functions, local extrema with and without constraints; vector fields and potentials;
- Ordinary differential equations, existence, uniqueness, elementary methods of solution.

Fundamental 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 knowledge:
School knowledge in mathematics (upper secondary school)

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:
Bachelor Physics (Basic modules)

Linear algebra I (Lineare Algebra I)			0111
Semester	Winter semester		
Responsibility	Institut for Algebra, Number theory and Discrete mathematics and Institut for Algebraic geometry		
Courses	Lecture "Lineare algebra I" Exercises to "Linear algebra I"		
Assessment of credit points	**Study achiement:** Exercises **Exam achievemnt:** Exam		
Note compound	doesn't enter the bachelor note		
Credit points (ECTS): 10	**Attendance study (h):** 90	**Self study (h):** 210	

Competence:
Basic understanding of the mathematical way of thinking and its application towards a variety of problems. Solid competence in handling systems of linear equations and the corresponding methods for solving them; sound knowledge of the underlying algebraic structures. Capability of expressing and presenting mathematical reasoning, and knowledge of adequate methods for this.

Content:
- Basic properties of vector spaces (basis and dimension);
- linear maps and matrices;
- determinants;
- systems of linear equations and methods for solving them (Gauss algorithm);
- eigenvalues and eigenvectors;
- diagonalisation.

Fundamental literature:
- 🕮 G. Fischer, *Lineare Algebra*, Vieweg

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

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:
- Bachelor Physics (Basic modules)

Mathematics for physicists (Mathematik für Physiker)			0050
Semester	Winter and summer semester		
Responsibility	Institut for Analysis and Institut for Differential geometry		
Courses	Lecture "Mathematics for physicists I" Exercises for "Mathematics for physicists I" Lecture "Mathematics for physicists II" Exercises for "Mathematics for physicists II"		
Assessment of credit points	**Study achievement:** Exercises **Exam achievement:** Oral examination for mathematics education for the 4 semesters (Analysis I+II, Linear Algebra and Mathematics for physicists)		
Note compound	Note of the oral exam		
Credit points (ECTS): 8 **Weight:** 2	**Attendance study (h):** 90	**Self study (h):** 150	

Competence:
The students have an in-depth understanding of analytical methods, in particular of integration and function theory. They have the ability to independently develop mathematical arguments and to present them independently in the practice group. The students understood the mathematical structure of important differential equations of physics and can apply suitable solutions strategies.

Content:
- Lebesgue function spaces and convergence theorems
- Differential forms and integral sentences
- Fourier Analysis
- Linear partial differential equations
- Elements of function theory

Fundamental literature:
will be given in the lecure

Recommended knowledge:
Modules Analysis I + II

If applicable, admission prerequisites and limited number of participants: no

Module affiliation:
- Bachelor Physics (Basic module)
- Bachelor Meteorology (Natural scientific technical electoral area)

Mechanics and relativity (Mechanik und Relativität)				1011
Semester	Winter semester			
Responsibility	Experimental Physics Institutes			
Courses	Lecture „Mechanics and relativity " Exercises to "Mechanics and relativity"			
Assessment of credit points	**Study achievement:** Problem sets			
Note compound	-			
Credit points (ECTS): 6	**Attendance study (h):** 90		**Self study (h):** 90	

Competenc:
The students have an intuitive understanding of physical processes in the areas of mechanics and relativity. They know the relevant physical laws and can make them plausible with key experiments. The students are familiar with the treatment of sample problems in mechanics and relativity and can solve appropriate problems in these areas independently.

Content:
- Mechanics of a point mass, systems of point masses, and collisions
- Dynamics of rigid bodies
- Solid and liquid states of matter, moving liquids and gases
- Temperature, ideal gas, heat transport
- Mechanical oscillations and waves
-

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

Recommended knowledge:
High school knowledge of mathematics and physics

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:
- Bachelor Physics (Basic module)
- Bachelor Meteorology (Basic module)

Electricity (Elektrizität)			1012
Semester	Summer semester		
Responsibility	Experimental Physics Institutes		
Courses	Lecture „Electricity" Exercises to „Electricity" Beginners' Lab I: "Mechanics and electricity"		
Assessment of Credit Points	**Study achievemt:** Problem sets and labs		
Note compound	-		
Credit points (ECTS): 12	**Attendance study (h):** 150	**Self study (h):** 210	

Competence:
The students have a sound factual knowledge about Electricity. They know the relevant physical laws and can make them plausible with key experiments. The students are familiar with the treatment of problems of appropriate difficulty in electricity and can solve appropriate problems in these areas independently.
The students know the basic principles of experimenting in the lab. They know the function and resolution oft he most important equipment and computer-based data acquisition. They are able to present their measurement results in tabular and graphical form.

Content:

Lecture and Exercises:
- Electrostatics, electric current
- Static magnetic fields
- Time-varying fields
- Maxwell's equations
- Electromagnetic waves

Beginners' Lab I: Mechanics und Electricity
Lab experiments, selection out of: Oscillations, coupled pendulums, spinning top, ultrasound, acoustics, Maxwell-wheel, temperature, viscosity, specific heat, water vapour, resistance, resonant circuits, transistor, operational amplifier, flop circuit, feedback, galvanometer, fluorescent lamp, oszilloscope, magnetic field, full cell

Fundamental 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 knowledge:
Lectures „Mechanics and relativity", and „Mathematical methods of physics"

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:
- Bachelor Physics (Basic module)
- Bachelor Meteorology (Basic module)

Optics, atomic physics, quantum phenomena (Optik, Atomphysik, Quantenphänomene)			1013
Semester	Winter semester		
Responsibility	Institute of Experimental physics		
Courses	Lecture "Optics, atom physics, quantum phenomena" Exercises to "Optics, atom physics, quantum phenomena" Laboratory II: Optics and atom physics		
Assessment of credit points	**Study achievement:** Exercises and laboratory		
Note compound	-		
Credit points (ECTS): 10	**Attendance study (h):** 120	**Self study (h):**	180

Competence:
The students know the fundamental experimental results and understand the underlying physical principles of optics and atomic physics. The students are able to apply these principles independently to physical problems. The students know the functionality and accuracy of different measurement instruments and are familiar with fitting functions to measurement data. They can estimate measurement errors appropriately and are familiar with error propagation.

Content:

optics, atomic physics, quantum phenomena
- Geometric optics
- Wave properties of light: interference, diffraction, polarisation, birefringence
- optics, optical instruments
- matter waves, wave-particle-dualism
- structure of atoms
- energy states, angular momentum, magnetic moment
- multi-electron systems, Pauli-principle spectroskopy, spontaneous and stimulated emission

Laboratory II: Optics and atomic physics
possible practical experiments: lenses, interferometer, diffraction, microscope, prism, grating, photo effect, spectroscopic instrument, polarisation

Fundamental literature:
- 🕮 Demtröder *Experimentalphysik 2 und 3*, Springer Verlag
- 🕮 Berkeley Physikkurs
- 🕮 Bergmann/Schäfer
- 🕮 Haken, Wolf, *Atom- und Quantenphysik, Springer Verlag*

Recommended knowledge:
Lectures "Mechanics und relativity" and "Electricity"

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:
- Bachelor Physics (Basic module)
- Bachelor Meteorology (Basic module)

Molecules, nuclei, particles and solids (Moleküle, Kerne, Teilchen, Festkörper)			**1014**
Semester	Summer semester		
Responsibility	Institute for Experimental physics		
Courses	Lecture Molecules, nuclei, particles and solids Exercises for Molecules, nuclei, particles and solids Grundpraktikum III: Thermodynamics		
Assessment of credit points	**Study achievement:** Exercises and laboratory		
Note compound	-		
Credit points (ECTS): 10	**Attendance study (h):** 120	**Self study (h):**	180

Competence:
The students know fundamental experimental findings and the laws governing the structure of matter ranging from elementary particles to solid-state physics. They understand the basic connections to the fundamental laws of mechanics, electrodynamics, and quantum mechanics. The students are able to apply these principles independently to physical problems.
The students are familiar with the operation of the usual measuring instruments. They are able to log the results of measurements cleanly and completely and to question them critically.

Content:

Molecules, Nuclei, Particles and Solids:
- Molecules: Chemical binding, molecular spectrocopy
- Structure of matter
- Nuclei and elementary particles
- Radioactivity and measurement methods in the context of nuclear physics
- Fundamentals of statistics
- Fundamental theorems of thermodynamics

Basics practical course III: Thermodynamics
possible practical courses: Pyrometer, Black body radiation, Stirlingvmotor

Fundamental literature:
- Demtröder *Experimentalphysik 2 und 3*, Springer Verlag
- Berkeley Physikkurs
- Bergmann/Schäfer
- Haken, Wolf, *Atom- und Quantenphysik* sowie *Molekülphysik und Quantenchemie, Springer Verlag*

Recommended knowledge:
Lectures "Mechanics and relativity", "Electricity" and "Optics, atom physics, quantum phenomena"

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:
- Bachelor in physics (Basic module)
- Bachelor in meteorologie (Natural scientific technical electoral area)

<table>
<tr><th colspan="2">Module-Spanning Examine in Experimental Physics
(Modulübergreifende Prüfung Experimentalphysik)</th><th>1001</th></tr>
<tr><td>Semester</td><td colspan="2">Winter and summer semester</td></tr>
<tr><td>Responsibility</td><td colspan="2">Institute for Experimental physics</td></tr>
<tr><td>Courses</td><td colspan="2">Oral exam</td></tr>
<tr><td>Assessment of credit points</td><td colspan="2">Study achievement: oral exam</td></tr>
<tr><td>Note compound</td><td colspan="2">Note of the oral exam</td></tr>
<tr><td>Weight:</td><td colspan="2">2 (Physics)
28 (Meteorology)</td></tr>
<tr><td colspan="3">Competence:
The students acquired a thorough overview over the fundamental aspects of Experimental Physics.
They recognized the parallels and connections of the individual aspects of Physics and are able to present them in a scientific context. The students have an understanding of Physics as a whole and it's different characteristics at the individual length- and energy-scales. They are proficient in the knowledge acquisition through study of scientific literature.</td></tr>
<tr><td colspan="2">Content:
Physics:
• Mechanics and Relativity
• Electricity
• Optics, Atomic Physics and Quantum Phenomena
• Molecules, Nuclei, Particles and Solid State Physics</td><td>Meteorology:
• Mechanics and Relativity
• Electricity
• Optics, Atomic Physics and Quantum Phenomena</td></tr>
<tr><td colspan="3">If applicable, admission prerequisites and limited number of participants:</td></tr>
<tr><td colspan="2">Physics:
Three modules out of Mechanics and Relativity; Electricity; Optics, Atomic Physics and Quantum Phenomena; Molecules, Nuclei, Particles and Solid State Physics</td><td>Meteorology:
Two modules out of Mechanics and Relativity, Electricity, Optics, Atomic Physics and Quantum Phenomena.1021</td></tr>
<tr><td colspan="3">Module affiliation:
• Bachelor in Physik (Basic module)
• Bachelor in Meteorology (Basic module)</td></tr>
</table>

Mathematical Methods of Physics / Theoretical Electrodynamics (Mathematische Methoden der Physik / Theoretische Elektrodynamik)	1111

Semester	Winter and summer semester		
Responsibility	Institut for Theoretcal physics		
Courses	Lecture: Mathematical methods of physics Exercises for Mathematical methods of physics Lecture: Theoreical elektrodynamics Exercises for Theoretical elektrodynamics		
Assessment of credit points	**Study achievement:** each exercise on Mathematical Methods of Physics and Theoretical Electrodynamics **Exam achievement:** one of the exams to Mathematical Methods of Physics and to Theoretical Electrodynamics		
Note compound	does not enter the bachelornote		
Credit points (ECTS): 14	**Attendance study (h):** 150	**Self study (h):**	270

Compence:
Students learn the mathematical tools to formulate physical theories. Simple physical problems can be mathematically formalized and solved.
Students understand the logical structure of electrodynamics and can formulate its laws mathematically. They know prominent electrodynamical phenomena and are able to deduce these from the basic laws. Students find analytical strategies and apply suitable mathematical and physical approximations towards solving electrodynamical problems.

Content:

Mathematical Methods of Physics:

- vector algebra: scalar and cross product, index notation, determinants
- space curves: differentiation, chain rule, gradient, Frenet formula
- ordinary differential equations: solution techniques
- Newtonian mechanics of a point mass, systems of masse points
- tensors: matrices, rotations, transformation to principle axes, moment of inertia tensor
- harmonic oscillations: normal coordinates, resonance
- functions: inverse function, power series, Taylor series, complex numbers
- integration: one- and multi-dimensional, line and surface integrals
- one-dimensional motion: solution via energy conservation
- curvilinear coordinates: integration neasure, substitution rule, delta distribution

Theoretical Electrodynamics:

- vector analysis: vector fields, Gauss and Stokes theorem, Laplace operator
- Maxwell equations: integral form, initial and boundary data, boundary layers
- potentials, gauge redundancy, vacuum solution, solution in the presence of sources, retardation
- linear partial differential equations: separation of variables, Green's function
- Fourier analysis: function spaces, Fourier series, Fourier transformation
- electrostatics: boundary value problems, potential theory, multipole Eexpansion
- magnetostatics: one-dimensional current distributions, field energy
- moving point charges, Lienard-Wiechert potentials
- electromagnetic waves: in vacuum, with sources, radiation

Fundamental literature:

- Feynman, *Lectures on Physics*, Band 1+2, Addison-Wesley Verlag
- Großmann, *Mathematischer Einführungskurs für die Physik*, Teubner 2000
- Landau-Lifschitz, *Lehrbuch der Theoretischen Physik*, Band II, Harri
- J.D. Jackson, *Klassische Elektrodynamik,* Gruyter, Walter de GmbH
- Römer & Forger, *Elementare Feldtheorie,* Wiley

Recommended knowledge:

- High school knowledge of mathematics and physics

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:
- Bachelor in Physics (Basic module)
- Bachelor in Meteorology (Basic module)

Analytical mechanics and special relativity (Analytische Mechanik und sprezielle Relativitättstheorie)				1112
Semester	Winter semester			
Responsibility	Institut for Theoretical physics			
Courses	Lecture: Analytical mechanics and special relativity Exercises for Analytical mechanics and special relativity			
Assessment of credit points	**Study achievement:** Exercises			
Note compound	-			
Credit points (ECTS): 8	**Attendance study (h):** 90		**Self study (h):** 150	

Competence:
Students understand the logical structure of classical mechanics and special relativity and can formulate their laws mathematically. For both they know prominent phenomena and are able to deduce these from the basic laws. Students find analytical strategies and apply suitable mathematical and physical approximations towards solving selected problems.

Content:
- Lagrangian mechanics: constraints, Lagrange multipliers, Lorentz force
- variational calculus: funktional derivative, extrema under constraints
- action principle, Noether's theorem, conservation laws
- accelerated coordinate systems, ficticious forces, rigid-body kinematics
- rigid-body dynamics: Euler equations, spinning top, precession, nutation
- Hamiltonian mechanics: Legendre transformation, canonical equations, conservation laws
- canonical transformations: phase portrait, symplectic structure, invariants
- Lorentz-covariant formulation of Maxwell & Lorentz, Lagrangian density, conservation laws
- special relativity: kinematics, dynamics of point masses, four-vector notation

Fundamental literature:
- 🕮 Honerkamp & Römer, *Klassische Theoretische Physik,* Springer
- 🕮 Landau-Lifschitz, *Lehrbuch der Theoretischen Physik, Band I, Harri*
- 🕮 H. Goldstein, Poole & Safko, *Classical Mechanics,* Wiley-VCH Verlag GmbH & Co
- 🕮 L.N. Hand and J. D. Finch, *Analytical Mechanics,* Cambridge University Press
- 🕮 Römer + Forger, *Elementare Feldtheorie,* Wiley-VCH
- 🕮 Arnold, *Classical Mechanics,* Springer

Recommended knowledge:
- Lechture "Mathematical methods of physics/ Theoretical elektrodynamics"

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:
- Bachelor in Physics (Basic module)
- Bachelor in Meteorology (Natural scientific technical electoral area)

Modulübergreifende Prüfung Theoretische Physik I (Cross-module examination theoretical physics I)			1101
Semester	Winter and summer semester		
Responsibility	Institut for Theoretical physics		
Courses	oral exam		
Assessment of credit points	**Exam achievement:** oral exam		
Note compound	mark of the oral exam		
Weight: 1	**Attendance study** -	**Self study (h):** -	

Competence:
The students have a well-founded overview of classical die Gebiete der klassischen Mechanik, der speziellen Relativitätstheorie und der Elektrodynamik. They understand the areas as parts of a coherent theory and can sho parallels in the logical structure of the areas. They master the independent acquisition of knowledge party English books.

Content:
- Calculation methods of physics
- Theoretical electrodynamics
- Analytische Mechanik und spezielle Relativitätstheorie

If applicable, admission prerequisites and limited number of participants:
One of the lectures „Mathematical methods/ Theoretical elektrodynamics" or Analytical mechanics and special relativity

Module affiliation:
- Bachelor in Physics (Basic module)

Introduction to quantum theory (Einführung in die Quantentheorie)			1113
Semester	Summer semester		
Responsibility	Institut for Theoretical physics		
Courses	Lecture "Introduction to quantum theory" Exercises for "Introduction to quantum theory"		
Assessment of credit points	**Study achievement:** Exercises		
Note compound	-		
Credit points (ECTS): 8	**Attendance study (h):** 90	**Self study (h):** 150	

Competence:
The students are proficient in the mathematical tools of quantum theory. They understand the physical implications of the theory und know its relation to classical physics. They are able to apply the mathematical formalism of quantum theory to selected problems. They are familiar with the concepts of perturbation theory.

Content:
- Photons as simple quantum systems, particle motion, Schrödinger equation
- Hamiltonian formalism: postulates, transformations, Heisenberg picture
- Simple systems: oscillators, potential well, potential step, periodical potential
- Angular momentum: rotation symmetry, algebra, representation, addition of angular momenta, spin
- Central potential: separation of variables in the Schrödinger equation, Coulomb potential
- Approximation methods: stationary and time-dependent perturbation theory, variational methods, semiclassical approximation, applications
- Particle systems: identical particles, Fock space, Hartree-Fock approx., molecules, quantum field

Fundamental 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

Recommended knowledge:
Lectures "Mathematical methods/ Theoretical elektrodynamics" and "Analytical mechanics and special relativity"

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:
- Bachelor in Physics (Basic module)
- Bachelor in Meteorology (Natural scientific technical electoral area)

Statistical physics (Statistische Physik)				1114
Semester	Winter semester			
Responsibility	Institut for Theoretical physics			
Courses	Lecture: Statistical physics Exercises for Statistical physics			
Assessment of credit points	**Study achievement:** Exercises			
Note compound	-			
Credit points (ECTS): 8	**Attendance study (h):** 90		**Self study (h):** 150	

Competence:
The students are proficient in the mathematical description of the main principles of statistical physics. They are able to apply the concepts to problems in classical physics as well as in the quantum theory. They know the paradigms of statistical physcis and can discuss some of them mathematically.

