Leibniz Universität Hannover

Bachelor's Degree in Physics
Bachelor's Degree in Meteorology

Master's Degree in Physics
Master's Degree in Meteorology

Module Catalogue

As of 19.11.2021

Faculty of Mathematics and Physics
Leibniz University Hannover

Contact

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Preliminary Remarks

The module catalogue Physics and Meteorology consists of two parts: the module list and the appendix with the lecture list. As different lectures can be chosen in the elective modules, these are described in more detail in the appendix. In such cases information on the content and frequency of the lectures are to be found in the course descriptions (lecture list) rather than in the modules section.

Please note that this is a compilation of the lectures that are offered on a regular basis. In particular, further lectures in the university lecture list can be part of elective modules.

The module catalogue is to be seen as supplementary to the exam regulations. The most recent version of our exam regulations can be found at:

Physics :
https://www.maphy.uni-hannover.de/en/studies/students-and-courses/physics/

Meteorology :
https://www.maphy.uni-hannover.de/en/studies/students-and-courses/meteorology/

Contents

Course Sequence Plans

Course Sequence Plan BA Meteorology

	1st Semester	2nd Semester	3rd Semester	4th Semester	5th Semester	6th Semester	CP
Mathematics	Mathematics 1: Linear Algebra 8 LP, SL, PL Analysis A	Mathematics 2: Analysis 10 LP, SL, PL	Stochastics A 4 CP, SL, PL				
Experimental Physics	Mechanics and Heat 6 CP, SL	Electricity and Relativity 12 CP, SL	Optics, Nuclear Physics, Quantum Phenomena 10 CP, SL				28
	PL						
Theoretical Physics			Theoretical Physics A 7 CP, SL	Theoretical Physics B 7 CP, SL			14
General and Applied Meteorology	Introduction to Meteorology 8 CP, SL, EP	Climatology 4 CP, SL, EP	Radiation I 4 CP	Radiation II 4 CP	Practical Work with Instruments 6 CP, SL		38
			SL, EP				
				Cloud Physics 4 CP, SL, EP			
				Synoptic Meteorology 8 CP, SL			
Theoretical Meteorology			Thermodynamics and Statics 4 CP, SL, EP	Turbulence and Diffusion 4 CP, SL, EP			12
				Kinematics and Dynamics 4 CP, SL, EP			
Studium Integrale	Introduction						5

	to the Study of Meteorology						
	Work Internship SL						
Specialisation				Meteorological Field Trip I 2 CP, SL			34
				Elective Module Meteorology chosen from relevant courses worth 20 CP minimum 20 CP, (SL), EP			
				Scientific – Technical Elective min. 12 CP from courses of the faculties listed in the exam regulations 12 CP, (SL)			
Key Skills	A course held by the Language Centre or the Centre for Soft Skills or offered by the Faculty. 2 CP				Scientific Writing 2 CP		4
Presentation and Project Work						Bachelor's Project	15
Credit Points/Exam Points	28/4	32/4	30/5	According to individual planning			180