Content:
- Basic concepts of statistical mechanics: probabilities, statistical ensembles, partition function, density matrix, entropy
- Ideal gas: polyatomic gases, Fermi gas, Bose gas, noninteracting spins, quasi-particles
- Phenomenological theory (Thermodynamics): Laws of thermodynamics, heat engines, irreversible processes, thermodynamical potentials and relations
- Interacting systems: mean-field theory, Monte Carlo simulations, Ising model, percolation, real gases, phase transitions
- Out-of-equilibrium statistical physics: fluctuations, Brownian motion kinetic gas theory, transport

Fundamental literature:
- L.P. Kadanoff, *Statistical Physics: Statics, Dynamics and Renormalization,* World Scientific Pub Co
- C. Kittel, H. Krömer, *Thermodynamik,* Oldenbourg
- L.D. Landau, E.M. Lifshitz, *Theoretische Physik*, Bd V+VI, Harri
- F. Schwabl, *Statistische Physik,* Springer

Recommended knowledge:
Lectures "Analytical mechanics and special relativity" and "Introduction to quantum theory"

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:
- Bachelor in Physics (Basic module)
- Bachelor in Meteorology (Natural scientific technical electoral area)

Modulübergreifende Prüfung Theoretische Physik II (Cross-module examination theoretical physik II)	1102
Semester	Winter and summer semester
Responsibility	Institut for Theoretical physics
Courses	Oral examination
Assessment of credit points	**Exam achievement:** oral examination
Note compound	The mark of the oral exam
Weight:	1

Competence:
The students have an overview of the fields of mechanics, electrodynamics, quantum mechanics and statistical physics. They understand these areas as parts of a comprehensive physical theory building.
They understand the similarities between the domains in terms of physical concepts and mathematical methods, such as the delineation of areas on different lengths and energy scales.
They master the independent acquisition of knowledge from textbooks.

Content:
- Introduction to quantum theory
- Statistical physics

If applicable, admission prerequisites and limited number of participants:
One of the modules "Introduction to quantum theory" or "Statistical physics" as well as the "Cross-module examination theoretical physics I"

Module affiliation:
- Bachelor Physics (Basic module)

Presenting Physics (Physik präsentieren)				1611
Semester	Winter and summer semester			
Responsibility	Institute for physics			
Courses	Proseminar			
Assessment of credit points	**Study achievement:** Seminar achievement			
Note compound	-			
Credit points (ECTS): 3	**Attendance study (h):** 30		**Self study (h):** 60	

Compentce:
The students are able to familiarize themselves with a given topic under guidance.
They can independently research literature and structure and hold a lecture.
They know common presentation and visualization techniques. The students speak the German language in free speech.

Content:
- Physical topics (selection from a topic field specified by the lecturer)
- Preparation of a presentation
- Success factors of a comprehensible presentation
- Use visualization media effectively
- Handling stage fright
- Scientific discussion

Fundamental literature:
Will be given tot he topic

Recommended knowledge:
- In consultation with the lecturer

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:
- Bachelor in Physics (Basic module)

Bachelor Physics – Deepence modules

Introduction to the solid state physics (Einführung in die Festkörperphysik)			1211
Semester	Winter semester		
Responsibility	Institut for Solid state physics		
Courses	Lecture "Introduction to the solid state physics" Exercises for "Introduction tot he solid stste physics" Internship to "Introduction to the solid state physics"		
Assessment of credit points	**Study achievement:** Exercises and laboratory		
Note compound	-		
Credit points (ECTS): 8	**Attendance study (h):** 105	**Self study (h):** 135	
Competentce: Students understand the basic concepts of solid state physics and can apply them independently to selected problems. They know advanced experimental methods of the area and can apply them under guidance.			
Content: • Crystals and crystal structure • reciprocal lattice • Crystal bond • Lattice vibrations, thermal properties, quantization, density of states • Fermi gas • Energy bands • Semiconductors, metals, fermi surface • Suggestions in solids • experimental methods: Roentgen diffraction, Scanning probe microscopy and electron microskopy, Conductivity, Magnetoresistance, Hall effect, Quantum hall effect			
Fundamental literature: 🕮 Ashcroft and Mermin, *Solid State Physics,* Oldenbourg 🕮 C. Kittel, *Einführung in die Festkörperphysik, Oldenbourg* 🕮 K. Kopitzki, *Einführung in die Festkörperphysik,* Vieweg+Teubner 🕮 H. Ibach, H. Lüth, *Festkörperphysik,* Springer			
Recommended knowledge: • Lectures „Mechanics and relativity", „Electricity", „Optics, atomic physics, quantum phenomena" and "Molecules, nuclei, particles and solids"			
If applicable, admission prerequisites and limited number of participants: Cross-module examination "Experimental physics"			
Module affiliation: • Bachelor in Physics (Deepence module) • Bachelor in Meteorology (Natural scientific technical electoral area)			

Atomic and molecular physics (Atom- und Molekülphysik)			1311
Semester	Winter semester		
Responsibility	Institut for Quantum optics		
Courses	Lecture „Atomic and molecular physics" Exercises for „Atomic and molecular physics" Internship to „ Atomic and molecular physics"		
Assessment of credit points	**Study achievement:** Exercises and laboratory		
Note compound	-		
Credit points (ECTS): 8	**Attendance study (h):** 105	**Self study (h):**	135

Competence:
The students understand the basic concepts of atomic and molecular physics and can apply them independently to selected problems. They know advanced experimental methods of the area and can apply them under guidance.

Content:
- Summary H-atoms
- Atoms in static electric and magnetic fields
- Fine and hyperfine structures of atomic states
- Interaction with the EM radiation field
- Many-electron system
- Atomic spectra/Spectroscopy
- Vibration und rotation of molecules
- Electronic structure of molecules
- Dissociation and Ionization of molecules
- Selected experiments of modern atomic and molecular physics

Fundamental 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 Molekülphysik und Quantenchemier,* Springer
- 🕮 R. Loudon, *The Quantum Theory of Light*, OUP, 1973
- 🕮 W. Demtröder, *Molekülphysik,* Oldenbourg, 2003 ISBN: 3486249746

Recommended knowledge:
- Lectures „Mechanicsa and relativity", „Electricty", „Optics, atomic physics, quantum phenomena" and „Molecules, nuclei, particles and solids"

If applicable, admission prerequisites and limited number of participants:
Cross-module examination „Experimental physics"

Module affiliation:
- Bachelor in Physics (Deepence module)
- Bachelor in Meteorology (Natural scientific technical electoral area)

Coherent Optics (Kohärente Optik)			1312
Semester	Summer semester		
Responsibility	Institut for Quantum optics		
Courses	Lecture „Coherent optics" Exercises for "Coherent optics" Laboratory „Coherent optics"		
Assessment of credit points	**Study achievement:** Exercises and laboratory		
Note compound	-		
Credit points (ECTS): 8	**Attendance study (h):** 105	**Self study (h):** 135	

Competence:
The student understands the fundamental concepts of coherent optics and can autonomously apply those on selected problems. He knows the relevant advanced experimental methods and can apply those under instructions.

Content:
- Maxwell equation and electromagnetic waves
- wave optics and matrix formalism in optics (such as ABCD-, Jones-, Müller-, Scattering-, Transfermatrices)
- Theory of diffraction, Fourier optics
- Resonators, concept of modes
- Light-matter interaction (classical, semi-classical and Bloch formalism)
- Rate equation and laser dynamics
- Types and important components of lasers as well as applications of lasers
- Concept of mode-coupled lasers
- single-mode and single-frequency laser
- Laser noise and control
- Laser interferometry
- Heterodyne und Homodyne measurements

Fundamental 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
- 🕮 Originalliteratur

Recommended knowledge:
- Lecture „Mechanics and relativity", „Electricity", „Optics, atomic physics, quantum phenomena" and "Molecules, nuclei, particles, solids"

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:
- Bachelor in Physics (Deepence module)

Cross-module exam deepence area (Modulübergreifende Prüfung Vertiefungsbereich)	1002
Semester	Winter and summer semester
Responsibility	Institute for Experimental physics
Courses	oral exam
Assessment of credit points	**Exam achievement:** oral exam
Note compound	oral examination mark
Weight:	1

Competence:
The students understand the basic concepts of two advanced areas of physics. They know the relationships of the territories to each other and are able to show effects of new insights of one area on the other.

Content:
Two oft he modules:

- Introduction to the solid state physics
- Atomic and molecular physics
- Coherent optics

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:

- Bachelor in Physics (Deepence area)

Bachelor Physik – Elective area

Modern aspects of physics (Moderne Aspekte der Physik)				1601
Semester	Winter and summer semester			
Responsibility	Institute for Physics			
Courses	Selection of courses with a minimum of 12 credits according to the course catalog.			
Assessment of credit points	**Study achievement:** gemäß §6 der Prüfungsordnung **Exam achievement:** mündliche Prüfung			
Note compound	oral examination mark			
Credit Points (ECTS): 12 **Weight:** 1	**Attendance study (h):** 240		**Self study (h):** 240	
Competence: The students have in-depth knowledge in selected areas of physics. They are able to classify newly acquired knowledge in the logical thought building of physics. Students are able to understand English language literature.				
Content: Further physics courses of your choice. The examination comprises courses of at least 4 credits at the choice of the students.				
Fundamental literature: It will be announced in the lecture.				
Recommended knowledge: Basic lectures of Physics				
If applicable, admission prerequisites and limited number of participants: none				
Module affiliation: • Bachelor in Physics (physical elective module)				

Foundations of laser medicine and biomedical optics **(Grundlagen der Lasermedizin und Biomedizinischen Optik)**			
Semester	Winter semester		
Responsibility	Alexander Heisterkamp, Holger Lubatschowski		
Courses	**Foundations of laser medicine and biophotonics**		
Assessment of credit points	**Study achievement:** regular participation, participation at the block seminar and excursion **Exam achievement:** oral or written exam at professors choice		
Note compound	Examination mark		
Credit points (ECTS): 4 **Weight:** 1	**Attandence study (h):** 45	**Self study (h):** 30	

Competence:
The students will be introduced to the foundation of laser tissue interaction and they learn to implement the knowledge in clinical relevant application example. In the block seminar and in tutorials (end of semester) they develop and discuss current original article. At the end of the class an excursion to the research lab at the Laser Center Hanover (LZH) and the company Rowiak takes place.

Content:
- Laser systems for the use in medicine and biology
- Ray control system and optical medical equipment
- Optical characteristics of tissue
- Thermal characteristics of tissue
- Photochemical interactions
- Vaporization/coagulation
- Photoabliation, opto acoustic
- Photodisruption, nonlinear optics
- Applications in ophthalmology, refractive surgery
- Laser based diagnosis, optical biopsy
- Optical coherence tomography, theragnostics
- Clinical application example

Fundamental 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 knowledge:
- Lecture „Coherent Optics"

If applicable, admission prerequisites and a limited number of participants:
Limited number of presentations at the block seminar (20 available places, 5 ECTS), Participation in lecture class and block seminar unlimited (4 ECTS)

Module affiliation:
- Bachelor in Physics (Deepence phase/ modern aspects of physics)
- Master in Physics (Advanced deepence phase/ modern aspects to physics)

Key competencies (Schlüsselkompetenzen)		????
Semester	Winter and summer semester	
Responsibility	Student deanery	
Courses	Courses from the offer of the specialized language center or the center for key competences and correspondingly advertised offers of the faculties as well as computer courses from the data center offer.	
Assessment of credit points	**Study achievement:** according to §6 of the examination regulation	
Note compound		
Credit points (ECTS): 2-4	**Attendance and self study (h):**	60-120
Competence: You learn and master exemplary key competences in the field of the chosen course		
Content: • Content depending on the chosen course		
Fundamental literature: It will be announced in the course.		
Recommended knowledge: none		
If applicable, admission prerequisites and limited number of participants: none		
Module affiliation: • Bachelor in Physics		

Bachelor Meteorology – Basic modules

The module description for the basic modules „Mechanics and relativity", „Electricity", „Optics, atomic physics, quantum phenomena", „Cross-module exam Experimental physics" and „Mathematical methods of physics/ Theoretical elektrodynamics" can be found in the section **Bachelor Physics – Basic modules** (From page 4).

Linear algebra (Lineare Algebra)				**2550**
Semester		Winter and summer semester		
Responsibility		Institut for Algebra, Number theory and Discrete mathematics and Institut for Algebraic geometry		
Courses		Lecture Linear Algebra A Exercises for Linear Algebra A Lecture Linear Algebra B Exercises for Linear Algebra B		
Assessment of credit points		**Study achievement:** Exercises for Linear Algebra A und B **Exam achievement:** One exam each to Linear Algebra A and B		
Note compound		The bettermark of the two exams determines the overall mark of the module.		
Credit points (ECTS): **Weight:**	8 4	**Attendance study (h):**	90	**Self study (h):** 150

Competence:
Basic understanding of the mathematical way of thinking and its application towards a variety of problems. Solid competence in handling systems of linear equations and the corresponding methods for solving them; sound knowledge of the underlying algebraic structures. Capability of expressing and presenting mathematical reasoning, and knowledge of adequate methods for this.

Content:

- Basic properties of vector spaces (basis and dimension);
- linear maps and matrices;
- determinants;
- systems of linear equations and methods for solving them (Gauss algorithm);
- eigenvalues and eigenvectors;
- diagonalisation;
- Euclidean vector spaces
- quadrics

Fundamental literature:

- 🕮 G. Fischer: *Lineare Algebra*

Recommended knowledge:

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:

- Bachelor Meteorology (Basic module)

Analysis			2551
Semester	Winter and summer semester		
Responsibility	Institut for analysis		
Courses	Lecture „Analysis A" Exercises for „Analysis A" Lecture „Analysis B" Exercises for „Analysis B"		
Assessment of credit points	**Study achievement:** Exercises for Analysis A und B **Exam achievement:** One exam each for Analysis A and B		
Note compound	The better note of the two exams determines the overall grade		
Credit points (ECTS): 10 **Weight:** 5	**Attendance study (h):** 120	**Self study (h):** 180	
Competence goals: Competence in dealing with mathematical language. Basic understanding of the correct solution of mathematical problems by means of one-dimensional convergence considerations, differential and integral calculus. As a result of the exercise sessions, the students are familiar with mathematically exact formulations and conclusions in simple contexts and are able to present them.			
Content: Analysis A: Sequences and series. Convergence and continuity. Differential and integral calculus for functions of one variable. Analysis B: Differentiation of functions of several variables, extrema; ordinary differential equations.			
Fundamental literature: 🕮 H. Amann & J. Escher: *Analysis I und II, Birkhäuser Verlag, 2002* 🕮 O. Forster: *Analysis 1 und 2, Vieweg+Teubner* 🕮 K. Meyberg & P. Vachenauer: *Höhere Mathematik 1, Springer-Verlag 2001*			
Recommended knowledge:			
If applicable, admission prerequisite and limitednumber of participants: none			
Module affiliation: • Bachelor Meteorology (Basic module)			

Applied mathematics (Angewandte Mathematik)			2552
Semester	Winter and summer semester		
Responsibility	Institut for Mathematical stochastics, Institut for Applied mathematics		
Courses	Lecture „Numerical mathematics A" Exercises for „Numerical mathematics A" Lecture „Stochastics A" Exercises for „Stochastics A"		
Assessment of credit coints	**Study achievement:** Exercises for "Numerical mathematics A" and "Stochastics A" **Exam achievement:** One exam each for "Numerical mathematics A" and "Stochastics A"		
Note compound	Grade of the two exam (to the same weight)		
Credit points (ECTS): 8 **Weight:** 8	**Attendance study (h):** 90	**Self study (h):** 150	

Competence:
Knowledge of numerical methods for approximatively solving basic mathematical problems. Assessing the suitability of different methods. Being aware of areas of application and limitations of numerical methods.
Safe handling of stochastic methods and statistical questions.
Knowledge of the basics of combinatorics, probability theory and statistical methods. Understanding the models, mastering elementary stochastic ways of thinking. Ability to mathematically describe and analyze simple random problems and to solve simple tasks with presentation in the exercise.

Content:
Numerical mathematics A:

- Interpolation of functions by polynomials and splines
- Quadrature formulae for numerical integration
- Direct methods for linear systems of equations: LU and Cholesky decomposition
- Iterative methods for linear systems of equations: Jacobi, Gauss-Seidel, CG
- Newton's method for systems of nonlinear equations.
- Condition of mathematical problems and stability of numerical algorithms.

Stochastics A:

- Probability theory
- Laplace experiments
- Conditional probabilities and independence,
- Random variables and their distributions,
- Central limit value set

Fundamental literature:

- Quarteroni, R. Sacco, F. Saleri*: Numerische Mathematik I und II. Springer-Verlag.*
- Georgii, H.: *Stochastik, de Gruyter*

Recommended knowledge:

If applicable, admission prerquisite and limited number of participants: none

Module affiliation:

- Bachelor Meteorology (Basic module)

Applied programming (Angewandtes Programmieren)			2553
Semester	Summer semester		
Responsibility	Institut for Meteorology and Climatology		
Courses	Lecture Applied programming Exercises Applied programming		
Assessment of credit points	**Study achievement:** Exercieses		
Note compound	-		
Credit points (ECTS): 4	**Attendance study (h):** 45	**Self study (h):**	

Competence:
The students master the basics of programming in a high-level programming language and can apply them themselves when developing their own programs for solving simple problems (methodological competence).

Content:

- Blocks of programs: application sequences, loops, alternatives
- Program schedules, structograms
- FORTRAN95 language elements: data types, fields, expressions, field expressions, IF, CASE, DO structures
- formatted and unformatted input / output, NAMELIST I / O
- Program units: subprograms, modules, interfaces

Fundamental literature:

🕮 Metcalf, M. und J. Reid: *FORTRAN 90/95 Explained.* Oxford University Press.

Recommended knowledge: none

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:

- Bachelor Meteorology (Basic module)

Introduction to meteorology (Einführung in die Meteorologie)			2560
Semester	Summer and winter semester		
Responsibility	Institut for Meteorology and limatology		
Courses	Lecture „Introduction to meteorology I" Exercises for „Introduction to meteorology I" Lecture „Introduction to meteorology II" Exercises for „Introduction to meteorology II"		
Assessment of credit points	**Study achievement:** Exercises to „Introduction to meteorology I and II" **Exam achievement:** One exam each for „Introduction to meteorology I and II"		
Note compound	Grade of the two exams (to the same weight)		
Credit points (ECTS): 8 **Weight:** 8	**Attendance study (h):** 90	**Self study (h):** 150	

Competence:
Upon completion of the cycle, the students will have an overview of meteorology and environmental physics so that competencies will be available for the subsequent lectures in atmospheric physics and meteorology. The exercises also promote communication skills and methodological competence in the implementation of specialist knowledge.

Content:
Introduction to Meteorology I:
The atmosphere and the earth system. Weather and climate. Atmospheric scales. The most important physical quantities for describing the atmosphere; Their typical spatial and temporal variability and their measurement methods. The basics of solar and terrestrial radiation. The chemical composition of the air, water vapor, ozone including the ozone hole formation mechanisms, the greenhouse gases and climate change, the water cycle and the mass circulation of various trace gases.
Introduction to Meteorology II:
Basics of aerosols, clouds and rainfall. Mass, impulse, and energy fluxes in the Earth system. Energy conversion, thermodynamic basic equations, meteorological observation systems as well as international measuring networks, energy meteorology.

Fundamental literature:
- 🕮 **Kraus, *Die Atmosphäre der Erde: Eine Einführung in die Meteorologie,* Springer**
- 🕮 Hauf, Seckmeyer, *Skript zur Vorlesung Einführung in die Meteorologie I*
- 🕮 Hauf, Seckmeyer, *Skript zur Vorlesung Einführung in die Meteorologie II*
- 🕮 Häckel, *Meteorologie,* UTB, Stuttgart
- 🕮 Roedel, *Physik unserer Umwelt,* Springer
- 🕮 Liljequist, *Allgemeine Meteorologie*, Springer

English:
- 🕮 Kshudiram Saha, The Earth's Atmosphere - Its Physics and Dynamis, Springer

Recommended knowledge:

If applicable, admission prerequisite and limited number of participants: none

Module affiliation:
- Bachelor Meteorology (Basic module)
- Bachelor Geography
- Master Landscape architecture
- Bachelor and Master Physics

Radiation (Strahlung)			2003
Semester	Summer and winter semester		
Responsibility	Institut for Meteorology and climatology		
Courses	Lecture "Radiation I" Lecture "Radiation II" Exercises to „Radiation I" Exercises to „Radiation II"		
Assessment of credit points	**Study achievement:** Exercises to "Radiation I" and "Radiation II" **Exam achievement:** Oral exam		
Note compound	Mark of the oral exam		
Credit points (ECTS): 8 **Weight:** 8	**Attendance study (h):** 90	**Self study (h):** 150	

Competence:
The students have deepened their physical and meteorological knowledge in the field of solar radiation and can apply it. They know various measurent techniques of radiation physics of non-ionizing radiation and their quality assurance as well as their quality control. The theoretical and experimental exercises also promote communication skills and methodological competence in the implementation of specialist knowledge.

Content:
- Basic concepts of radiation physics, radiation processes in the atmosphere
- Measurement methods of radiation physics
- Basics of light technology
- Basic astronomical, chemical, biological and medical principles
- Methods for calculating the radiation transfer in the atmosphere

Findamental literature:
- 🕮 Seckmeyer et al., *Instruments to measure solar ultraviolet radiation, Parts 1-4*: WMO-GAW reports, No.126, 2001, No. 164, 2006, No. 190, 2010, No. 191, 2011
- 🕮 Seckmeyer, *Skript zur Vorlesung Strahlung*
- 🕮 Bergmann-Schäfer, Band 3 *Optik*, Gruyter

Englisch:
- 🕮 Petty, A first course in atmospheric radiation

Recommended knowledge:
- Module "Introduction to meteorology (Einführung in die Meteorologie)"

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:
- Bachelor Meteorology (Basic module)
- Master Optical technologies
- Bachelor and Master Physics

Cloud physics (Wolkenphysik)			2011
Semester	Summer semester		
Responsibility	Institut for Meteorology and climatology		
Courses	Lecture „Cloud physics" Exercises to „Cloud physics"		
Assessment of credit points	**Study achievement:** Exercises **Exam achievement:** Oral exam		
Note compound	Note of the oral exam		
Credit points (ECTS): 4 **Weight:** 4	**Attendance study (h):** 45	**Self study (h):** 75	

Competence:
Students will get deeper physical knowledge in cloud physics processes and are able to apply them in theoretical examples.

Content:
- theory of aerosol activation, diffusional growth, and collision/coalescence
- the warm rain process
- basics of ice- and mixed-phase clouds
- fundamentals of numerical cloud models

Fundamental literature:
- 🕮 Pruppacher und Klett, *Microphysics of Clouds and Precipitation,* Springer
- 🕮 Rogers, *Cloud Physics* A Butterworth-Heinemann Title; 3 edition,
- 🕮 Lamb and Verlinde, 2011: *Physics and Chemistry of Clouds*, Cambridge

Recommended knowledge:
- Modul "Introduction to meteorology (Einführung in die Meteorologie)"
- Lecture and exercises „Thermodynamics and statics (Thermodynamik und Statik)"

If applicable, admission prerequisites and limited number of participants: no

Module affiliation:
- Bachelor Meteorology (Basic module)
- Bachelor and Master Physics

Instrument internship (Instrumentenpraktikum)			2102
Semester	Winter semester		
Responsibility	Institut for Meteorology and Climatology		
Courses	Internship Instrument internship		
Assessment of credit points	**Study achievement:** Laboratory		
Note composition	-		
Credit points (ECTS): 6	**Attendance study (h):** 90	**Self study (h):** 90	

Competence:
The students know the basic meteorological measurement methods and can apply them practically, whereby the critical assessment of measurement results in terms of their informative value and accuracy is of major importance. Conducting the experiments in small groups also promotes teamwork.

Content:
- Carrying out laboratory and field tests with measurements of the basic meteorological variables temperature, pressure, humidity, wind speed as well as individual components of the radiation and energy balance

Fundamental literature:
Script to Instrument internship

Recommended knowledge:
- Module Introduction in meteorology (Einführung in die Meteorologie)
- Module Mechanics and relativity (Mechanik und Relativität), Electricity (Elektrizität), Optics, nuclear physics, quantum phenomena (Optik, Atomphysik, Quantenphänomene) and Molecules, cores, particles, solids (Moleküle, Kerne, Teilchen, Festkörper)
- Module Radiation (Strahlung)

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:
- Bachelor Meteorology (Basic module)
- Master Landscape sciences
- Bachelor Physics

Climatology (Klimatologie)				2002
Semester	Winter semester			
Responsibility	Institut for Meteorology and Climatology			
Courses	Lecture Climatology Exercises to Climatology			
Assessment of credit points	**Study achievement:** Exercises **Exam achievement:** Exam			
Note compound	Note of the exam			
Credit points (ECTS): 4 **Weight:** 4	**Attendance study (h):** 45		**Self study (h):** 75	

Competence:
The students have an overview of the climatology, so that competencies for the later classification of special knowledge of meteorology and climatology within the climatology are obtained. The exercises also foster communication skills and methodological skills in the implementation of expertise.

Content:

Climate system: Components of the climate system
climates of the earth
Energy and water balance
General circulation of the atmosphere and the ocean
regional circulation systems
Climate change
Climate Modeling
Air Forecast
Climate Policy

Fundamental literature:
- Mahlberg, *Meteorologie und Klimatologie*, Springer Verlag
- Peixoto & Oort, *Physics of Climate*, Springer Verlag
- Roedel, *Physik unserer Umwelt*, Springer Verlag
- Schönwiese, *Klimatologie*, UTB, Stuttgart

Recommended knowledge:
- Module Introduction in meteorology

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:
- Bachelor Meteorology (Basic module)
- Bachelor Geography
- Bachelor und Master Physics

Theoretical meteorology (Theoretische Meteorologie)			2561
Semester	Winter and summer semester		
Responsibility	Institut for Meteorology and climatology		
Courses	Lecture „Thermodynamics and statistics" Exercise to "Thermodynamics and statistics" Lecture "Kinematics and dynamics" Exercises to "Kinematics and dynamics" Lecture "Turbulencs and diffusion" Exercises to "Turbulencs and diffusion"		
Assessment of credit points	**Study achievement:** Exercises to „Thermodynamics and statics", "Kinematics and dynamics" and "Turbulence and diffusion" **Exam achievement:** One eaxm each for „Thermodynamics and statics", "Kinematics and dynamics" and "Turbulence and diffusion"		
Note compound	Grade of the three exams (tot he same weight)		
Credit points (ECTS): 12 **Weight:** 12	**Attendance study (h):** 135	**Self study (h):** 225	

Competence:
Students are learning the basics of theoretical meteorology and are able to apply them in exercises (Methodenkompetenz).

Content:
Thermodynamics and Statics
- first and second principle of thermodynamics, entropy, Carnot circle, thermodynamic efficiency
- potential temperature, thermal stratification, vertical structure of the atmosphere at rest
- water and its phase changes
- thermodynamic diagrams

Kinematic and Dynamic
- physical-mathematical basics of atmospheric flows: Euler equation of motion, vorticity-equation (2D/3D), quasi-geostrophic equations
- meteorological phenomena: geostrophic and thermal wind, sound waves, gravity waves, Rossby waves
- linearisation, stability analysis
- barotropic and baroclinic instability

Turbulence and Diffusion
- meteorological phenomena which are dominated by friction
- Navier-Stokes-equation
- Reynolds-averaging, equation for the turbulent kinetic energy, Richardson-flux-number
- vertical wind profiles and processes in the atmospheric boundary layer: constant-flux layer, Ekman layer

Fundamental literature:
- 🕮 Etling, *Theoretische Meteorologie*, Springer Verlag
- 🕮 Bohren und Albrecht, *Atmospheric Thermodynamics, Oxford University Press*
- 🕮 Holton, J.R.: *An Introduction to Dynamic Meteorology, Academic Press*
- 🕮 Dutton, J.A.: *The Ceaseless Wind,* Dover Pubns
- 🕮 Stull, R.B.: *An Introduction to Boundary Layer Meteorology,* Springer

Recommended knowledge:
- Module „Introduction to meteorology (Einführung in die Meteorologie)"
- Module „Mechanics and relativity (Mechanik und Relativität)"
- Lecture and exercises to "Mathematical methods of physics (Mathematische Methoden der Physik)"

If applicable, admission prerequisites and limited number of participants : none

Module affiliation:
- Bachelor Meteorology (Basic module)
- Bachelor und Master Physics

Synoptic meteorology (Synoptische Meteorologie)				2104
Semester	Winter and summer semester			
Responsibility	Institut for meteorology and climatology			
Courses	Lecture „Synoptic meteorology I" Exercises for „Exercises to operational synoptic" Lecture „ Synoptic meteorology II" Seminar „Weather discussion" Exercises for "Introduction to the working with NINJO"			
Assessment of credit points	**Study achievement:** Exercises to the lectures and seminar achievement to "Weather discussion"			
Note compound	-			
Credit points (ECTS): 8	**Attendance study (h):** 164		**Self study (h):** 76	

Competence:
The students understand the basics of weather analysis and forecasting, create weather analyzes and forecasts under guidance and with existing information systems and present them in writing and orally with subsequent discussion. In addition to their expertise, they will develop skills in media use, critical discussion, presentation to specialist audiences, as well as customer-oriented processing / presentation of specialist knowledge.

Content:

- Use of modern meteorological information systems
- Analysis of atmospheric states
- Prediction of weather development
- Presentation of results
- Own contributions to the scientific discussion of weather analysis and prediction

Fundamental literature:

- 🕮 Kurz, *Synoptische Meteorologie*, Band 8 der Leitfäden für die Ausbildung im Deutschen Wetterdienst, Offenbach 1990.
- 🕮 Bott, *Synoptische Meteorologie – Methoden der Wetteranalyse und –prognose*, Springe, Berlin Heidelberg 2012

Recommended knowledge:

- Module „Introduction to meteorology"
- Lecture and exercises to Thermodynamics and statics and "Kinematics and dynamics"

If applicable, admission prerequisite and limited number of participants: none

Module affiliation:

- Bachelor meteorology (Basic module)
- Master Landscape achitecture

Study and job (Studium und Arbeit)		2105
Semester	Winter semester, no lecture time (internship), following winter semester (presentaion)	
Responsibility	Institut for Meteorology and Climatology	
Courses	Seminar „Introduction in the study of meteorology" Internship „Professional internship"	
Assessment of credit points	**Study achievement:** Internship with report	
Note compound	-	
Credit Points (ECTS): 5	**Attendance and self study (h):** 150	

Competence:
In the first semester, the students are introduced to the study of meteorology, familiarized with the specific requirements in terms of subject matter and methodology, and get to know lecturers and research at the institute and the meteorological professional world in relation to their own professional and study concepts.

Content:

- Introduction to university facilities and student life
- Introduction to research at the institute
- 4-week practical employment in research, government or industry under meteorological supervision individual student counseling / mentoring

Fundamental literatue:

- 🕮 Hans-Werner Rückert *Studieneinstieg, aber richtig. Das müssen Sie wissen: Fachwahl, Studienort, Finanzierung, Studienplanung*, 2002, ISBN: 3-593-36899-4, Gruppe: Studienratgeber, Reihe: campus concret, Band: 65
- 🕮 Otto Kruse, *Handbuch Studieren,Von der Einschreibung bis zum Examen*,1998, ISBN: 3-593-36070-5, Gruppe: Studienratgeber, Reihe: campus concret, Band: 32

Recommended knowledge:

If applicable, admission prerequisite and limited number of participants: none

Module affiliation:

- Bachelor Meteorology (Basic module)

Meteorological excursion I (Meteorologische Exkursion I)		2106
Semester	Summer semester, no lecture time (internship)	
Responsilbility	Institut for Meteorology and climatology	
Courses	Excursion „Meteorological excursion I"	
Assessment of credit points	**Study achievement:** Excursion report	
Note compound	-	
Credit points (ECTS): 2	**Attendance and self study (h):**	60

Competence:
Before the excursion, the students will deal with a thematic aspect of the excursion, present it during the excursion and will be available as discussion and contact persons, write a written contribution to the excursion report, discuss it with the supervisor and then report during the final seminar, Thus, a thematic aspect is permeated in a special way in content. The presentation will further train the lecture technique.

Content:
- Participation in a one-week or two-week thematic excursion (eg maritime or alpine)
- Preparation for a thematic part of the excursion and a written elaboration as contribution to the excursion report. Presentaion (10 min.) in the excursion seminar.

Fundamental literature:
- Ursula Steinbuch *Raus mit der Sprache. Ohne Redeangst durchs Studium.* 2005 ISBN: 3-593-37838-8, Gruppe: Studienratgeber, Reihe: campus concret

Recommended knowledge:
- Module „Study and job"
- Lecture "Introduction to meteorology I"

If apllicable, admission prerequisite and limited number of participants: none

Module affiliation:
- Bachelor meteorology (Basic module)

Bachelor meteorology – Elective subject

Elective module meteorology (Wahlmodul Meteorologie)		2107
Semester	Winter semester or summer semester	
Responsibility	Institut for meteorology and climatology	
Courses	See in the lecture-catalog (Lehrveranstaltungskatalog)	
Assessment of Credti Points	**Study achievement:** according to §6 of the examination regulation **Exam achievement :** oral exam (exam equivalent to at least 8LP)	
Note compound	the note of the oral exam	
Credit Points (ECTS): 20 **Weight:** 8	**Attendance and self study (h):** 600	
competence goals: Expansion of expertise.		
Content: • See in the lecture-catalog (Lehrveranstaltungskatalog**)** • A programming internship must be chosen		
Fundamental literature: See in the lecture-catalog (Lehrveranstaltungskatalog)		
Recommended knowledge: • See in the lecture-catalog (Lehrveranstaltungkatalog)		
If applicable, admission prerequisite and limited number of participants: See in the lecture-catalog (Lehrveranstaltungskatalog)		
Module affiliation: • Bachelor meteorology (Elective subject meteorology)		

Bachelor Meteorology – Scientific-technical elective area

Scientific-technical elective area (Wisschenschaftlich-technischer Wahlbereich)	2108
Semester	Winter or summer semester
Responsibility	Institut for Meteorology and Climatology
Courses	Lectures of 12 credit points of the F aculty of Mathematics and Physics, Faculty of Electrical Engineering and Computer Science, Faculty of Mechanical Engineering and Faculty of Natural Sciences or, upon application, modules of other faculties
Assessment of credit points	Study achievement: According to the examination regulations of the offering faculty. If the examination regulations of the offering faculty don't provide a study achievement but an exam achievement, then the exam achievement will be treated and recognized as study achievement.
Note compound	-
Credit Points (ECTS): 12	**Attendance and self study (h):** 360
Competence: Acquisition of interdisciplinary knowledge into other scientific or technical disciplines.	
Content: • See lecture-catalog (Lehrveranstaltungskatalog)	
Fundamental literature:	
Recommended knowledge:	
If applicable, admission prerequisites and limited number of participants:	
Module affiliation: • Bachelor Meteorology (Scientific-technical elective area)	

Bachelor Meteorologie – Schlüsselkompetenzen

Key competences (Schlüsselkompetenzen)		2570
Semester	Winter and summer semester	
Responsibility	Institut for Meteorology and Climatology	
Courses	Courses from the offer of the specialized language center or the center for key competences and correspondingly advertised offers of the faculties as well as computer courses from the data center offer. A course in the area of "Scientific Writing" amounting to 2LP must be taken.	
Assessment of credit points	**Study achievement:** according to §6 of the examination regulation	
Note compound		
Credit points (ECTS): 2-4	**Attendance and self study (h):**	60-120
Competence: • Students can write scientific texts and master the basics of correct citation and evidence. • You learn and master exemplary key competences in the field of the selected course		
Content: • Basics of scientific writing • Handling of specialist literature • Correct citation and evidence • Further content depending on the chosen course		
Fundamental literature: • Will be said in the course		
Recommended knowledge: • none		
If applicable, admission prerequisites and limited number of participants: none		
Module affiliation: • Bachelor Meteorology (Basic module)		

Master physics – Advanced expansion phase

Advanced solid state physics (Fortgeschrittene Festkörperphysik)				**1221**
Semester	Winter semester			
Responsibility	Institute für Festkörperphysik			
Courses	Lecture „Advanced solid state physics" Exercises to „Advanced solid state physics"			
Assessment of credit points	**Study achievement:** short tests and/or solving problems **Exam achievement:** oral or written exam (lecturer's choice)			
Note compound	note of the exam			
Credit Points (ECTS): 5 **Weight:** 1	**Attendance study (h):** 60		**Self study (h):** 90	

Competence goals:
Students will acquire in-depth knowledge of theoretical models and experimental results in solid state physics. They will be enabled to classify selected phenomena and to develop models suited for their understanding. They get to know important developments in the field that evolved over the last decades and have a clear impression of actual unsolved problems in solid state physics. The students will be able to judge advantages and disadvantages of certain experimental techniques and acquire knowledge about the complementarity of various experimental possibilities.