Course Sequence Plan BA Physics

<table>
<tr><th></th><th>1st Semester</th><th>2nd Semester</th><th>3rd Semester</th><th>4th Semester</th><th>5th Semester</th><th>6th Semester</th><th>CP</th></tr>
<tr><td rowspan="3">Mathematics</td><td>Analysis I
10 CP, SL, EP</td><td>Analysis II
10 CP, SL, EP</td><td>Mathematics for Physicists I
4 CP, SL</td><td>Mathematics 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">pass in one of the exams</td><td colspan="2">EP</td></tr>
<tr><td>Linear Algebra I
10 CP, SL, EP</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Experimental Physics</td><td>Mechanics and Heat
6 CP, SL</td><td>Electricity
12 CP, SL</td><td>Optics, Nuclear Physics, Quantum Phenomena
10 CP, SL</td><td>Molecules, Nuclei, Particles, Solids
10 CP, SL</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">38</td></tr>
<tr><td colspan="4">EP</td></tr>
<tr><td rowspan="2">Theoretical Physics</td><td>Mathematical Methods in Physics
7 CP, SL,</td><td>Theoretical Electrodynamics
7 CP, SL</td><td>Analytical Mechanics and Special Relativity Theory
4 CP, SL</td><td>Introduction to QuantumTheory
8 CP, SL</td><td>Statistical Physics
8 CP, SL</td><td rowspan="2"></td><td rowspan="2">38</td></tr>
<tr><td>EP</td><td colspan="2">EP</td><td colspan="2">EP</td></tr>
<tr><td>Specialisation</td><td></td><td></td><td></td><td></td><td colspan="2">2 of 3 Specialisation modules each L3+Ü1+P3 each 8 CP
- Solid-State Physics
- Atomic and Molecular Physics
- Coherent Optics</td><td>16</td></tr>
<tr><td>Physics Elective Area</td><td></td><td></td><td></td><td></td><td colspan="2">Min. 12 CP from the Physics Programme</td><td>12</td></tr>
<tr><td>Key Skills</td><td></td><td colspan="3">Seminar or Lecture
4 CP</td><td></td><td></td><td>4</td></tr>
<tr><td>Electives</td><td colspan="6">Business Administration, Chemistry, Electrical Engineering, Geodesy and Geoinformatics, IT, Mechanical Engineering, Mathematics, Meteorology, Philosophy and Economics.</td><td>16</td></tr>
</table>

Presentation and Project Work				Presenting Physics Seminar 3 CP, SL		Bachelor's Thesis 15 CP, Sl	18
Credit Points/Exam Points	33/2	29/1	Varies according to individual planning.				180

Bachelor's in Physics – Core Modules

<table>
<tr><th colspan="3">Analysis I + II</th><th>0211</th></tr>
<tr><td>Frequency</td><td colspan="3">Winter Semester and Summer Semester</td></tr>
<tr><td>Responsible for Module</td><td colspan="3">Elmar Schrohe, Institute of Analysis</td></tr>
<tr><td>Type of Course (SH)</td><td colspan="3">Lecture: "Analysis I"
Tutorial: "Analysis I"
Lecture: "Analysis II"
Tutorial: "Analysis II"</td></tr>
<tr><td>Assessment Components for Acquisition of CP</td><td colspan="3">Course Achievement:
Tutorial: Analysis I and Analysis II
Exam Performance:
One of the exams Analysis I or Analysis II</td></tr>
<tr><td>Grade Composition</td><td colspan="3">Not included in final grade</td></tr>
<tr><td>Credit Points (ECTS): 20</td><td>Study in Class (h): 180</td><td colspan="2">Independent Study (h): 420</td></tr>
<tr><td colspan="4">Learning Outcomes:
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 Tutoriales, students are familiar with mathematically exact formulations and conclusions in simple contexts and are able to present them.</td></tr>
<tr><td colspan="2">Topics:
Analysis I:
Number systems; systematic introduction of real and complex numbers
Sequences and series
Convergence and continuity
Differential calculus for functions of one variable
Integral calculus for functions of one variable.
Sequences of functions and power series</td><td colspan="2">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; path integrals
Ordinary differential equations, existence, uniqueness, elementary methods of solution.</td></tr>
<tr><td colspan="4">Reading List:
🕮 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</td></tr>
<tr><td colspan="4">Recommended Prior Knowledge:
School knowledge of mathematics (gymnasiale Oberstufe)</td></tr>
<tr><td colspan="4">Where applicable entrance requirements and/or restricted number of participants: None</td></tr>
<tr><td colspan="4">Applicability:
Bachelor's Programme in Physics (Core Module)</td></tr>
</table>

Linear Algebra I			0111
Frequency	Winter Semester		
Responsible for Module	Institute of Algebra, Number Theory and Discrete Mathematics and Institute of Algebraic Geometry		
Type of Course (SH)	Lecture: "Linear Algebra I" Tutorial: "Linear Algebra I"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial exercises **Exam Performance:** Exam		
Grade Composition	Not included in final grade		
Credit Points (ECTS): 10	**Study in Class (h):** 90	**Independent Study (h):** 210	

Learning Outcomes:
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. Ability to express and present mathematical reasoning, and knowledge of suitable methods for this.