Content:
- superconductivity
- dia- and paramagnetism
- ferro- and antiferromagetism
- magnetic resonance
- physics in systems of finite size
- physics in one and two dimensions, at surfaces and interfaces
- disorder: defects, alloys and glasses

Fundamental literature:
- 🕮 Ashcroft, Mermin, *Festkörperphysik*, Oldenbourg Verlag
- 🕮 Ch. Kittel, *Einführung in die Festkörperphysik*, Oldenbourg Verlag

Recommended knowledge:
- Introduction to solid state physics (Einführung in die Festkörperphysik)

If applicable, admission prerequisites and limited number of participants: no

Module affiliation:
- Master physics (Adcanced expansion phase)

Advanced gravitational physics (Fortgeschrittene Gravitationphysik)			1421
Semester	Summer semester		
Responsibility	Institute for gravitational physics		
Courses	Lecture "Avanced gravitational physics" Exercises to „Advanced gravitational physics"		
Assessment of credit points	**Study achievement:** Exercises **Exam achievement:** oral exam or written exam after the choice of the lecture		
Note compound	note of the exam		
Credit Points (ECTS): 5 **Weight:** 1	**Attendance study (h):** 60	**Self study (h):** 90	

Competence goals:
Students understand the fundamental concepts of gravitational physics and can apply these independently to selected problems. They are familiar with advanced experimental methods in the field and can apply these under guidance.

Content:
- General relativity
- equivalence principle, Lense–Thirring effect
- Cosmology
- Astrophysics
- Sources and propagation of gravitational waves
- Laser interferometer
- Interferometer-recycling-technics
- modulation fields
- Homodyn- und Heterodyndetektion
- Control of Interferometer
- Optical, mechanical and thermic properties of mirrors and there dialectric surface coating

Fundamental literature:
will be given in the lecture

Recommended knowledge:
- Basics of special relativity theory
- Module „Coherent optics"

If applicable, admission prerequisites and limited number of participants: no

Module affiliation:
- Master physics (Adnaced expansion phase)

Quantum optics (Quantenoptik)			1321
Semester	Winter semester		
Responsibility	Institut for quantum optics		
Courses	Lecture "Quantum optics" Exercises to "Quantum optics"		
Assessment of credit points	**Study achievement:** Exercises **Exam achievement:** oral or written exam after the choice of the lecture		
Note compound	Note of the exam		
Credit Points (ECTS): 5 **Weight** 1	**Attendance study (h):** 60	**Self study (h):** 90	

Competence goals:
Students understand the fundamental 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 these under guidance.

Content:

- Quantisation of the electromagnetic field
- Quantum states of the electromagnetic field (Fock, Glauber and squeezed states)
- Heisenberg uncertainty relation (number/phase, amplitude/phase quadrature)
- Photon statistics, quantum noise
- Generation of squeezing and entanglement
- Bell inequalities and nonlocality
- Spontaneous emission, Lamb shift, Casimir effect
- Atom-field interaction with coherent fields, dressed states
- Photon scattering, Feynman diagrams
- Multiphoton processes
- Quantum theory of the nonlinear susceptibility
- Modern quantum optics experiments

Fundamental literature:

- 🕮 Mandel/Wolf, *Optical Coherence and Quantum Optics*, Cambridge University Press
- 🕮 Walls/Milburn, *Quantum Optics*, Springer
- 🕮 Bachor/Ralph, *A Guide to experiments in Quantum Optics*, Wiley-VCH
- 🕮 Schleich, *Quantum Optics in Phase space*, Wiley-VCH
- 🕮 Originalliteratur

Recommended knowledge:

- Module „Coherent optics"

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:

- Master physics (Advanced expansion phase)

Quantum field theory (Quantenfeldtheorie)			1121
Semester	Winter semester of summer semester		
Responsibility	Institut for Theoretical physics		
Courses	Lecture „Quantum field theory" Exercises to „Quantum field theory"		
Assessment of credit points	**Study achievement:** Exercises **Exam achievement:** oral or written exam (lecturer's choice)		
Note compound	Examination mark		
Credit Points (ECTS): 5 **Weight:** 1	**Attendance study (h):** 60	**Self study (h):** 90	

Competence goals:
The student acquires a solid and formal understanding of quantum field theory and can autonomously apply its quantitative mathematical methods. He or she is able to deduce the physical content of the mathematical models and to interpret them in the context of established theories.
The student is familiar with the mathematical techniques and master analytical and numerical procedures suitable for problem solving in this field.

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

Fundamental 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 knowledge:
- Module „Advanced quantum theory (Fortgeschrittene Quantentheorie)"

If applicable, admission prerequisites and limited number of participants: no

Module affiliation:
- Master Physics (Advanced expansion phase)

Electronics and measuring technology (Elektronik und Messtechnik)				1222
Semester	Winter semester or summer semester			
Responsibility	Institut for Solid state physics			
Courses	Lecture "Electronics" Lecture „Measuring technology" Electronics internship			
Assessment of credit points	**Study achievement:** Laboratory exercises **Exam acievement:** Oral or written exam at the choice of the lecturer			
Note compound	Examination mark			
Credit Points (ECTS): 8 **Weight:** 1	**Attendance study (h):** 120		**Self study (h):** 120	

Competence goals:
The students become familiar with experimental and numerical methods, apply them themselves and develop models to explain the experimental and numerical results. They know the function of electronic components and can use them correctly for measuring data acquisition.

Content:

- Basic terms of electronics
- Passive components
- transistor
- Basic analog circuits (filters)
- Operational Amplifiers
- Static and dynamic OR wiring
- Fundamentals of high frequency technology
- Signal generators / phase shifters
- Electronic controllers
- DAAD conversion
- Internship: Selection of various experiments on the topics of the lectures

Fundamental literature:

- 🕮 U.Tietze, C. Schenk, *Halbleiter Schaltungstechnik*, Springer Verlag
- 🕮 Hering, Bressler, Gutekunst, *Elektronik für Ingenieure*, Springer Verlag
- 🕮 P. Horowith, W. Hill, *The Art of Electronics*, Cambridge University Press

Recommended knowledge:

Modules:

- Mechanics and relativity
- Electricity
- Optics, atomic physics, quantum phenomena
- Molecules, cores, particles, solid

If applicable, admission prerequisuites and limited number of participants: none

Module affiliation:

Master Physics – Priority phase

Selected topics of modern physics A (Ausgewählte Themen der modernen Physik A)			1621
Semester	Winter or summer semester		
Responsibility	All institutes of Physics		
Courses	Courses amounting to min. 31 credit points according to the lecture timetable		
Assessment of credit points	**Required performance:** according to §14 from the Examination Regulation **Examination:** oral exam		
Note compound	Oral examination mark		
ECTS: 31 **Weight:** 1	**Attendance study (h):**	**Self-study (h):**	
Competence: Student will acquire a broad overview of modern physics on an advanced level, and will be able to classify this knowledge within the general context of physics. Within this module they will also exemplarily go into greater depth in a special subject of physics, which will enable them to join a research group working in this field on their master thesis.			
Content: Advanced courses of physics according to the choice of the student. The exam will cover the contents of thematically connected courses of at least 12 CP.			
Fundamental Literature: To be announced in class			
Recommended knowledge: Description of each course in the module catalogue			
If applicable, admission prerequisite and a limited number of participants : none			

Selected topics of modern physics B (Ausgewählte Themen moderner Physik B)			1622
Semester	Winter or summer semester		
Responsibility	Institute of Physics		
Courses	Courses of at least 17 credit points according to the course catalog.		
Assessment of credit points	**Study achievement:** according to §6 of the examination regulation **Exam achievement:** oral exam		
Note compound	Note of the oral exam		
Credit points (ECTS): 17 **Weight:** 1	**Attendance study (h):**	**Self study (h):**	
Competence: The students have a broad overview of the range of topics of modern physics and can classify this knowledge in the overall building of physics. By way of example, they have worked their way into a selected area of specialization in physics and are in a position to start in a research group in this field.			
Content: Advanced courses in physics according to the students' choice The exam covers subject-related courses of at least 12 credits.			
Fundamental literature: Will be said in the course			
Recommended knowledge: according tot he course catalog			
If applicable, admission prerequisites and limited number of participants: Should be selected together with the module "Industrial internship"			
Module affiliation: • Master Physics (Priority phase)			

Selected Topics in Photonics (Ausgewählte Themen der Photonik)			1021
Semester	Winter or summer semester		
Responsibility	Institut for Quantumnoptics		
Courses	**Courses of at least 18 credits according to the course catalog**		
Assessment of credit points	**Study achievement:** according to §14 of the examination regulation **Exam achievement:** oral exam		
Note compound	Note of the oral exam		
Credit points (ECTS): 18 **Gewicht:** 1	**Präsenzstudium (h):**	**Selbststudium (h):**	
Competence: The students have a comprehensive overview over the field of optics and photonic. They can embed this knowledge into the larger context of physics. The students have deeply studied one topical sub-area and are prepared to work in the corresponding research groups.			
Content: Advanced physics courses of student's choice. The examination covers topical courses of at least 4 LP			
Fundamental literature: See the individual courses			
Recommended knowledge:			
If applicable, admission prerequisites and limited number of participants: none			
Module affiliation: • Master Physics			

Seminar			1622
Semester	Winter or summer semester		
Responsibility	Institute of Physics		
Courses	Seminar		
Assessment of credit points	**Exam achievement:** Seminar performance		
Note compound	Note of the seminar performance		
Credit points (ECTS): 3 **Weight:** 1	**Attendance study (h):** 30	**Self study (h):** 60	

Competence:

- Students are able to research autonomously for a literature to a given actual issue from modern physics.
- Students are able to work out independently an actual science field.
- Students are able to structure and make a presentation about a complex issue from the modern physics, which could be followed by physical competent audience. By presenting the layout they are able to interest the audience for a complex special topic.
- Students are able to develop an appealing presentation (e.g. PowerPoint).
- Students are able to conduct a scientific discussion (on topics of their own and their's classmates as well). Students are able to communicate fluently in German and English.

Content:
Advanced topics of physics

Fundamental literature:
Will be said in the course

Recommended knowledge:

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:

- Master Physics (Priority phase)

Key competencies (Schlüsselkompetenzen)		1970
Semester	Winter and Summer semester	
Responsibility	Student Deanery	
Courses	According to the obligatory counseling, the students have to pass language courses in German in an extent of up to 10 CP. Classes from the offer by the Applied Linguistics and Special Languages (FSZ) or the Key Skills Centre (ZfSK) and relevant classes from the Faculties and computer classes offered by the computing centre (LUIS) as well.	
Assessment of credit points	**Required performance:** according to §6 from the examination regulation	
Note compound		
ECTS: 10 **Weight:** 10	**Attendance and self study (h):**	120 -300

Competence:

- You learn and handle exemplarily key skills in the field of the chosen class.

Content:

- Topics according to the chosen class

Fundamental literature:

- To be announced in class

Recommended knowledge:

- none

If applicable, admission prerequisites and limited number of participants:
none

Module affiliation:

- Master Physics
- For all other students, this module includes 4 credit points

Industrial Internship (Industriepraktikum)			1831
Semester	Winter or summer semester		
Responsibility	Institutes of Experimental Physics		
Courses	-		
Assessment of credit points	**Required performance:** Internship report		
Note compound	-		
Credit points (ECTS): 10	**Attendance study (h):**	**Self study (h):**	
Competence: Students are aware of typical task fields and scope of activities of graduates in technical physics in the professional practice. They are able to integrate into a working environment with scientists and engineers and to work in teams. They know exemplarily the implementation of scientific knowledge into an industrial process and understand the occurred task.			
Content: Internship at an industrial enterprise			
Fundamental literature:			
Recommended knowledge:			
If applicable, admission prerequisite and a limited number of participants : none			

Master Meteorology – Advanced Meteorology

Seminars on advanced meteorology (Seminare zur Fortgeschrittene Meteorologie)				2301
Semester	Winter and summer semester			
Responsibility	Institut for Meteorology and Climatology			
Courses	2 seminars from different fields of meteorology			
Assessment of credit points	**Study achievement:** 2 seminar performance			
Note compound	-			
Credit points (ECTS): 10 **Weight:** 1	**Attendance study (h):** 56		**Self study (h):** 244	

Competence:

- The students are able to work on a given, up-to-date subject from modern meteorology, the z. The subject of the research is the independent research of literature.
- The students are able to independently develop a current area of knowledge.
- Students can structure a lecture on a complex topic of modern meteorology and consider that a meteorologically educated audience can follow the lecture well.
- By designing the lecture, you can also interest the audience in a complex special topic.
- The students are able to create an appealing presentation. (PowerPoint or similar).
- The students are able to conduct a scientific discussion (about their own topic as well as about the topics of the other seminar participants).

The students speak German or English jargon in free speech

Content:

- Advanced topics of meteorology

Fundamental literature:

Will be said in the course

Recommeded knowledge:

Will be said in the course

If applicable, admission prerequisites and limited number of participants: none

Module affiliation:

- Master Meteorology (Advanced Meteorology)

Advanced internship (Fortgeschrittenenpraktikum)	2304
Semester	Lecture free time between winter and summer semester
Responsibility	Institut for Meteorology and Climatology
Courses	Advanced internship
Assessment of credit points	**Study achievement:** Laboratory
Note composition	-
Credit points (ECTS): 6	**Attendance and self study (h):** 180

Competence:
The students can apply modern meteorological measurement methods even close to research and practically in a field measurement campaign. The methodological competence in dealing with large amounts of data and their evaluation is strengthened and the critical assessment of the measurement results is trained. Working in small groups, cooperating between the small groups, as well as the preparation of a joint final report promotes especially the ability to work in a team.

Content:
- Conducting field trials as part of a typically two-week measurement campaign on selected current research tasks.

Fundamental literature:
Script for instrument internship

Recommended knowledge:

If applicable, admission prerequisites and limited number of participants : none

Module affiliation:
- Master Meteorology (Advanced Meteorology)

Key competencies (Schlüsselkompetenzen)		2670
Semester	Winter and summer semester	
Responsibility	Institut for Meteorology and Climatology	
Courses	Courses from the offer of the language center or the center for key competencies and correspondingly advertised offers of the faculties, as well as computer courses from the data center offer.	
Assessment of credit points	**Study achievement:** according to §6 of the examination regulation	
Note compound	--	
Credit points (ECTS): 4	**Attendance and self study (h):**	120
Competence: The students learn and master exemplary key competencies in the field of selected courses.		
Content: Content depending on the chosen course		
Fundamental literaure: • Content depending on the chosen course		
Recommended knowledge: • None		
If applicable, admission prerequisites and limited number of participants : none		
Module affiliation: • Master Meteorology (Key competencies)		

Master Meteorology – Elective area

Selected topics of modern meteorology A (Ausgewählte Themen moderner Meteorologie A)		2202
Semester	Winter and summer semester	
Responsibility	Institut for Meteorology and Climatology	
Courses	Courses of at least 8 credit points from the course catalog of meteorology	
Assessment of credit points	**Study achievement:** Election of the lecturer **Exam achievement:** Oral exam	
Note compound	Note of the oral exam	
Credit points (ECTS): 8 **Weight:** 1	**Attendance and self study (h):**	240
Competence: 08		
Content: Courses of 8 credit points according to the course catalog. The exam covers subject-related courses of at least 8 credit points.		
Fundamental literature: See course catalog		
Recommended knowledge: See course catalog (Lehrveranstaltungskatalog)		
If applicable, admission prerequisites and limited number of participants: See course catalog (Lehrveranstaltungskatalog)		
Module affiliation: • Master Meteorology (Elective area Meteorology)		

Selected topics of modern meteorology B (Ausgewählte Themen moderner Meteorologie B)	2650
Semester	Winter and summer semester
Responsibility	Institut for Meteorology and Climatology
Courses	Courses of at least 8 credit points from the courses catalog of meteorology
Assessment of credit points	**Study achievement:** Election oft he lecturer **Exam achievement:** Oral exam
Note composition	Note of the oral exam
Credit points (ECTS): 8 **Weight:** 1	**Attendance and self study (h):** 240
Competence: Expanding the expertise, as well as depending on the choice of events deepening or acquiring new methodological skills in the context of internships, for example in the programming of models, applying complex models or in experimentation.	
Content: Courses of 8 credit points according to the course catalog. The exam covers subject-related courses of at least 8 credits points.	
Fundamental literature: Siehe Lehrveranstaltungskatalog	
Recommended knowledge: See course catalog (Lehrveranstaltungskatalog)	
If applicable, admission prerequisites and limited number of participants: See course catalog (Lehrveranstaltungskatalog)	
Module affiliation: • Master Meteorology (Elective area Meteorology)	

Selected topics of modern meteorology C (Ausgewählte Themen moderner Meteorologie C)	2651
Semester	Winter and summer semester
Responsibility	Institut for Meteorology aqnd Climatologiy
Courses	Courses of at least 8 credit points from the courses catalog of meteorology
Assessment of credit points	**Study achievement:** Election of the lecturer **Exam achievement:** -
Note compound	Module is not graded
Credit points (ECTS): 8	**Attendance and self study (h):** 240
Competence: Expanding the expertise, as well as depending on the choice of events deepening or acquiring new methodological skills in the context of internships, for example in the programming of models, applying complex models or in experimentation.	
Content: Courses of 8 credit points according to the course catalog. It is also possible to introduce a maximum of another seminar on advanced meteorology (5CP) (see course catalog): In consultation with a lecturer in meteorology, a written paper of 3 CP may be added to the module instead of a course.	
Fundamental literature: See course catalog (Lehrveranstaltungskatalog)	
Recommended knowledge: See course catalog (Lehrveranstaltungskatalog)	
If applicable, admision prerequisites and limited number of participants: See course catalog (Lehrveranstaltungskatalog)	
Module affiliation: • Master Meteorology (Elective area Meteorology)	

Theses and research phase

Bachelor project (Bachelorprojekt)		9001
Semester	Possible all year round	
Responsibility	Dean of students	
Courses	Project „Bachelor thesis “ Seminar „Working group seminar“	
Assessment of credit points	**Exam achievement:** Bachelor thesis **Study achievement:** Seminar performance	
Note compound		
Credit points (ECTS): 15	**Attendance and self study (h):**	450

Competence:
The students have the ability to become self-employed in a research topic. You can independently acquire knowledge from z.T. acquire English-language books and journals. You will be able to plan, schedule and implement a scientific project under scientific guidance. You are able to write a text according to scientific standards. They can present a scientific topic using appropriate media and they are capable of scientific discussion of their own work with fellow students and teachers. They master the German and z.T. English technical language in spoken and written.

Content:

- Introduction to scientific work
- Independent project work under guidance
- Scientific writing
- Presentation techniques
- Scientific lecture
- Discussion guide

Fundamental literature:

- Aktuelle Literatur zum Thema der Bachelorarbeit
- 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 knowledge:
Basic modules oft he respective degree program

If applicable, admission prerequisites and limited number of participants:

- **Physics:** Completed module “Mathematics for physicists” and passed cross-module examinations “Experimental physics” and “Theoretical physics I”
- **Meteorology:** At least 100 CP from the basic modules of the Bachelor's degree program

Module affiliation:

- Bachelor Physics (Module Bachelor thesis)
- Bachelor Meteorology (Module Bachelor thesis)

Examination procedure: The topic of the bachelor thesis is determined by the examiner after consultation with the examinee. The issue must be recorded and communicated in writing to the candidate and the Dean of Studies. The examiner is appointed with the issue of the topic. During the preparation of the work, the candidate is supervised by the examiner.

Research Internship (Forschungspraktikum)		9031
Semester	Winter and summer semester	
Responsibility	Institutes of Physics and Meteorology	
Courses	Internship: Research internship Class: Working group class	
Assessment of credit points	-	
Note compound	-	
Credit points (ECTS): 15	**Attendance study (h):**	450

Competence:
Students are able to familiarize themselves with the measurement techniques or theoretical concepts of a field of research. They can develop an overview of the relevant literature related to a research project. Students are capable of working in a multi-national team and can communicate without problems in English and German.

Content:
- Literature research
- Getting acquainted with theoretical and experimental methods
- Discussion of current research topics in the research group seminar

Fundamental literature:
- 🕮 Relevant literature about current reasearch area
- 🕮 Abacus communications, *The language of presentations*, CDROM Lehr- und Trainingsmaterial
- 🕮 Alley, *The Craft of Scientific Presentation*, Springer

Recommended knowledge:
- Advanced modules of the relative Master course

If applicable, admission prerequisite and a limited number of participants : none

Project Planning (Projektplannung)		9032
Semester	Winter and summer semester	
Responsibility	Institutes of Physics	
Courses	Project: Project planning for Master thesis Class: Working group class	
Assessment of credit points	-	
Note compound	-	
Credit points (ECTS) 15	**Attendance and self study (h):**	450

Competence:
The students have acquired social skills which enable them to be part of a research or development team. They are capable of performing independent scientific work and planning complex projects. Students can make their own inquiries and can develop an overview for example of the English literature and publications relevant for a research project.

Content:
- Definition of a scientific problem
- Methods of project management
- Conceiving, presenting and discussing a project plan

Fundamental literature:
- 🕮 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 knowledge:
- Advanced module of the relative Master course
- Module Research training

If applicable, admission prerequisite and a limited number of participants : none

Comprehensive Exam, Research Training / Project Planning (Modulübergreifende Prüfung Forschungspraktikum/ Projektplanung)	**9033**
Semester	Winter and summer semester
Responsibility	Institutes of Physics
Courses	Required performance: Course participation
Assessment of credit points	Examination: Project work
Note compound	does not effect the Master mark
Weight:	0
Competence: The student can acquire an overview of the scientific literature pertaining to a research project. He or she is able to conduct a scientific presentation and to describe his or her own research project in relation to the current state of the field.	
Content: Project planning, research training	
If applicable, admission prerequisite and a limited number of participants : none	

Master Thesis (Masterarbeit)		9021
Semester	Winter and summer semester	
Responsibility	Institutes of Physics	
Courses		
Assessment of credit points	**Examination**: Master thesis	
Note compound	Master thesis mark	
Credit points (ECTS) **Weight:** 30 5	**Attendance and self study (h):** 900	

Competence:
Students are able to work independently on a research project. They are able to structure, prepare and conduct scientific projects under guidance. They are able to provide an overview of a literature and they analyze and solve komplex problems. Students are able to conduct critical discussions on other's and their's own research results and they can handle constructively questions and critics. Students are able to use fluently technical German and English language. They are able to make a scientific presentation and to present their own results in the context of the actual scientific knowledge and progress.

Content:
- Independent processing of an actual scientific problem definition in an international research environment
- Written documentation and oral presentation of the reasearch project and the results
- Scientific discussion of the results

Fundamental literature:
- 🕮 Relevant literature about current scientific problem definition
- 🕮 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 knowledge:
-

If applicable, admission Prerequisite and a limited number of participants:
- Project planning

Examination procedure: The topic of the Master thesis is determined by the first examiner after consultation with the examinee. The issue must be recorded and communicated in writing to the candidate and the Dean of Studies. With the issue of the topic, the first examiner and the second examiner are appointed. During the preparation of the work the candidate is supervised by the first examiner.

Courses catalog

Courses of Physics

Institut for Theoretical physics

Institut for Solid state physics

Institut for Quantum optics

Institut for Gravitational physics

Institut for Radioecology and radiation protection

Courses of meteorology

Table Assigment of courses

	Bachelor Physics	Bachelor Meteorology	Master Physics		Master Meteorology		
Courses	Modern aspects of physics	Elective module Meteorology	Selected topics of modern physics	Seminar	Selected topics of modern meteorology A	Selected topics of modern meteorology B	Selected topics of modern meteorology C
Courses							
Advanced quantum theory	X		X				
Seminar to Advanced quantum theory	X		X	X			
Computer physics	X		X				
Theoretical solid state physics			X				
Statistical field theory			X				
Seminar to Theory of condensed matter			X	X			
Advanced computer physics	X		X				
Current problems of the theory of condensed matter			X				
Theory of fundamental interactions			X				
Seminar to Theory of fundamental interactions			X	X			
Additions to classical physics	X		X				

	Bachelor Physics	Bachelor Meteorology	Master Physics		Master Meteorology		
Courses	Modern aspects of physics	Elective module Meteorology	Selected topics of modern physics	Seminar	Selected topics of modern meteorology A	Selected topics of modern meteorology B	Selected topics of modern meteorology C
Solid state physics in low dimensions	X		X				
Laboratory internship Solid state physics in low dimensions	X		X				
Surface physics			X				
From the atom to the solid	X		X				
Seminar to From the atom to the solid			X	X			
Semiconductor physics			X				
Semiconductor measurement technology in photovoltaics	X		X				
Scanning probe technology	X		X				
Molecular electronics	X		X				
Methods of surface analysis	X		X				
Laboratory practical methods of surface analysis			X				
Spintronics			X				
Optical spectroscopy of solids			X				
Quantum structure devices			X				
Physics of the solar cell	X		X				
Laboratory practical solid state physics			X	X			
Current research topics in solid state physics	X		X				
Non linear optics			X				
Photonics			X				

	Bachelor Physics	Bachelor Meteorology	Master Physics		Master Meteorology		
Courses	Modern aspects of physics	Elective module Meteorology	Selected topics of modern physics	Seminar	Selected topics of modern meteorology A	Selected topics of modern meteorology B	Selected topics of modern meteorology C
Seminar to Photonics			X				
Atom optics			X				
Laboratory internship optics			X				
Data Analysis			X				
Neutron Stars and Black Holes			X	X			
Seminar to Gravitational waves			X	X			
Seminar to Gravitational physics			X				
Laser interferometry			X				
Laboratory internship Laser interferometry			X				
Laser stabilization and control of optical experiments	X		X				
Nonclassical light			X				
Nonclassical laser interferometry			X				
Nuclear physics and nuclear chemistry of radiation protection and radioecology	X		X				
Nuclear energy and fuel cycle, technical aspects and social discourse	X		X				
Radioactivity in the environment and radiation hazard to humans	X		X				
Radiation protection and radioecology	X		X				
Laboratory internship Radiation protection	X		X				

	Bachelor Physics	Bachelor Meteorology	Master Physics		Master Meteorology		
Courses	Modern aspects of physics	Elective module Meteorology	Selected topics of modern physics	Seminar	Selected topics of modern meteorology A	Selected topics of modern meteorology B	Selected topics of modern meteorology C
Nuclear analysis methods	X		X				
Nuclear physical applications	X		X				
Sem./Practice Radiation protection and radioecology	X		X				
Introduction to partical physics	X		X				
Electronic metrology in the optics laboratory			X				
Basics of laser medicine and biophotonics			X				
Solid state laser			X				
Optical layers			X				
Thermodynamics, kinetics and structure of defects in semiconductors			X				
Physics in nanostructures	X		X				
Expertise in radiation protection	X		X				
Numerical weather forecast		X			X	X	X
Programmind internship for Numerical weather forecast		X			X	X	X
Pollutant spread in the atmosphere		X			X	X	X
Turbulence II		X			X	X	X
Atmospheric convection		X			X	X	X
Programming internship for Atmospheric convection		X			X	X	X
Simulation of turbulent flows with LES models		X			X	X	X

	Bachelor Physics	Bachelor Meteorology	Master Physics		Master Meteorology		
Courses	Modern aspects of physics	Elective module Meteorology	Selected topics of modern physics	Seminar	Selected topics of modern meteorology A	Selected topics of modern meteorology B	Selected topics of modern meteorology C
Numerical internship for Simulation of turbulent flows with LES models		X			X	X	X
Agricultural meteorology		X			X	X	X
Local climates		X			X	X	X
Seminar to Advanced meteorology							X
Meteorological exkursion II							X
External internship in Germany							X
External internship abroad							X

Courses of Physics

Advanced quantum theory (Fortgeschrittene Quantentheorie)

Courses (SWS)	Credit points:	Responsibility:
3+1	5	Institut for Theoretical Physics

Regularity: Summer semester

Content:

- Many-particle systems: identical particles, Fock space, field quantization
- Open quantum systems: density operator, measurement process, Bell inequalities
- Information and thermodynamics: partition functions, entropy, thermodynamic equilibrium
- Semiclassical approximation: Bohr-Sommerfeld, tunneling, path integral
- Relativistic quantum mechanics: spcae-time symmetries, Dirac equation
- Scattering theory

Fundamental 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 knowledge:

- Mathematics for physicists, Introduction to quantum theory

Module affiliation:

- Modern aspects of physics
- Selected topics of modern physics

Seminar to Advanced quantum theory (Seminar zu Fortgeschrittene Quantentheorie)

Courses (SWS)	Credit points:	Responsibility:
2	3	Institut for Theoretical Physics

Regularity: Summer semester

Content:
In agreement with the lecturer. The seminar has to be attended in connection with the lecture course on Advanced Quantum Theory.

Fundamental 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 knowledge:

- Mathematics for physicists

Module affiliation:

- Modern aspects of physics
- Selected themes of modern physics
- Seminar

Introduction to electronic measurement data acquisition and processing with LabView (with practical parts)

Courses (SWS) 2	**Credit points:** 4	**Responsibility** Institut for Solid state physics

Regularity: Summer semester

Competence:

Students will learn about experimental methods of computer aided electronic measurement data acquisition and data processing using LabView. LabView is a graphical programming environment, which is widely used throughout research facilities and the industry. Participants will know about the physical working principles of the sensors used for the experiments. They are able to solve metrological tasks, to acquire and process measurement data and to analyze the uncertainty of the results.

Content:

- Basics of programming in LabView
- Basics of electronic measurement data acquisition using LabView
- Physical basics of working principles of selected sensors
- Basics of systematic evaluation of measurement uncertainties
- Practical experiments concerning the contents of the lecture

Fundamental literature:

- 🕮 W. Georgi, P. Hohl, Einführung in LabView, Hanser-Verlag
- 🕮 W. Demtröder, Experimentalphysik 1: Mechanik und Wärme, Springer Verlag
- 🕮 W. Demtröder, Experimentalphysik 2: Elektrizität und Optik, Springer Verlag
- 🕮 E. Hering, K. Bressler, J. Gutekunst, Elektronik für Ingenieure und Naturwissenschaftler, Springer Verlag

Recommended knowledge:

- Lecture Mechanics und Relativity and Electricity

If applicable, admission prerequisites and limited number of participants:

20 participants, registration via Stud.IP

Module affiliation:

- Modern aspects of physics
- Selected themes of modern physics
- Elektronics and measurement technology
- Scientific-technical elective area of Meteorology

Computer physics (Computerphysik)

Courses (SWS)	Credit points:	Responsibility
2+2	6	Institut for Theoretical Physics

Regularity: Winter or summer semester

Content:

- Basic numerical methods (differentiation, integration, interpolation, non-linear equations, systems of linear algebraic equations, Monte Carlo integration)
- Numerical solution of typical problems in physics (differential equations eigenvalue problems, optimization integration and sums of many variables)
- Applications to mechanics, electrodynamics and thermodynamics
- Data analysis (statistics, fit, extrapolation, spectral analysis)
- Visualization (graphical representation of data)
- Introduction to the simulation of physical systems (dynamical systems, simple molecular dynamics)
- Computer algebra

Fundamental 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
- S. Brandt, „*Datenanalyse*", Spektrum Akademischer Verlag
- V. Blobel und E. Lohrmann, „*Statistische und numerische Methoden der Datenanalyse*", Teubner Verlag
- R.H. Landau, M.J. Paez, and C.C. Bordeianu, *Computational Physics*, Wiley-VCH, 2007

Recommended knowledge:

- Experience with computers and basics programming knowledge
- Analysis I+II
- Theoretical Electrodynamics
- Analytical Mechanics and Special Relativity
- Introduction to Quantum Theory

Module affiliation:

- Modern aspects of physics
- Scientific-technical elective area
- Selected themes of modern physics

Theoretical solid-state physics (Theoretische Festkörperphysik)

Courses (SWS)	Credit points:	Responsibility
3+1	5	Institut for Theoretical Physics

Regularity: Winter or summer semester

Content:

- Transport
- Electronic correlations
- Low-dimensional systems
- Magnetism
- Superconductivity
- Disorder and impurities
- Mesoscopic systems

Fundamental 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)

Recommended knowledge:

- Advanced Qunatum Theory

Quantum Field Theory

Module affiliation:

- Selected Topics of Modern Physics

Statistical field theory (Statische Feldtheorie)

Courses (SWS)	Credit points:	Responsibility
3+1	5	Institut für Theoretische Physik

Regularity: Winter or summer semester

Content:

- Partition function as a path integral
- Critical phenomena
- Condensed matter in two dimensions
- Quantum spin chains
- Non-equilibrium phenomena

Fundamental literature:

- A. Altland and B. Simons, *Condensed Matter Field Theory (*Cambridge University Press, 2006*)*
- H. Bruus and K. Flensberg, *Many Body Quantum Theory in Condensed Matter Physics (*Oxford University Press, 2004)
- J.M. Thijssen, *Computational Physics* (Cambridge University Press, 2007)
- D. J. Amit & V. Martin-Mayor*: Field theory, the renormalization, group, and critical phenomena (*World Scientific 2005)
- G. Mussardo*: Statistical field theory: An introduction to exactly solved models in statistical physics, (Oxford 2010)*
- A. M. Tsvelik: *Quantum field theory in condensed matter physics*, (Cambridge 2003)

Recommended knowledge:

- Advanced Quantum Theory
- Advanced Quantum Theory
- Quantum Field Theory

Module affiliation:

- Selected Topics of Modern Physics

Seminar to Theorie of condensed matter
(Seminar zu Theorie der kondensierten Materie)

Courses (SWS)	Credit points:	Responsibility
2	3	Institut für Theoretische Physik

Regularity: Winter or summer semester

Content:
In consultation with the teachers. This seminar can only be taken in conjunction with the courses Theoretical solid-state physics or Statistical field theory.

Fundamental literature:

- 🕮 See the references for the courses Theoretical solid-state physics and Statistical field theory

Recommended knowledge:

- Advanced Quantum Theory
- Quantum Field Theory

Module affiliation:

- Selected Topics of Modern Physics
- Seminar

Advanced computational physics (Fortgeschrittene Computerphysik)

Courses (SWS)	Credit points:	Responsibility
4+2	8	Institut for Theoretical physics

Regularity: Winter or summer semester

Content:

- Exact diagonalizations
- Monte Carlo simulations
- Numerical renormalization group methods
- Density functional theory
- Molecular dynamics
- Quantum dynamics

Fundamental literature:

- J.M. Thijssen, *Computational Physics* (Cambridge University Press, 2007*)*
- S.E. Koonin and D.C Meredith, *Computational Physics*, Addison-Wesley, 1990.
- T. Pang, *Computational Physics*, Cambridge University Press, 2006
- H. Gould, J. Tobochnik, and W. Christian, *Computer Simulation Methods*, Pearson Education, 2007

Current problems of the theory of condensed matter theory (Aktuelle Probleme der Theorie der kondensierten Materie)

Courses (SWS)	Credit points:	Responsibility
2	2	Institut for Theoretical physics

Regularity: Winter or summer semester

Content:

Current topics at the teacher's option:

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

Fundamental literature:

will be announced by the lecturer

Recommended knowledge:

- Advanced Quantum Theory
- Advanced Solid State Physics

Module affiliation:

- Selected Topics of Modern Physics

Theory of fundamental interactions (Theorie der fundamentalen Wechselwirkung)

Courses (SWS)	Credit points:	Responsibility
3+1	5	Institut for Theoretical physics

Regularity: Winter or summer semester

Content:

Varying topics, will be chosen by the lecturer, for example:

- String Theory
- Supersymmetry
- General Relativity
- Gauge Theory and its Quantization
- Conformal Field Theory

Fundamental 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
- 🕮 und aktuelle Forschungspublikationen

Recommended knowledge:

- Advanced quantum theory

Module affiliation:

- Selected Topics of Modern Physics

Seminar to Theory of fundamental interactions
(Seminar zu Theorie der fundamentalen Wechselwirkung)

Courses (SWS)	Credit points:	Responsibility
2	3	Institut for Theoretical physics

Regularity: Winter or summer semester

Content:
In agreement with the lecturer. The seminar has to be attended in connection with the lecture course on Theory of Fundamental Interactions.