Topics:
- 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.

Reading List:
- 🕮 G. Fischer, *Lineare Algebra*, Vieweg

Recommended Prior Knowledge:
School knowledge of mathematics (gymnasiale Oberstufe)

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:
- Bachelor's Programme in Physics (Core Module)

Mathematics for Physicists (Mathematik für Physiker)			0050
Frequency	Winter Semester and Summer Semester		
Responsible for Module	Elmar Schrohe, Institute of Analysis		
Type of Course (SH)	Lecture: "Mathematics for Physicists I" Tutorial: "Mathematics for Physicists I" Lecture: "Mathematics for Physicists II" Tutorial: "Mathematics for Physicists II"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial: exercises **Exam Performance:** Oral or written exam, lecturer's option		
Grade Composition	Grade of exam		
Credit Points (ECTS): 8	**Study in Class (h):** 90	**Independent Study (h):** 150	

Learning Outcomes:
Students have an advanced understanding of analytical methods, particularly of integration theory and complex analysis. They are able to work independently to develop difficult mathematical arguments and present their results in the Tutorial. The students have grasped the mathematical structure of important differential equations in physics and are able to apply suitable strategies for solving them.

Topics:
- Lebesgue function spaces and convergence theorems
- Differential forms and integral theorems
- Fourier analysis
- Linear partial differential equations
- Elements of complex analysis

Reading List:
As announced in the lecture

Recommended Prior Knowledge:
Module Analysis I + II

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:
- Bachelor's Programme in Physics (Core Module)
- Bachelor's Programme in Meteorology (Scientific-technical Elective Area)

Mechanics and Heat (Mechanik und Wärme)			1011
Frequency	Winter Semester		
Responsible for Module	K. Danzmann, AEI		
Type of Course (SH)	Lecture: "Mechanics and Heat" Tutorial: "Mechanics and Heat"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial exercises		
Grade Composition	-		
Credit Points (ECTS): 6	**Study in Class (h):** 90	**Independent Study (h):** 90	

Learning Outcomes:
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.

Topics:

- 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, degrees of freedom
- Mechanical oscillations and waves
- Newton's axioms
- work, energy and potential
- Harmonic osscillator
- rotational motion, dynamcis of rigid, extended objects
- frames of reference, fictitious forces
- the $1/r^2$ law, gravitation, Kepler's laws
- real gases, solid and fluid objects, surface tension, friction
- streaming fluids and gases, , Bernoulli's equation
- transport processes, diffusion, heat conduction
- transformation of energy, fundamental thermodynamic laws changes of state, cyclic processes, heat engines, entropy

Reading List:

- 🕮 Demtröder, *Experimentalphysik1, Mechanik und Wärme*, Springer Verlag
- 🕮 Gerthsen, *Physik*, Springer Verlag
- 🕮 Tipler, *Physik*, Spektrum Akademischer Verlag
- 🕮 Feynman, *Lectures on Physics*, Band 1; Addison-Wesley Verlag

Recommended Prior Knowledge:
High school knowledge of mathematics and physics

Where applicable entrance requirements and/or restricted number of participants: none

Applicability:

- Bachelor's Programme in Physics (Core Module)
- Bachelor's Programme in Meteorology (Core Module)

Electricity and Relativity (Elektrizität und Relativität)			1012
Frequency	Summer Semester		
Responsible for Module	Institutes of Experimental Physics		
Type of Course (SH)	Lecture: "Electricity" Tutorial: "Electricity" Laboratory practical I: Mechanics, Thermodynamics and Electricity		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial exercises and labs		
Grade Composition	-		
Credit Points (ECTS): 12	**Study in Class (h):** 150	**Independent Study (h):** 210	

Learning Outcomes:
The students have a sound factual knowledge of 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 functionality and accuracy of different measurement instruments and are familiar with computer-based data acquisition. They are able to present their measurement results in tabular and graphical form.