Fundamentale 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
- und aktuelle Forschungspublikationen

Recommended knowledge:

- Advanced Quantum Theory

Module affiliation:

- Selected Topics of Modern Physics
- Seminar

Addition to classical physics (Ergänzungen zur klassischen Physik)

Courses (SWS)	Credit points:	Responsibility
3+1	5	Institut für Theoretische Physik

Regularity: Winter or summer semester

Content:

Selected areas of classical physics, chosen by the lecturer, for example:

- General Relativity: Minkowski space, Lorentz group, its representations, relativistic particles, coupling to the electromagnetic field, Liénard-Wiechert potentials, Schwarzschild metric, tests of General Relativity in the solar system, Thirring-Lense effect, deflection of light, Einstein-Hilbert action, covariant energy-momentum conservation, gravitational waves: generation and detection, cosmology
- Gauge Theories: Parallel transport, covariant derivative, field strength, holonomy group, Bianchi identities, action principle, Noether identities, algebraic Poincaré lemma, the Standard Model of fundamental interactions, monopoles, spontaneous symmetry breaking, BRS(T) symmetry, anomalies
- Integrable and Chaotic Motion: Hamiltonian equations of motion, canonical transformations, Poincaré's integral invariants, action-angle variables, perturbation theory, Kolmogorov-Arnol'd-Moser theorem, Poincaré recurrence, Birkhoff's fixpoint theorem, self-similar Hamiltonian flow

Fundamental 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 knowledge:

- Analytical Mechanics and Special Relativity

Module affiliatiom:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Introduction to Particle Physics (Einführung in die Teilchenphysik)

Courses (SWS)	Credit points:	Responsibility
3+1	5	Institut for Theoretical physics

Regularity: Summer semester

Content:

- fundamental particles and their interactions
- symmetries and conservation laws
- hadrons, quarks, partons
- strong interaction: quantum chromodynamics
- electromagnetic and weak interaction and their unification
- the Standard Theory of particle physics
- accelerators and detectors
- neutrino physics
- open questions and future projects in particle physics

Fundamental 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 knowledge:

Module affiliation:

- Modern aspects of phcsics
- Selected topics of modern physics

Solid state physics in lower dimensions
(Festkörperphysik in niedrigen Dimensionen)

Courses (SWS)	Credit points:	Responsibility
3+1	5	Institut for Solid state physics

Regularity: Summer semester

Content:

- Production of structures lower dimension, epitaxy
- Electronical characteristics in 0 to 2 dimensions
- Effects of the electron correlations
- Resonant units
- Magnetic characteristics
- One-dimensional chains: dispersion, instability, defects
- Solitons
- Supercondoctivity in strong anisotropic systems
- Charge- and spin-density-waves

Fundamental literature:

- 🕮 Roth, Carroll, *One-dimensional metals*, VCH
- 🕮 I. Markov, *Crystal growth for beginners*, World Scientific
- 🕮 R. Waser, *Nanotechnology*, Wiley-VCH

Recommended knowledge:

- Introduction to the solid state physics

Module affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Surface physics (Oberflächenphysik)

Courses (SWS)	Credit points:	Responsibility
3+1	5	Institut for Solid state physics

Regularity: Summer semester

Content:

- Structure of solid state surfaces and methods
- Electronic properties of interfaces and methods
- Bonding of atoms and molecules on surfaces
- Simple reaction kinetics
- Structuring and self-assembly
- Defects and their physical impact

Fundamental literature:

- 🕮 Zangwill, *Physics at Surfaces*, Cambridge University Press
- 🕮 M. Henzler, M. Göpel, *Oberflächenphysik des Festkörpers*, Teubner
- 🕮 F. Bechstedt, *Principles of surface physics*, Springer
- 🕮 Ph. Hoffmann, Wiley

Recomended knowledge:

- Introduction to Solid State Physics
- Advanced Solid State Physics

Module affiliation:

- Selected Topics of Modern Physics

From the atom to the solid (Vom Atom zum Festkörper)

Courses (SWS)	Credit points:	Responsibility
3+1	5	Institut for Solid state physics

Regularity: Summer semester

Content:

- Generation of low-dimensional structures, epitaxy
- electronic properties in 0 to 2 dimensions
- Consequences of electron correlation
- resonant electronic devices
- magnetic properties
- one-dimensional chains: dispersion, instabilities defects
- solitons
- superconductivity on strongly anisotropic systems
- charge and spin density waves

Fundamental literature:

- 🕮 Roth, Carroll, *One-dimensional metals*, VCH
- 🕮 R. Waser, *Nanotechnology*, Wiley-VCH
- 🕮 Bovensiepen, Wolf

Recommended knowledge:

- Introduction to Solid State Physics

Module affiliation:

- Selected Topics of Modern Physics
- Modern Aspects of Physics

Seminar From the atom to the solid (Seminar zu Vom Atom zu Festkörper)

Courses (SWS)	Credit points:	Responsibility
2	3	Institut für Festkörperphysik

Regularity: Summer semester

Content:
According to the agreement with the instructor. The course has to be taken in combination with the lecture From atoms to solids.

Fundamental literature:

- Roth, Carroll, *One-dimensional metals*, VCH
- I. Markov, *Crystal growth for beginners*, World Scientific
- R. Waser, *Nanotechnology*, Wiley-VCH

Recommended knowledge:

- Introduction to Solid State Physics

Module affiliation:

- Selected Topics of Modern Physics
  - Seminar

Semiconductor Physics (Halbleiterphysik)

Courses (SWS)	Credit points:	Responsibility
2+1	4	Institut for Solid state physics

Regularity: Winter semester

Content:

- Energy band
- Electric transport
- Defects
- Optical Property
- Quantum Confinement
- P-n-junctions, bipolar transistors
- Field effect transistors
- Manufacturing techniques

Fundamental literature:

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

Recommended knowledge:

- Introduction to Solid State Physics

Module affiliation:

- Selected Topics of Modern Physics

Semiconductor measurement technology in photovoltaics (Halbleitermesstechnik in der Photovoltaik)

Courses (SWS)	Credit points:	Responsibility
2	3	Institut for Solid state physics

Regularity: Winter semester

Content:

In this lecture we discuss different characterization techniques which are used to assess each process step during the production of crystalline silicon solar cells from a silicon ingot. In particular, these are techniques for:

Materials characterization: conductivity, charge carrier density, charge carrier lifetime (photoluminescence, photoconductivity, thermography), defects (deep level transient spectroscopy, charge carrier lifetime spectroscopy, infrared spectroscopy), crystal orientation (electron back scattering diffraction)

Process characterization: doping profile (electrochemical capacitance voltage profliling), texturing (scanning electron microscope, reflection), charge carrier lifetime (photoluminescence, photoconductivity, thermography), layer thickness und refractive index (ellipsometry, infrared spectroscopy)

Solar cell characterization: current-voltage-curve, quantum efficiency, reflection, shunt analysis (thermography), series resistant (transmission line method, Photolumineszenz))

Fundamental literature:

- *D.K. Schroder*, Semiconductor Material and Device Characterization (2nd ed.), Wiley (1998)
- *S. M. Sze*, Semiconductor Devices: Physics and Technology, Wiley (1985)
- *Bergmann, Schaefer*, Lehrbuch der Experimentalphysik Bd. 6: Festkörper, de Gruyter (1992)

Recommended knowledge:

- Introduction to solid state physics
- Semiconductor physics
- Physics of solar cells

Module affiliation:

- Selected Topics of Modern Physics
- Modern Aspects of Physics

Scanning Probe Technology (Rastersondentechnik)

Courses (SWS)	Credit points:	Responsibility
2	2	Institut for Solid state physics

Regularity: Winter semester

Content:

- Scanning tunnel microscopy
- State density and transmission probabilties
- Scanning tunnel spectroscopy
- Atomic force microscopes
- Occuring forces on surfaces
- Detection of local electrical and magnetic fields
- Friction images
- Scanning electron microscopy

Fundamental literature:

- E. Meyer; H. J. Hug, R. Bennewitz, *Scanning probe microscopy : the lab on a Tipp*, Springer
- B. Bushan, *Applied scanning probe methods*, Springer

Recommended knowledge:

- Introduction to solid state physics

Module affiliation:

- Selected Topics of Modern Physics
- Modern Aspects of Physics

Molecular electronics (Molekulare Elektronik)

Courses (SWS)	Credit points:	Responsibility
2	2	Institut for Solid state physics

Regularity: Summer semester

Content:

- Geometric and electronic structure of molecules
- molecular crystals
- organics films, doping, electronic transport in organic material, OLED
- molecules on surfaces
- one-dimensional molecular structures
- instabilities, charge and spin density waves, solitons
- atomistic contacts and quantized transport
- transport through single molecules

Fundamental literature:

- J. Tour, *Molecular electronics*, World scientific 2002
- M. Schwoerer, H.C. Wolf: *Organic molecular solids*, Wiley-VCH 2007 (also in german)
- J.C. Cuevas, E. Scheer: *Molecular electronics: an introduction to theory and experiment,* World Scientific 2010

Recommended knowledge:

- Introduction to solid state physics

Module affiliation:

- Selected Topics of Modern Physics
- Modern Aspects of Physics

Methods of surface analysis (Methoden der Oberflächenanalytik)

Courses (SWS)	Credit points:	REsponsibility
2	2	Institut for Solid state physics

Regularity: Summer semester

Content:

- Vakuum techniques and sample preparation
- Methods fort he chemcial analysis:
  XPS, UPS, AES, EELS, ISS, TDS, ESD
- Determiniation of the geometric structure:
  STM, AFM, FIM, LEED, SEM
- Analysis of the electron structure:
  UPS, XPS, IPESD, NEXAFS

Fundamental literature:

- D.P. Woodruff, T.A. Delchar, *Modern Techniques of Surface Sciencem,* Cambridge University Press
- H. Bubert , H. Jenett, *Surface and Thin Film Analysis,* Wiley-VCH
- Springer Series in Surface Science

Recommended knowledge:

Introduction to solid state physics

Module affiliation:

- Selected Topics of Modern Physics
- Modern Aspects of Physics

Laboratory internship Methods of surface analysis (Laborpraktikum Methoden der Oberflächenanalytik)

Courses (SWS)	Credit points:	Responsibility
3	3	Institut for Solid state physics

Regularity: Summer semester

Content:

Appropriate experiments, e.g. XPS, UPS, LEED, EELS, STM, AFM. The lab course should be attended together with the Surface Science lecture.

Fundamental literature:

- D.P. Woodruff, T.A. Delchar, *Modern Techniques of Surface Sciencem,* Cambridge University Press
- H. Bubert , H. Jenett, *Surface and Thin Film Analysis,* Wiley-VCH
- Springer Series in Surface Science

Recommended knowledge:

- Introduction to Solid State Physics

Module affiliation:

- Selected Topics of Modern Physics
- Modern Aspects of Physics

Physics in nanostructures (Physik der Nanostrukturen)

Courses (SWS)	Credit points:	Responsibility
2+1	5	Institute for Solid State Physics

Semester: not regulary

Content:

- Preparation of nanostructures by lithography and self-assembly
- Electronic structure, interface states, heterostructures
- Quantum size effects
- Transport signatures in mesoscopic systems
- Magneto resistance effects
- Quantum Hall effect
- New 2D materials: graphene and topological insulators
- Instabilities in 1-dimensional structures
- Single electron transistors
- Molecular electronics
- Experimental methods

Fundamental literature:

- 🕮 Crystal Growth for Beginners, Ivan V Markov (World Scientific)
- 🕮 Mesoscopic Electronics in Solid State Nanostructure, Thomas Heinzel (Wiley)
- 🕮 Surface Science: An Introduction, Philip Hofmann (kindle.edition)
- 🕮 Nanoelectronics and Information Technology, Rainer Waser (Wiley)

Recommended knowledge:

- Introduction to solid state physics
- Surface physics

Module affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Optical spectroscopy of solids (Optische Spektroskopie von Festkörpern)

Courses (SWS)	Credit points:	Responsibility
2	2	Institute for Solid state physics

Semester: Winter semester

Content:

- Short-pulse-laser
- Light-matter-interaction
- Pumps-request Techniques
- Time resolved photoluminescence
- Polarisation (Jones-matrix, Stokes-vector)
- Semiconductor optics
- Physical limits of time resolution and measuring sensitivity
- Noises as measurand

Fundamental literature:

- 🕮 Jean-Claude Diels, Wolfgang Rudolph, *„Ultrashort Laser Pulse Phenomena"*, Academic Press
- 🕮 C. Klingshirn, *„Semiconductor Optics" Second Edition*, Springer

Recommended knowledge:

- Introduction to Solid State Physics

Module affiliation:

- Selected Topics of Modern Physics

Quantum structure devices (Quantumstrukturbauelemente)

Courses (SWS)	Credit points:	Responsibility
3+1	5	Institute for Solid State Physics

Semester: Summer semester

Content:

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

Fundamental 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 knowledge:

- Introduction to solid state physics
- Advanced solid state physics

Module affiliation:

- Selected Topics of Modern Physics

Physics of solar cells (Physik der Solarzellen)

Courses (SWS)	Credit points:	Responsibility
2+2	6	Institute for Solid State Physics

Semester: Summer semester

Content:

- Fundamentals of semiconductor physics
- Optical properties of semiconductors
- Transport of electrons and holes
- Mechanisms of charge carrier recombination
- Manufacturing process for solar cells
- Characterization methods for solar cells
- Possibilities and limitations for efficiency improvements

Fundamental literature:

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

Recommended knowledge:

- Introduction to Solid State Physics

Module affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Introduction to electronic measurement data acquisition and processing with LabView

(with practical parts)

(Einführung in die elektronische Messdatenerfassung und -verarbeitung mit LabView

(mit praktischen Teilen)

Courses (SWS)	**Credit points:**	**Responsibility**
2+2	4	Institut for Solid state physics

Semester: Summer semester

Content:

- Basics of programming in LabView
- Basics of electronic measurement data acquisition using LabView
- Physical basics of working principles of selected sensors
- Basics of systematic evaluation of measurement uncertainties
  Practical experiments concerning the contents of the lecture

Fundamental literature:

- 🕮 W. Georgi, P. Hohl, Einführung in LabVIEW, Hanser-Verlag
- 🕮 W. Demtröder, Experimentalphysik 1: Mechanik und Wärme, Springer-Verlag
- 🕮 W. Demtröder, Experimentalphysik 2: Elektrizität und Optik, Springer-Verlag
- 🕮 E. Hering, K. Bressler, J. Gutekunst, Elektronik für Ingenieure und Naturwissenschaftler, Springer-Verlag

Recommended knowledge:

- Module „Mechanics and relativity" and "Electricity"

Module affiliation:

- Modern aspects of physics
- Selected topics of modern physics
- Elektronics and Measuring technology
- Scientific-technical elective area Meteorology
- Selected topics of nanoelectronics
- Elective course in the master Nanotechnology

Laboratory internship Solid state physics
(Laborpraktikum Festkörperphysik)

Courses (SWS)	Credit points:	Responsibility
6	6	Institute for Solid State Physics

Semester: Winter and summer semester

Content:

- Quantum Hall effect
- Epitaxy
- Vacuum techniques
- Binding at surfaces and interfaces
- Diffraction methods with x-rays and slow electrons
- tunneling microscopy and –spectroscopy
- Nanostructuring, electron beam lithography
- electron microscopy
- Resonant tunneling

Fundamental literature:

will be given during the course

Recommended knowledge:

- Introduction to Solid State Physics

Module affiliation:

- Selected Topics of Modern Physics

Seminar Current research topics of the solid state physics
(Seminar Aktuelle Forschungsthemen der Festkörperphysik)

Courses (SWS)	Credit points:	Responsibility
2	3	Institute for Solid State Physics

Semster: Summer semester

Content:

Problems of the current Research, e.g. from the topics:

- Ultrathin metallic layers
- Phase transistions in two dimensions
- Molecular electronics
- Defect analysis in silicon wafers
- Isolator epitaxie
- Nanostructured metal/isolator system
- Electron-beam lithography
- Structuring of semiconducter components with atomic force microscope
- Resonant tunnel through InAs quantum dots
- High frequency experiments in quantum hall effect
- Electron- phonon-correlation in quantum hall sysytems
- Transport experiments in Si/SiGe heterostructure
- Noises in low dimensional electronic system
- Spintronics in semiconducters
- Optics in quantum hall regime

Fundamental literature:

Will be announced to every topic

Recommended knowledge:

- Advanced solid state physics

Module affiliation:

- Seminar

Thermodynamics, kinetics and structure of defect semiconductors
(Thermodynamik, Kinetik und Struktur von Defekten in Halbleitern)

Courses (SWS):	Credit points:	Responsibility:
2	2	Institut for Solid State Physics

Semester: Winter semester

Content:

The electronical and optical characteristics of semiconductors are multiple determined by defects, they are brought both unintentional (e.g. through crystal growing and processing) or intentional (e.g. as doping). This class deals with thermodynamics, kinetics and structure of defect semiconductors considering especially semiconductor specific problems, concepts and methods. Besides fundamental handling of the relevant concepts this class discuss cross connections to technological applications in photovoltaics, micro- and optoelectronics.

Fundamental literature:

🕮 to be announced in class

Recommended knowledge:

- Basics of semiconductor physics, e.g. within lecture class Solid State Physics

Module affiliation:

- Selected topics of modern physics

Physics in nanostructure (Physik in Nanostrukturen)

Courses (SWS)	Credit points:	Responsibility
2+1	4	Institut for Solid state physics

Regularity: Summer semester

Content:

- Fabrication of nanostructures by lithography and self-assembly
- Electronic structure, interface states
- quantum size effects
- Transport signatures in mesoscopic systems
- magnetoresistance effects
- Quantum effect, i.a. in graphs

Instabilities of 1-dimensional structures

- Single-electron transistors
- Molecular electronics
- Experimental methods

Fundamental literature:

- 🕮 Crytsal Growth for Beginners, Ivan V Markov (World Scientific)
- 🕮 Mesoscopic Electronics in Solid State Nanostructure, Thomas Heinzel (Wiley)
- 🕮 Surface Science: An Introduction, Philip Hofmann (kindle.edition)
- 🕮 Nanoelectronics and Information Technology, Rainer Waser (Wiley)

Recommended knowledge:

- Introduction to Solid state physics
- Surface physics

Module affiliation:

- Modern aspects of physics
- Selected topics of modern physics

Nonlinear Optics (Nicht lineare Optik)

Courses (SWS)	Credit points:	Responsibility
3+1	5	Institute of Quantum Optics

Semester: Summer semester

Content:

- Nonlinear optical susceptibility
- Crystal optics, tensor optics
- Wave equation with nonlinear source terms
- Frequency doubling, sum-, 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
- Nonlinear propagation, solitons

Fundamental 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 knowledge:

- Atom and molecular physics

Module affiliation:

- Modern Aspects of Physics
  - Selected Topics of Modern Physics

Photonics (Photonik)

Courses (SWS)	Credits points:	Responsibility
2+1	4	Institute of Quantum Optics

Semester: Winter semester

Content:

- Waves in Media and at Boundaries
- Dielectric Waveguides (planar, fiber), Integrated Waveguides
- Waveguide Modes
- Nonlinear Fiber Optics
- Fiber optical components (Cirkulators, AWG, Fiber-Bragg-Gratings, Modulators), Optical Communication (WDM/TDM)
- Faserlaser
- Laserdiods, Photodetectors
- Plasmonics, Photonic Crystals
- Transformation Optics

Fundamental literature:

- 🕮 Saleh, Teich: Photonics, Wiley;
- 🕮 Maier: Plasmonics: Fundamentals and Applications, Springer
- 🕮 Boyd: Nonlinear Optics, Academic Press
- 🕮 Original literature

Recommended knowledge:

- Coherent Optics
- Nonlinear Optics

Module affiliation:

- Selected topics of modern physics
- Selected topics of photonics

Seminar Photonics (Seminar Photonik)

Courses (SWS) 2	**Credit points:** 3	**Responsibility** Institute of Quantum Optics
Semester: Winter semester		
Content: According to discussion with lecturers. The seminar has to be chosen in combination with the lecture Photonics.		
Fundamental literature: 🕮 Saleh, Teich: Photonics, Wiley; 🕮 Maier: Plasmonics: Fundamentals and Applications, Springer 🕮 Boyd: Nonlinear Optics, Academic Press 🕮 Original literature		
Recommended knowledge: • Coherent Optics • Nonlinear Optics		

Atom optics (Atomoptik)

Courses (SWS)	Credit points:	Responsibility:
2+1	4	Institute of Quantum Optics

Semester: Summer semester

Content:

- Atom-light interaction Atom-Licht Wechselwirkung
- Radiation pressure forces Strahlungsdruckkräfte
- Neutral atom and ion traps Atom- und Ionenfallen
- Evaporative cooling Kühlung durch Evaporation
- Bose-Einstein Condensation Bose-Einstein-Kondensation
- Ultracold Fermi Gases Ultrakalte Fermi-Gase
- Experiments with ultracold and quantum degenerate gases Experimente mit ultrakalten und entarteten Quantengasen
- Atoms in optical lattices Atome in optischen periodischen Gittern
- ATOMICS and modern matter wave optics experiments ATOMICS und moderne Experimente zur Atomoptik

Fundamental literature:

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

Recommended knowledge:

- Atomic and molecular physics Atom- und Molekülphysik
- Quantum optics Quantenoptik

Module Affiliation:

- Selected Topics of Modern Physics
- Selected topics of photonics

Laboratory internship optics (Laborpraktikum Optik)

Courses (SWS)	Credit points:	Responsible:
6	6	Institute of Quantum Optics

Semester: Winter and summer semester

Content:

- Resonant power enhancement („Power-Recycling")
- Interferometric determination of gas density
- Magneto optical trap
- Fiber laser
- Dielectric coatings for optical components
- Saturation spectroscopy with diode lasers
- Optical tweezer
- Ultra short pulse laser

Fundamental literature:

Will be specified in the lab course

Recommended knowledge:

- Coherent optics

Module affilation:

- Modern aspects of physics
- Selected topics of modern physics

Solid state lasers (Festkörperlaser)

Courses (SWS):	Credit points:	Responsibility:
2	2	Institute for Quantum Optics

Semester: Summer semester

Content:

- Solid state laser media
- Optical resonators
- Laser modes of operation
- Diode pumped solid state lasers
- Laser designs: fiber, rod, disc
- Tunable lasers
- Single-frequency lasers
- Ultrashort-pulse lasers
- Frequency conversion

Fundamental literature:

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

Recommended knowledge:

- Coherent Optics or Nonlinear optics

Module affiliation:

- Selected Topics of Modern Physics

Optical layers (Optische Schichten)

Courses (SWS)	Credit points:	Responsibility
2 + 1	4	Institute of Quantum Optics

Semester: Winter semester

Content:

- Relevance, functional principle and application areas of optical coatings, present quality level of coating systems for laser technology
- Theoretical basis (compilation of common formulas and phenomena, calculation of coating, systems)
- Production of optical components (substrates, coating materials, deposition processes, control of deposition processes)
- Optics characterization (measurement of transfer properties, losses: total scattering, optical absorption, damage thresholds of optical laser components, non-optical properties)

Fundamental literature:

- Will be announced during the lecture
- For an introduction: Macleod, H.A.: Thin Film Optical Filters, Fourth Edition, CRC Press 2010

Recommended knowledge:

- Lectures „Coherent optics" or „Nonlinear optics"

Module affiliation:

- Selected Topics of Modern Physics

Data Analysis

Courses (SWS)	Credit points:	Responsibility:
2	2	Institute for Gravitational Physics

Semester: Summer semester

Content:

- Detectors (interferometer and „resonant mass" detectors)
- Data analysis
- Templates
- vetoes

Fundamental literature:

to be announced in class

Recommended knowledge:

- Basics of special relativity theory
- Coherent optics

Module affiliation:

- Selected Topics of Modern Physics

Neutron Stars und Black Holes		
Courses (SWS) 2	**Credit points:** 2	**Responsibility:** Institute for Gravitational Physics
Semester: Summer semester		
Content: • Sources and expansion of gravitational waves • Neutron stars and Black Holes		
Fundamental literature: to be announced in class		
Recommended knowledge: • Basics of special relativity theory • Coherent optics		
Module affiliation: • Selected Topics of Modern Physics		

Seminar Gravitational waves (Seminar Gravitationswellen)		
Courses (SWS) 2	**Credit points:** 3	**Responsibility:** Institute for Gravitational Physics
Semester: Summer semester		
Content: In agreement with the professor		
Fundamental literature: to be announced in lecture class and course		
Recommended knowledge: • Basics of special relativity theory • Coherent optics		
Module affiliation: • Selected Topics of Modern Physics		

Seminar Gravitational physics (Seminar Gravitationsphysik)

Courses (SWS)	Credit points (ECTS):	Responsibility:
3	3	Institute for Gravitational Physics (Institut für Gravitationsphysik)

Regularity: Summer semester and Winter semester

Content:

- General Theory of relativity
- Sources of Gravitational waves
- Gravitational waves detectors
- Astrophysics and cosmology
-

Fundamental Literature:

to be announced in class

Recommended knowledge:

- Gravitational Physics

Module Affiliation:

- Selected Topics of Modern Physics
- Seminar

Laser Interferometry (Laserinterferometrie)

Courses (SWS)	Credit points:	Responsibility:
3	3	Institute for Gravitational Physics

Semester: Summer or winter semester (irregular)

Content:

- Michelson-, Mach-Zehnder-, und Fary-Perot interferometer,
- Thermal noise
- Mechanical quality of hanging lenses
- Applications for measurement of Gravitational waves and the gravity field of the earth
- Description Gaussion rays and higher methods
- Transformation of Gaussion rays
- Selction procedures: internal, external and Schnuppmodulation; Pound-Drever Hall procedure
- Polarization
- Transfer function and control loops

Fundamental literature:

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

Recommended knowledge:

Optics, complex linear algebra

Module affiliation:

- Selected Topics of Modern Physics

Laborytory internship Laser interferometry (Laborpraktikum Laserinterferometrie)

Courses (SWS)	Credit points:	Responsibility:
4	4	Institute for Gravitational Physics

Regularity: Summer or winter semester (irregular)

Content:

- Michelson-, Mach-Zehnder-, Sagnac-, Polarization interferomtery,
- "Power- and Signal recycling", "Resonant Sideband Extraction", „Delaylines"
- Modulation fields, Schnuppmodulation, external modulation
- Homodyne and Heterodyne detection
- Spectral noise density
- Interferometry noises and sensitives (Quantum-, thermal noises, ...)
- Mechanical quality of hanging lenses

Fundamental literature:

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

Recommended knowledge:

- Coherent optics
- Nonlinear opticschtlineare Optik

Module affiliation:

- Selected Topics of Modern Physics

Laser stabilization and control of optical experiments

(Laserstabilisierung und Kontrolle optischer Experimente)

Courses (SWS)	Credits:	Responsible
2	2	Institute for Gravitational Physics

Semester: winter or summer semester (irregular)

Content:

- description of light fields and interference
- descriptions of fluctuations and noise
- basics of feedback control
- length control of interferometers and optical resonators
- detection of laser frequency fluctuations and their reduction
- detection of laser power fluctuations and their reduction
- pointing control of laser beams

Fundamental literature:

- Lasers; Siegman, Anthony E; Mill Valley, Calif. Univ. Science Books;(1986);ISBN 0-935702-11-5
- Optical electronics in modern communications; Yariv, Amnon; New York, Oxford Univ. Press; (1997) ;ISBN 0195106261 (cl)
- Feedback control systems : a fast-track guide for scientists and engineers; Abramovici, Alex (Chapsky, Jake;); Boston, Kluwer Acad. Publ; (2000); ;ISBN 0792379357
- A. Freise und K. Strain: Interferometer Techniques for Gravitational Wave Detection, Living Rev. 13 (2010) http://relativity.livingreviews.org/Articles/lrr-2010-1/

Recommended knowledge:

- coherent optics

Module affiliation:

- special topics of modern physics

Laboratory internship Cluster Computing (Laborpraktikum Cluster Computing)

Courses (SWS)	Credit points:	**Responsibility**
4	4	Institut for Gravitational physics

Semester: Summer and winter semester

Content:

- basics of matched filtering search method
- template banks and different search algorithms
- mismatch statistic and roc curves
- handle cluster resources using HTCondor
- computation time versus sensitivity of the analysis

Fundamental literature:

- 🕮 To be announce in the class

Recommended knowledge:

- Experience with Linux

Module affiliation:

- Modern aspects of physics
- Selected topics of modern physics

Nonclassic light (Nichtklassisches Licht)

Courses (SWS)	Credit points:	Responsibility
2	2	Institute for Gravitational Physics

Semester: Winter semester (irregular)

Content:
classical and non-classical states of light
criteria for "non-classicity"
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

Fundamental 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 knowledge:

coherent optics
non-linear optics
non-classical light
quantum optics

Module affiliation:

- Selected Topics of Modern Physics

Nonclassic laser interferometry (Nichtklassische Laserinterferometrie)

Courses (SWS)	Credit points	Responsibility
2+2	5	Institute for Gravitational Physics

Semester: Summer semester (irregular)

Content:

- shot noise and radiation pressure noise in interferometers
- quadrature operators and "input-output" relations of interferometers
- the standard quantum limit of position measurements
- quantum non-demolition techniques
- interferometers with squeezed light and other non-classical states of light
- opto-mechanical coupling and optical springs
- quantum states of mechanical oscillators
- cooling of mechanical oscillators to their quantum mechanical ground state
- entanglement of mirrors and light

Fundamental literature:

- 🕮 Saulson, *Fundamentals of Interferometric GW detectors*, World Scientific Pub Co Inc
- 🕮 Original literature

Recommended knowledge:

coherent optics
non-linear optics
non-classical light
quantum optics

Module affiliation:

- Selected Topics of Modern Physics

Electronic metrology in the optics laboratory (Elektronische Metrologie im Optiklabor)

Courses (SWS)	Credit points:	Responsibility
2	2	Institute for Gravitational Physics

Semester: summer or winter semester (irregularly)

Content:

- Electronics basics: Kirchhoff's laws, impedance, phasor diagrammes
- Operational amplifiers: function principle and basic circuits
- Resonant circuits and filters (active / passive)
- Spectrum Analyser and Network Analyser
- Measurement und interpretation of transfer functions
- Fundamentals of controls theory
- Photodetection
- Sensors and actuators in optical experiments
- Noise measurements

Fundamental literature:

- 🕮 Horowitz & Hill, *The Art of Electronics*, Cambridge University Press
- 🕮 Abramovici & Chapsky, *Feedback Control Systems*, Kluwer Academic Publishers
- 🕮 Yariv, *Quantum Electronics*, Wiley
- 🕮 Primary literature (given in lecture)

Recommended knowledge:

- Coherent optics

Module affiliation:

- Selected Topics of Modern Physics

Nuclear physics and nuclear chemistry of radiationprotection and radioecology (Kernphysikalische und kernchemische Grundlagen des Strahlenschutzes und der Radioökologie)

Courses (SWS)	Credit points :	Responsibility:
2	2	Institute for Radioecology and Radiation Protection

Semester: Winter semester

Content:

Based on nuclear intrinsic properties the droplet model and the shell model are derived. Radioactive decay laws are discussed. Alpha, beta and gamma decay are introduced phenomenologically and the Gamov theory (alpha) and Fermi theory (beta) are derived. Neutron physics, nuclear reactions, fission, fusion and generation of super heavy elements are treated. Basic physical processes of radiation matter interaction are introduced in order to understand concepts of radiation exposure, dosimetry and radiation measurement techniques. Behavior of radioactive elements in living organisms including man and environment is discussed.

Fundamental literature:

- Kratz, Lieser *Nuclear and radiochemistry : fundamentals and applications / Vol. 1& 2,* Ausgabe: 3., rev. ed. Weinheim : Wiley-VCH, 2013
- Choppin, Rydberg, Liljenzin, *Radiochemistry and Nuclear Chemistry*, Butterworth Heinemann, Oxford, 1995
- Marmier, Sheldon, *Physics of Nuclei and Particles*, 2 volumes, Academic Press, New York, 1970
- Mayer-Kuckuk, *Kernphysik* (6. Aufl.) Teubner, Stuttgart, 1994
- Knoll, *Radiation detection and measurement*, J. Wiley & Sons, New York, 2000
- Vogt, *Grundzüge des praktischen Strahlenschutzes* 6. Auflage 2011, Hanser Verlag
- http://www.nucleonica.com/ : Karlsruhe Chart of Nuclides
- Strahlenschutzverordnung vom 20. Juli 2001 (BGBl. I S. 1714; 2002 I S. 1459), zuletzt geändert durch Artikel 5 Absatz7 des Gesetzes vom 24. Februar 2012 (BGBl. I S. 212)

Recommended knowledge:

- Mechanics / Quantum Mechanics
- Electrodynamics
- Molecules, Nuclei, Particles, Statistics

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Nuclear energy and fuel cycle, technical aspects and public discourse

(Kernenergie und Brennstoffkreislauf, technische Aspekte und gesellschaftlicher Diskurs)

Courses (SWS)	Credit points:	Responsibility:
2	2	Institute for Radioecology and Radiation Protection

Semester: Winter semester

Content:

In spite of, or maybe even because of, Germany's phase out of nuclear power, this topic is vigorously discussed by politics, stakeholders, NGOs and members of the public. This lecture provides technical basics of the nuclear energy cycle covering uranium mining, fuel fabrication recent and future reactor concepts and the disposal of spent nuclear fuel. Besides the view on technical aspects, the issue is discussed by guest docents of social sciences, ethics and law. You are welcome to articulate your own opinion and discuss with the experts !

Fundamental literature:

- 🕮 Streffer, *Radioactive Waste*, Springer
- 🕮 Michaelis, *Handbuch Kernenergie*
- 🕮 Heinloth, *Die Energiefrage*, Vieweg
- 🕮 Additional literature and references will be announced in the lecture

Recommended knowledge:

- Advantageous: Lecture "Basics of radioecology and radiation protection: Nuclear Physics and Nuclear Chemistry Aspects" (can be attended in parallel)
- Mechanics / Quantum Mechanics
- Electrodynamics
- Molecules, Nuclei, Particles, Statistics
-

Module affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Radioactivity in the environment and radiation hazard to humans (Radioaktivität in der Umwelt und Strahlengefährdung des Menschen)

Courses (SWS)	Credit points:	Responsibility:
2	2	Institute for Radioecology and Radiation Protection

Regularity: Summer semester

Content:

Abundance and migration of natural and anthropogenic radioactivity in the environment are presented. Pathways to man are discussed and risks for humans due to radiation exposure are assessed. The following topics are discussed in detail: Radiation exposure due to the nuclear explosions in Hiroshima and Nagasaki and due to the subsequent decades of nuclear weapons testing. Nuclear accidents of Windscale, Chernobyl, Fukushima, Kystym and criticality accidents. Lost highly radioactive sources (Goiania) . Consequences of uranium mining for workers and environment. Patients exposure due to radium and radon treatments.

Fundamental 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
- Further literature announced and provided in the lecture (original papers and web links)

Recommended knowledge:

- Lecture "Basics of radioecology and radiation protection: Nuclear Physics and Nuclear Chemistry Aspects"

Module affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Radiation Protection and Radioecology (Strahlenschutz und Radioökologie)

Courses (SWS)	Credit points:	Responsibility:
2	2	Institute for Radioecology and Radiation Protection

Regularity: Summer semester

Content:

The lecture comprises ionizing radiation, radioactive decay, interaction of radiation with matter, radiometric measurement techniques, dosimetry, biological effects of radiation, effects of radioactive substances and ionizing radiation on humans, contamination path ways, radioecological modelling of radionuclide migration to humans, natural radiation doses, anthropogenic radiation doses, radiation risk assessment, radiation dose and radiation risk, dose effect curves, collective dose, radiation protection concepts, regulatory dose limits and constraints, radiation protection (emergency) measures, legal regulations, EURATOM basic safety standards

(option to obtain the legal "Knowledge in Radiation Protection" (for radiation protection officers, "Strahlenschutzbeauftragter") for handling unsealed radioactive substances acc. to StrSchV S 4.1)

Fundamental literature:

- Vogt, *Grundzüge des praktischen Strahlenschutzes* 6. Auflage 2011, Hanser Verlag
- Siehl, *Umweltradioaktivität*, Ernst & Sohn Verlag Berlin (1996)
- Ahrens, Pigeot *Handbook of Epidemiology*, Springer Berlin Heidelberg New York (2205)
- *Strahlenschutzverordnung* vom 20. Juli 2001 (BGBl. I S. 1714; 2002 I S. 1459), zuletzt geändert durch Artikel 5 Absatz7 des Gesetzes vom 24. Februar 2012 (BGBl. I S. 212)
- Allgemeine Verwaltungsvorschrift zu § 47 Strahlenschutzverordnung: *Ermittlung der Strahlenexposition durch die Ableitung radioaktiver Stoffe aus Anlagen oder Einrichtungen* , Drucksache 88/12 15.02.12
- Additional literature to be announced in the lecture

Recommended knowledge:

- Prerequisite: Lecture "Basics of radioecology and radiation protection: Nuclear Physics and Nuclear Chemistry Aspects"

Module affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Nuclear radioanalytical techniques (Nukleare Radioanalytische Techniken)

Courses (SWS)	Credit points:	Responsibility:
2	2	Institute for Radioecology and Radiation Protection

Regularity: Winter semester

Content:

Analytics *of* radioactive substances and analytics *by use of* radioactive substances and ionizing radiation. Measurement of radiation fields, radiation matter interaction, solid state nuclear track detection, alpha, beta, gamma detection, neutron detection, neutron activation, laser based detection and speciation methods, production and characterization of super heavy elements, use of tracer techniques, isotope dilution analysis, nuclear spectrometry, X-ray based analysis techniques, Mossbauer spectroscopy, nuclear magnetic resonance spectroscopy, accelerator mass spectrometry, statistics, characteristic limits, QC and QA, DIN ISO 11929

Fundamental literature:

- Kratz, Lieser *Nuclear and radiochemistry : fundamentals and applications / Vol. 1& 2*, Ausgabe: 3., rev. ed. Weinheim : Wiley-VCH, 2013
- Vogt, Schultz: *Grundzüge des praktischen Strahlenschutzes*, 6. Aufl., Hanser Verlag München 2011,
- 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
- Mayer-Kuckuk, *Kernphysik* (6. Aufl.) Teubner, Stuttgart, 1994
- Knoll, Radiation detection and measurement, J. Wiley & Sons, New York, 2000
- Gordon Gilmore, Practical Gamma Ray Spectrometry Wiley, & Sons, New York 2008
- Http://www.nucleonica.com/ : Karlsruhe Chart of Nuclides
- Strahlenschutzverordnung vom 20. Juli 2001 (BGBl. I S. 1714; 2002 I S. 1459), zuletzt geändert durch Artikel 5 Absatz7 des Gesetzes vom 24. Februar 2012 (BGBl. I S. 212)

Recommended knowledge:

- Lecture "Basics of radioecology and radiation protection: Nuclear Physics and Nuclear Chemistry Aspects" (can be attended in parallel)

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Nuclear Physics Applications in the Environmental Sciences
(Kernphysik-Anwendungen in den Umweltwissenschaften)

Courses (SWS)	Credit points:	Responsibility:
2	2	Institute for Radioecology and Radiation Protection

Regularity: Summer semester

Content:

Stellar nuclear synthesis processes are derived from basic nuclear physics principles. Formation of the elements in stars and supernova explosions (r- and s-processes) is presented. The concepts of isotopes and physical and chemical isotope effects are introduced. Natural isotope effects and their technical applications are discussed. Use of stable and radioactive tracers and "clocks" in geosphere, atmosphere, hydrosphere, pedosphere and biosphere are treated. Primary, radiogenic, cosmogenic and nucleogenic anomalies of isotope abundances are discussed with respect to their use in age determination: age of the chemical elements, formation of the solar system, and collision history of small extraterrestrial bodies. Environmental element cycles are modelled using simple compartments with special focus on H-3, Be-10, C-14, Cl-36 and I-129. Production of cosmogenic nuclides in the atmosphere and in situ production in the earths surface are explained. Stable and radioactive isotopes in various environmental compartments allow for the investigation of environmental evolution and changes due to anthropogenic influences.