Topics:

Lecture and Exercises:

- Electrostatics, electric charge, Coulomb's law-Gesetz, multipoles, Gauss law, capacitors
- Electric current, Ohm's law, Kirchhoff's rules, Stokes' law, conversation of charge
- Static magnetic fields, law of Biot-Savart, permanent magnets, Lorentz force, static Maxwell equations, Hall effect
- Time dependent fields, induction, Lenz' rule, alternating current, dynamic Maxwell-equations
- magnetic und electric properties of matter, Maxwell's equations in matter
- elektromagnetic oscillations and the generation of electromagnetic waves, energy density in electromagnetic fields, oscillating circuits, Hertz dipole
- Electromagnetic waves, waves in vacuum, wave equation, velocity of light
- Elektromagnetic Waves in matter, index of refraction, absorption, dispersion
- moving frames, special theory of relativity, Michelson-Morley, Lorentz transformation, Doppler effect, addition ofvon velocities

Beginners' Lab I:

Mechanics
possible Lab experiments: energy conservation for the pendulum, Oscillations, coupled pendulums, gyroscopes, ultrasound, acoustics, Maxwell-wheel

Thermodynamics
possible Lab experiments: temperature, ideal gas, viscosity, specific heat, water vapour, radiation and temperature, Stirling motor, critical point, pressure fields/specific heat

Electricity
possible Lab experiments: el. resistance resonant circuits, transistors, operational amplifiers, flop circuits, feedback, membrane model, galvanometers, oscilloscopes, analysis of noise, storage oscilloscope

Reading List:

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

Recommended Prior Knowledge:
Lectures "Mechanics and Heat" and "Mathematical Methods in Physics"

Where applicable entrance requirements and/or restricted number of participants: none

Applicability:
- Bachelor's Programme in Physics (Core Module)
- Bachelor's Programme in Meteorology (Core Module)

Optics, Atomic Physics, Quantum Phenomena (Optik, Atome, Moleküle, Quantenphänomene)			
Frequency	Winter Semester		
Responsible for Module	U. Morgner, Institute of Quantum Optics		
Type of Course (SH)	Lecture: "Optics, Atomic Physics, Quantum Phenomena" Tutorial: "Optics, Atomic Physics, Quantum Phenomena"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial exercises		
Grade Composition	-		
Credit Points (ECTS): 10	**Study in Class (h):** 120	**Independent Study (h):** 180	

Learning Outcomes:
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.
A continuous participation is required to achieve the learning outcomes of the Lab Exercise.

Topics:

Optics, Atomic Physics, Quantum Phenomena

- Geometric optics
- Complex refractive index
- Optics at interfaces
- Lenses and simple optical instruments
- Photometry
- Polarization, birefringence, optical aktivity
- interference, diffraction, scattering
- Gaussian optics, resonators, lasers
- Blackbody radiation, photoelectric effekt
- Compton effect, wave-particle-dualism
- Wave funktion in box potential, matter waves, Schrödinger equation, tunnel effect, Hydrogen atom
- Structure of atoms, Bohr's atom model, Quantum numbers, Pauli-principle, Spin, Zeeman-Effect, fine structure, spin orbit coupling
- Selection rules, X-ray spectra, atomic units
- Atoms with multiple electrons, structure oft he periodic table
- Molecules: chemical bond, molekular potential, Molekular orbitals, vibration, Rotation, Franck-Condon principle

Beginners' Lab II: Optics and Atomic Physics
possible practical experiments: lenses, microscopes, Michelson interferometer, Mach-Zehnder interferometer, interference/coherence, diffraction, polarisation, Faraday effect, prisms, grating, photo effects, absorption spectroscopy, Emission spectroscopy, spectral apparatus, X-rays

Reading List:

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

Recommended Prior Knowledge:
Modules "Mechanics and Heat" and "Electricity and Relativity"

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:
- Bachelor's Programme in Physics (Core Module)
- Bachelor's Programme in Meteorology (Core Module)

Nuclei, Particles and Solids (Kerne, Teilchen, Festkörper)			1014
Frequency	Summer Semester		
Responsible for Module	Institutes of Experimental Physics		
Type of Course (SH)	Lecture: "Nuclei, Particles" Tutorial: "Nuclei, Particles" Lecture: "Solid State Physics I" Tutorial: "Solid State Physics I"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorials		
Grade Composition	-		
Credit Points (ECTS): 8	**Study in Class (h):** 120	**Independent Study (h):** 180	

Learning Outcomes:
The students are familiar with 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.

Topics:

Nuclei, Particles and Solids:
- The terms energies in nuclei, cross section, Schrödinger equation, Heisenberg
- Radioaktive decay, chart of nuclides, properties of nuclei, particle properties
- Strong interaction, Binding energy, droplet modell
- alpha decay including Gamov Theory
- Nuclear forces, shell modell
- Gamma decay including transitions
- Weak interaction
- Beta decay including Fermi Theory
- Neutrons, moderation, fission
- Nuclear reactions, collective excitations, Compound nucleus
- Fusion
- Hadronen, leptons, bosons

Solid State Physics I
- Crystals and crystal structures
- Chemical bonds in solids
- Diffraction and scattering in crystal structures
- Lattice vibrations, quantization, Phonons
- Thermal properties of solids

Reading List:
- 🕮 R.Groß, A.Marx *Festkörper*, De Gruyter
- 🕮 Demtröder *Experimentalphysik2 und 3*, Springer Verlag
- 🕮 T.Mayer-Kuckuk *Kernphysik,* Teubner
- 🕮 Berkeley Physikkurs
- 🕮 Bergmann/Schäfer
- 🕮 Haken, Wolf, *Atom- und Quantenphysik* sowie *Molekülphysik und Quantenchemie, Springer Verlag*

Recommended Prior Knowledge:
Modules "Mechanics and Heat", "Electricity and Relativity", "Optics, Atomic Physics, Quantum Phenomena"

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:
- Bachelor's Programme in Physics (Core Module)
- Bachelor's Programme in Meteorology (Scientific-technical Elective Area)

Nuclei, Particles and Solids (Kerne, Teilchen, Festkörper)			**1014**
Frequency	Summer Semester		
Responsible for Module	Institutes of Experimental Physics		
Type of Course (SH)	Lecture: "Nuclei, Particles" Tutorial: "Nuclei, Particles" Lecture: "Solid State Physics I" Tutorial: "Solid State Physics I"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorials		
Grade Composition	-		
Credit Points (ECTS): 10	**Study in Class (h):** 120	**Independent Study (h):** 180	

Learning Outcomes:
The students are familiar with 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.
A continuous participation is required to achieve the learning outcomes of the Lab Exercise.

Topics:

Nuclei, Particles and Solids:

- The terms energies in nuclei, cross section, Schrödinger equation, Heisenberg
- Radioaktive decay, chart of nuclides, properties of nuclei, particle properties
- Strong interaction, Binding energy, droplet modell
- alpha decay including Gamov Theory
- Nuclear forces, shell modell
- Gamma decay including transitions
- Weak interaction
- Beta decay including Fermi Theory
- Neutrons, moderation, fission
- Nuclear reactions, collective excitations, Compound nucleus
- Fusion
- Hadronen, leptons, bosons

Solid State Physics I

- Crystals and crystal structures
- Chemical bonds in solids
- Diffraction and scattering in crystal structures
- Lattice vibrations, quantization, Phonons
- Thermal properties of solids

Reading List:

- 🕮 R.Groß, A.Marx *Festkörper*, De Gruyter
- 🕮 Demtröder *Experimentalphysik2 und 3*, Springer Verlag
- 🕮 T.Mayer-Kuckuk *Kernphysik,* Teubner
- 🕮 Berkeley Physikkurs
- 🕮 Bergmann/Schäfer
- 🕮 Haken, Wolf, *Atom- und Quantenphysik* sowie *Molekülphysik und Quantenchemie, Springer Verlag*