Fundamental 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 knowledge:

- Optics, atom physics, Quantum Phenomena
- Molecules, cores, particles, solid states
- Lecture "Basics of radioecology and radiation protection: Nuclear Physics and Nuclear Chemistry Aspects"

Module affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Radiochemistry and radioanalysis (Radiochemie und Radioanalytik)

Courses (SWS)	Credit points:	Responsibility
2	2	Institut for Radioecology and Radiation protection

Regulariry: Winter semester

Content:

This lecture provides knowledge of the chemical and physical properties of natural and artificial radionuclides, especially actinides. Based on element- or group-specific properties, quantitative radioanalytical methods and separation techniques are deepened. The lecture contents are complementary to the content of the lecture "Nuclear Methods of Analysis and Radioanalysis". The application of separation techniques depending on different matrices is discussed. The common methods of sampling and preparation upstream of an environmental sample analysis are explained. For the application of some separation techniques an understanding of the speciation of interesting radionuclides is indispensable. Dominant factors influencing the speciation are shown. A central theme is the migration behavior of radionuclides in the geosphere and biosphere. The main focus is on the chemical and physical properties of radioactive elements, aquatic chemistry of radionuclides, in particular f-elements, quantitative radioanalytics, separation techniques, environmental sampling and preparation, radioactive nuclides and radiation in of medicine, radionuclide production, behavior of radionuclides in the environment

Fundamental literature:

- 🕮 David Atwood, *Radionuclides in the Environment*, Wiley and Sons, 2010
- 🕮 Lehto, Hou, *Chemistry and Analysis of Radionuclides*, Wiley-VCH 2011

Recommended knowledge:

- Basics of chemistry
- Lecture "Nuclear physics and nuclear chemistry fundamentals of radiation protection and radioecology"

Module affiliation:

- Selected topics of modern physics

Introduction to radioecology and radiation protection

(Einführung in die Massenspektrometrie)

Courses (SWS)	Credit points:	Responsibility
2	2	Institut for Radioökologie und Strahlenschutz

Regularity: Winter semester

Content:

- Following the introduction of mass spectrometric basic concepts, various ionization, mass selection and detection methods as well as vacuum aspects are explained. Common mass spectrometric methods focusing on element and isotope ratio analysis, determination of solution species and MS imaging techniques are discussed. Finally, high-precision mass measurements are also presented on extremely short-lived radionuclides and antimatter, 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

Fundamental 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 knowledge:

- Mechanics
- Elektrodynamics
- Optics, nuclear physics, quantum phenomena

Module affiliation:

- Selected topics of modern physics

Seminar to Radiation protection and radioecology (Seminar Strahlenschutz und Radioökologie)		
Courses (SWS) 2	**Credit points:** 3	**Responsibility:** Institute for Radioecology and Radiation Protection
Semester: Winter and summer semester		
Content: To be arranged with the lecturer		
Fundamental literature: 🕮 Will be provided according to topic		
Recommended knowledge: • Lecture "Basics of radioecology and radiation protection: Nuclear Physics and Nuclear Chemistry Aspects"		
Module affiliation: • Modern Aspects of Physics • Selected Topics of Modern Physics		

Expertise in radiation protection (acc. to StrSchV)

(only in German language)

Courses (SWS)	Credit points:	Responsibility:
min. 2	2	Institute for Radioecology and Radiation Protection

Semester: Winter and summer semester

Content:

The IRS offers radiation protection courses to attain knowledge in radiation protection (so called "Fachkunde") according to the German radiation protection ordinance, StrSchV, and the German Röntgen ordinance, RöV. Contens are physical basics, dose concepts, biological radiation effects, and technical and organizational concepts of radiation protection.
Each student may choose freely one course from the program offered by IRS (www.strahlenschutzkurse.de). The work load of one course varies between 2 and 6 weekly hours per semester. As an additional qualification the successful completion of the course qualifies to apply for the "knowledge in radiation protection" at the regulator in charge (in Lower Saxony this is the "Gewerbeaufsichtsamt"). For this reason the course is credited with 2 ECTS points irrespective of the actual work load.

Fundamental literature:

- Vogt, Schultz: *Grundzüge des praktischen Strahlenschutzes*, 6. Aufl., Hanser Verlag München 2011
- Http://www.nucleonica.com/ : Karlsruhe Chart of Nuclides
- *Strahlenschutzverordnung* vom 20. Juli 2001 (BGBl. I S. 1714; 2002 I S. 1459), zuletzt geändert durch Artikel 5 Absatz7 des Gesetzes vom 24. Februar 2012 (BGBl. I S. 212)
- Röntgenverordnung

Recommended knowledge:

- Mechanic and Relativity
- Electricity
- Optics, Atom physics, Qunatum phenomenas
- Molecules, cors, Particals, Solid State

Module affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Courses in Meteorology

Numerical weather forecast (Numerische Wettervorhersage)

Courses (SWS)	Credit points:	Responsibility
2+1	4	Institut for Meteorology and Climatology

Regularity: Summer semester

Content:

- The basic equations
- Meteorological coordinate systems
- Map Projections
- The filter problem
- Filtered forecasting models
- Unfiltered forecasting models
- initialization
- For the numerical solution of the equation system
- The predictive models of the DWD
- Forecast examination

Fundamental literature:

- 🕮 Roache, *Computational Fluid Dynamics*, Hermosa Publishers

Recommended knowledge:

- Introduction to meteorology
- Kinematics and dynamics

Module affiliation:

- Elective area Meteorology
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology C
- Bachelor and Master Physics

Programming internship to Numerical weather forecast (Programmierpraktikum zur Numerischen Wettervorhersage)

Courses (SWS)	Credit points:	Responsibility
2	4	Institut for Meteorology and Climatology

Regularity: Winter semester

Content:

- Development and programming of a simple two-dimensional barotropic model which can be used to forecast the geopotential of the 500 hPa-level, based on the finite difference form of the 2D-vorticity-equation and the Poisson-equation for the geopotential
- The developed code will be used to simulate Rossby-waves, and to carry out a simple, idealized forecast for the North atlantic

Fundamental literature:

- Etling, D.: *Theoretische Meteorologie*, Springer
- Ferziger, J.H. und M. Peric: *Computational Methods for Fluid Dynamics*, Springer
- Roache, *Computational Fluid Dynamics*, Hermosa Publishers

Recommended knowledge:

- Applied programming
- Numerical weather forecast
- Kinematics and dynamics

Module affiliation:

- Wahlmodul Meteorologie
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
  Selected topics of modern meteorology C
- Bachelor and Master Physics

Pollutant spread in the atmosphere (Schadstoffausbreitung in der Atmosphäre)

Courses (SWS)	Credit points:	Responsibility
2+1	4	Institut for Meteorology and Climatology

Regularity: Winter semester

Content:

- Effects of air pollution on living and inanimate nature.
- Spread of pollutants in the atmosphere (Emission –Transmission – Immission).
- Mathematical Propagation Models (Gaussian Model, Euler Model, Lagrangian Particle Model).
- Air monitoring (limit and assessment values, TA-Luft).
- Selected problems of air pollution control (ozone, smog, acid rain, spreading in street canyons).

Fundamental literature:

- 🕮 Helbig et al., *Stadtklima und Luftreinhaltung*. Springer Verlag, Berlin.
- 🕮 Zenger, *Atmosphärische Ausbreitungsmodellierung*. Springer Verlag, Berlin

Recommended knowledge:

- Introduction to the meteorology
- Kinematics and dynamics
- Turbulence and diffusion

Module affliation:

- Elective module Meteorology
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology C
- Bachelor and Master Physics

Turbulence II (Turbulenz II)

Courses (SWS)	Credit points:	Responsibility
2+1	4	Institut for Meteorology and Climatology

Regularity: Winter semester

Content:

- turbulence features, Kolmogorov theory, Kolmogorov spectrum
- ensemble averaged equations, ergodicity
- spatial filtering, spatially averaged equations
- turbulent fluxes

Fundamental literature:

🕮 * Wyngaard, Turbulence in the Atmosphere, Cambridge University Press

Recommended knowledge:

- Kinematics and dynamics
- Turbulence and diffusion

Module affiliation:

- Elective area Meteorology
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology C
- Bachelor and Master Physics

Atmospheric convection (Atmosphärische Konvektion)

Courses (SWS)	Credit points:	Responsibility
2+1	4	Institut for Meteorology and Climatology

Regularity: Winter semester

Content:

- basics of thermally driven convection: Rayleigh-number, convection between plates, molecular/konvective heat transport, Nusselt-number, analytical derivation/calculation of the critical Rayleigh-number
- atmospheric convection: boundary layer growth, entrainment, coherent structures in convective flows

Fundamental literature:

- 🕮 Stull, R.B.: *An Introduction to Boundary Layer Meteorology,* Springer
- 🕮 Tritton: *Physical Fluid Dynamics,* Oxford University Press

Recommended knowledge:

- Thermodynamics and Statics
- Kinematics and dynamics
- Turbulence and diffusion

Module affiliation:

- Elective area Meteorology
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology B
- Bachelor and Master Physics

Programming internship to Simulation of atmospheric boundary layers (Programmierpraktikum zur Simulation der atmosphärischen Grenzschicht)

Courses (SWS)	Credit points:	Responsibility
2	4	Institut for Meteorology and Climatology

Regularity: Summer or winter semester

Content:

- development and programming of a simple one-dimensional boundary layer model based on finite differences
- simulation of boundary layer wind profiles (constant flux layer / Ekman layer)

Fundamental literature:

- Etling, D.: *Theoretische Meteorologie*, Springer
- Ferziger, J.H. und M. Peric: *Computational Methods for Fluid Dynamics*, Springer
- Roache, *Computational Fluid Dynamics*, Hermosa Publishers

Recommended knowledge:

- Applied programming
- Kinematics and dynamics
- Turbulence and diffusion
- Numerical weather forecast
- Atmospheric boundary layers and convection

Module affiliation:

- Elective area Meteorology
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology C
- Bachelor and Master Physics

Simulation of turbulent flows with LES Models

(Simulation turbulenter Strömungen mit LES-Modellen)

Courses (SWS)	Credit points:	Responsibility
2+1	4	Institut for Meteorology and Climatology

Regularity: Summer semester

Content:

- basics of turbulence simulation: direct numerical simulation (DNS), large-eddy simulation (LES), spatial filtering, inter-scale energy transfer, SGS-models
- numerics of LES models using the LES model PALM as an example: basic equations, numerical methods, parallelization
- examples of turbulence resolving simulations of atmospheric boundary layer flows

Fundamental literature:

- Fröhlich, J.: *Large Eddy Simulation turbulenter Strömungen*, Springer
- Sagault, P: *Large Eddy Simulation for Incompressible Flows*, Springer

Recommended knowledge:

- Turbulence and diffusion
- Numerical weather forecast
- Atmospheric boundary layers and convection
- Programming practical to numerical weather forecast

Module affiliation:

- Elective area Meteorology
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology C
- Bachelor and Master Physics

Numerical internship to Simulation of turbulent flows with LES Models (Numerisches Praktikum zur Simulation turbulenter Strömungen mit LES-Modellen)

Courses (SWS)	Credit points:	Responsibility:
2	4	Institut for Meteorology and Climatology

Regularity: Block event at the end of the summer semester

Content:

- installation of the LES model PALM
- development of setups and carrying out simulations for different phenomena (convective boundary layer, neutrally stratified flow, flow around buildings, etc.), incluing data analysis
- development and programming of the additional model features using PALM's user interface

Fundamental literature:

- Ferziger, J.H. und M. Peric: *Computational Methods for Fluid Dynamics*, Springer
- Fröhlich, J.: *Large Eddy Simulation turbulenter Strömungen*, Springer
- Roache: *Computational Fluid Dynamics*, , Hermosa Publishers
- Sagault, P: *Large Eddy Simulation for Incompressible Flows*, Springer

Recommended knowledge:

- Turbulence and diffusion
- Atmosphärische Grenzschicht und Konvektion
- Simulation of turbulent flows with LES-Models
- Programming practical to numerical weather forecast

Module affiliation:

- Elective area Meteorology
- Selected topics of modern meteorolog A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology C
- Bachelor and Master Physics

Agriculture meteorology (Agrarmeteorologie)

Courses (SWS)	Credit points:	Responsibility
2+1	4	Institut for Meteorology and Climatology

Regularity: Summer semester

Content:

- Radiation and water balance of plants
- Global water and radiation supply, climatic zones
- Foliation characteristic
- Water and plants
- Determination of evaporation and soil water content
- Inventory climates
- Phenology
- Plant damage and ist prevention
- The Climate in special rooms
- Peasants rules and singularities
- Agricultues and climate development

Fundamental literature:

Lecture notes

Recommended knowledge:

- Introduction to meteorology

Module affiliation:

- Elective area Meteorology
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology C
- Bachelor Geography
- Bachelor and Master Physics

Local climates (Lokalklimate)		
Courses (SWS) 2+1	**Credit points:** 4	**Responsibility** Institut for Meteorology and Climatology
Regularity: Winter semester		
Content: • The climate of the ground-level air layer • The climate of the city • Local climate forest • Local climate water and coast • The climate in orographically structured terrain		
Fundamental literature: Lecture notes		
Recommended knowledge: • Introduction to meteorology		
Module affiliation: • Elective area Meteorology • Selected topics of modern meteorology A • Selected topics of modern meteorology B • Selected topics of modern meteorology C • Bachelor Geography • Bachelor and Master Physics		

Remote sensing I (Fernerkundung I)		
Courses (SWS) 2+1	**Credit points:** 4	**Responsible** Institut for Meteorology and Climatology
Regularity: Winter semester		
Content: • Basics for measurements of satellites and their application for the detection of atmospheric processes • Remote sensing with satellite instruments. Derivation of temperature, clouds and trace gas measurements with remote sensing instruments from the satellite and the ground. • Derivation of radiation measurements from satellite data.		
Fundamantal literature: Kidder and Vonder Haar: *Satellite Meteorology: An Introduction, Academic Press*		
Recommended knowledge: • Introduction to meteorology • Radiation		
Module affiliation: • Elective area Meteorology • Selected topics of modern meteorology A • Selected topics of modern meteorology B • Selected topics of modern meteorology C • Master Optical technology • Bachelor and Master Physics		

Remote sensing II (Fernerkundung II)		
Courses (SWS) 2+1	**Credit points:** 4	**Responsibility** Institut for Meteorology and Climatology
Regularity: Summer semester		
Content: The contribution of land-based and satellite-based remote sensing to current research topics on climate, weather and global change. Presentation of the methods and the results.		
Fundamental literature: Kidder and Von der Haar: *Satellite Meteorology: An Introduction, Academic Press*		
Recommended knowledge: • Introduction to meteorology • Radiation • Remote sensing I		
Module affiliation: • Elective area Meteorology • Selected topics of modern meteorology A • Selected topics of modern meteorology B • Selected topics of modern meteorology C • Bachelor and Master Physics		

Seminar on advanced meteorology (Seminar zur fortgeschrittenen Meteorologie)		
Courses (SWS) 2	**Credit points:** 5	**Responsibiity** Institut for Meteorology and Climatology
Regularity: Winter and summer semester		
Content: Advanced topics of meteorology		
Fundamental literature: Will be announced in the seminar.		
Recommended knowledge: Will be announced in the seminar.		
Module affiliation: • Selected topics of modern meteorology C		

Meteorological excursion II (Meteorologische Exkursion II)		
Courses (SWS) 1	**Credit points:** 2	**Responsible** Institut for Meteorology and Climatology
Regularity: Summer or winter semester		
Content: Students in the master's program meteorology can take part in the annual and regular meteorological excursion. They prepare for a thematic aspect of the excursion, explain it during the excursion and are available for discussion and contact, write a contribution to the excursion report and present it in the final seminar. The content and formal requirements of these contributions to the excursion are determined by the qualification of a completed Bachelor's degree.		
Fundamental literature:		
Recommended knowledge:		
Module affiliation: • Selected topics of modern meteorology C		

External internship inland (Externes Praktikum Inland)		
Courses (SWS) 2	**Credit points:** 4	**Responsible** Institut for Meteorology and Climatology
Regularity: Summer or winter semester		
Content: The students apply independently to an inland institution (research institution, authority, engineering office, etc.) for a meteorological four-week internship and prepare for this. After successful completion of the internship they will write a report.		
Fundamental literature:		
Recommended knowledge:		
Module affiliation: • Selected topics of modern meteorology C		

External internship abroad (Externes Praktikum Ausland)		
Courses (SWS) 3	**Credit points:** 6	**Responsibility** Institut for Meteorology and Climatology
Regularity: Summer or winter semester		
Content: The students apply independently to a foreign institution (research institution, authority, engineering office, etc.) for a meteorological four-weeks internship and prepare for it. After successful completion of the internship they will write a report.		
Fundamental literature:		
Recommended knowledge:		