Recommended Prior Knowledge:
Modules "Mechanics and Heat", "Electricity and Relativity", "Optics, Atomic Physics, Quantum Phenomena"

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:

- Bachelor's Programme in Physics (Core Module)
- Bachelor's Programme in Meteorology (Scientific-technical Elective Area)

Cross-Module Exam in Experimental Physics (Modulübergreifende Prüfung Experimentalphysik)	**1001**
Frequency	Winter Semester and Summer Semester
Responsible for Module	Dean of Studies Office
Type of Course (SH)	oral exam
Assessment Components for Acquisition of CP	**Exam Performance:** oral exam
Grade Composition	Grade of oral exam

Learning Outcomes:
The students have acquired a thorough overview of the fundamental aspects of Experimental Physics.
They have 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 its different characteristics at the individual length- and energy-scales. They are proficient in independent knowledge acquisition through the study of scientific literature.

Topics:

Physics:
- Mechanics and Heat
- Electricity
- Optics, Atomic Physics and Quantum Phenomena
- Molecules, Nuclei, Particles and Solids

Meteorology:
- Mechanics and Heat
- Electricity
- Optics, Atomic Physics and Quantum Phenomena

Where applicable entrance requirements and/or restricted number of participants:

Physics:
Three modules from: "Mechanics and Heat"; "Electricity and Relativity"; "Optics, Atomic Physics, Quantum Phenomena"; "Nuclei, Particles and Solids"

Meteorology:
Two Modules from: "Mechanics and Heat", "Electricity and Relativity", "Optics, Atomic Physics, Quantum Phenomena".

Applicability:
- Bachelor's Programme in Physics (Core Module)
- Bachelor's Programme in Meteorology (Core Module)

Mathematical Methods in Physics (Mathematische Methoden der Physik)			1111
Frequency	Winter Semester		
Responsible for Module	L. Santos, Institute of Theoretical Physics		
Type of Course (SH)	Lecture: "Mathematical Methods in Physics" Tutorial: "Mathematical Methods in Physics"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutoriales **Exam Performance:** exams		
Grade Composition	Grade of oral or written exam		
Credit Points (ECTS): 7	**Study in Class (h):** 75	**Independent Study (h):** 135	

Learning Outcomes::
Students learn the mathematical tools to formulate physical theories. Simple physical problems can be mathematically formalized and solved.

Topics:

- Non-inertial reference systems: Inertial forces, dynamics of the rigid body
- 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 measure, substitution rule, delta distribution
- Programming of simple numerical methods for the solution and visualization of physical problems

Reading List:

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

Recommended Prior Knowledge:

- School knowledge of mathematics (gymnasiale Oberstufe)

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:

- Bachelor's Programme in Physics (Core Module)
- Bachelor's Programme in Meteorology (Core Module)

Theoretical Electrodynamics (Theoretische Elektrodynamik)			1111
Frequency	Summer Semester		
Responsible for Module	H. Frahm, ITP		
Type of Course (SH)	Lecture: "Theoretical Electrodynamics" Tutorial: "Theoretical Electrodynamics"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutoriales or exam **Exam Performance:** none		
Grade Composition	Not included in final grade		
Credit Points (ECTS): 7	**Study in Class (h):** 75	**Independent Study (h):** 135	

Learning Outcomes::
Students understand the logical structure of electrodynamics and can formulate its laws mathematically. They know prominent electrodynamic phenomena and are able to deduce these from the basic laws. Students find analytical strategies and apply suitable mathematical and physical approximations towards solving electrodynamic problems.

Topics:

- vector fields: vector analysis, theorem of Gauss and Stokes, 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 expansion
- magnetostatics: one-dimensional current distributions, field energy
- moving point charges, Lienard-Wiechert potentials
- electromagnetic waves: in vacuum, with sources, radiation
- Electrodynamics in matter
- Coding simple algorithms for the solution and visualization of physical problems

Reading List:

- Landau-Lifschitz, *Lehrbuch der Theoretischen Physik*, Band II, Harri
- J.D. Jackson, *Klassische Elektrodynamik,* Gruyter, Walter de GmbH
- Römer & Forger, *Elementare Feldtheorie,* Wiley
- Nolting, Grundkurs Theoretische Physik 3 - Elektrodynamik, Springer

Recommended Prior Knowledge:

- School knowledge of mathematics (gymnasiale Oberstufe)
- "Mathematical Methods in Physics"

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:

- Bachelor's Programme in Physics (Core Module)
- Bachelor's Programme in Meteorology (Core Module)

Analytical Mechanics and Special Relativity (Analytische Mechanik und Spezielle Relativitätstheorie)			**1112**
Frequency	Winter Semester		
Responsible for Module	D. Guilini, Institute of Theoretical Physics		
Type of Course (SH)	Lecture: "Analytical Mechanics and Special Relativity" Tutorial: "Analytical Mechanics and Special Relativity"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial exercises		
Grade Composition	-		
Credit Points (ECTS): 8	**Study in Class (h):** 90	**Independent Study (h):** 150	

Learning Outcomes:
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.

Topics:
- Lagrangian mechanics: constraints, Lagrange multipliers, Lorentz force
- variational calculus: functional derivative, extrema under constraints
- action principle, Noether's theorem, conservation laws
- accelerated coordinate systems, fictitious forces, rigid-body kinematics
- rigid-body dynamics: Euler equations, spinning top, precession, mutation
- 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

Reading List:
- 🕮 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 Prior Knowledge:
- "Mathematical Methods in Physics" and "Theoretical Electrodynamics"

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:
- Bachelor's Programme in Physics (Core Module)
- Bachelor's Programme in Meteorology (Scientific-technical Elective Area)

Cross-Module Exam in Theoretical Physics I (Modulübergreifende Prüfung Theoretische Physik I)		1101
Frequency	Winter Semester and Summer Semester	
Responsible for Module	L. Santos, Institute of Theoretical Physics	
Type of Course (SH)	Oral exam	
Assessment Components for Acquisition of CP	**Exam Performance:** oral exam	
Grade Composition	Grade of oral exam	
Weighting: 1	**Study in Class (h):** -	**Independent Study (h):** -
Learning Outcomes: The students have gained a thorough grounding in classical mechanics, special relativity and electrodynamics They understand these as part of physics as a whole and can draw parallels in the logical structure of these fields. They are proficient in independent knowledge acquisition through the study of scientific literature, partly in English.		
Topics: • Theoretical Electrodynamics • Analytical Mechanics and Special Relativity		
Where applicable entrance requirements and/or restricted number of participants: Either both modules "Mathematical Methods in Physics" and "Theoretical Electrodynamics" or the module "Analytical Mechanics and Special Relativity"		
Applicability: • Bachelor's Programme in Physics (Core Module)		

Statistical Physics (Statistische Physik)			1114
Frequency	Winter Semester		
Responsible for Module	E. Jeckelmann, Institute of Theoretical Physics		
Type of Course (SH)	Lecture: "Statistical Physics" Tutorial: "Statistical Physics"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial exercises		
Grade Composition	-		
Credit Points (ECTS): 8	**Study in Class (h):** 90	**Independent Study (h):** 150	

Learning Outcomes:
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 both classical physics and quantum theory. They know the paradigms of statistical physics and can discuss some of them mathematically.

Topics:
- 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, thermodynamic 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

Reading List:
- 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, *Statistical Physics*, Springer

Recommended Prior Knowledge:
"Analytical Mechanics and Special Relativity", "Introduction to Quantum Theory"

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:
- Bachelor's Programme in Physics (Core Module)
- Bachelor's Programme in Meteorology (Scientific-technical Elective Area)

Introduction to Quantum Theory (Einführung in die Quantentheorie)			1113
Frequency	Summer Semester		
Responsible for Module	R. Werner, Institute of Theoretical Physics		
Type of Course (SH)	Lecture: "Introduction to Quantum Theory" Tutorial: "Introduction to Quantum Theory"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial exercises		
Grade Composition	-		
Credit Points (ECTS): 8	**Study in Class (h):** 90	**Independent Study (h):** 150	

Learning Outcomes:
The students are proficient in the mathematical tools of quantum theory. They understand the physical implications of the theory and 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.

Topics:
- 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

Reading List:
- 🕮 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 Prior Knowledge:
"Mathematical Methods in Physics", "Theoretical Electrodynamics", "Analytical Mechanics and Special Relativity"

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:
- Bachelor's Programme in Physics (Core Module)
- Bachelor's Programme in Meteorology (Scientific-technical Elective Area)

Cross-Module Exam in Theoretical Physics II (Modulübergreifende Prüfung Theoretische Physik II)	**1102**
Frequency	Winter and Summer Semester
Responsible for Module	L. Santos, Instiute of Theoretical Physics
Type of Course (SH)	Oral exam
Assessment Components for Acquisition of CP	**Exam Performance:** oral exam
Grade Composition	Grade of oral exam
Weighting:	1

Learning Outcomes:
The students have gained an overview of mechanics, electrodynamics, quantum mechanics and statistical physics. They understand these as part of physics as a whole. They grasp what these fields have in common regarding physical concepts and mathematical methods and also their different characteristics at the individual length- and energy-scales.
They are proficient in independent knowledge acquisition through the study of scientific literature, partly in English.

Topics:
- Introduction to Quantum Theory
- Statistical Physics

Where applicable entrance requirements and/or restricted number of participants:
Either "Introduction to Quantum Theory" or "Statistical Physics", and the "Cross-Module Exam in Theoretical Physics I"

Applicability:
- Bachelor's Programme in Physics (Core Module)

Presenting Physics (Physik präsentieren)				1611
Frequency	Winter Semester and Summer Semester			
Responsible for Module	Dean of Studies Office			
Type of Course (SH)	Introductory seminar			
Assessment Components for Acquisition of CP	**Course Achievement:** Seminar performance			
Grade Composition	-			
Credit Points (ECTS): 3	**Study in Class (h):** 30		**Independent Study (h):** 60	

Learning Outcomes:
The students can familiarise themselves with a prescribed topic under guidance. They are able to conduct independent research of literature, and structure and give a lecture.
They are familiar with common presentation and visualisation techniques. The students can speak freely in German on topics in physics.

Topics:
- Selected topics in physics (Chosen from a prescribed list)
- Preparing a presentation
- Successful presentations
- Applying visualisation methods effectively
- Coping with stage fright
- Scientific Discussion

Reading List:
To be announced, according to the topic

Recommended Prior Knowledge:
- In consultation with the lecturer

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:
- Bachelor's Programme in Physics (Core Module)

Bachelor's in Physics – Area of Specialisation

Solid-State Physics II (Festkörperphysik II)			1211
Frequency	Winter Semester		
Responsible for Module	M. Oestreich, Institute of Solid State Physics Department Nanostructures		
Type of Course (SH)	Lecture: "Solid-State Physics II" Tutorial: "Solid-State Physics II" Lab "Solid-State Physics II"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutoriales and Labs		
Grade Composition	-		
Credit Points (ECTS): 8	**Study in Class (h):** 105	**Independent Study (h):** 135	

Learning Outcomes:
The students understand the fundamental concepts of Solid-State physics and can apply these independently to selected problems. They are familiar with advanced experimental methods in the field and can apply these under supervision.
A continuous participation is required to achieve the learning outcomes of the Lab Exercise.

Topics:
- Crystals and crystal structures
- Reciprocal lattice
- Crystallisation
- Lattice vibrations, thermal properties, quantisation, density of states
- Fermi gas
- Energy bands
- Semiconductors, metals, Fermi surfaces
- Stimuli in Solid-States
- Experimental methods: X-ray diffraction, scanning probe and electron microscopy, conductivity, magnetoresistance, Hall effect, quantum Hall effect

Reading List:
- 🕮 Ashcroft and Mermin, *Solid-State Physics,* Oldenbourg
- 🕮 C. Kittel, *Introduction to Solid-State Physics, Oldenbourg*
- 🕮 K. Kopitzki, *Introduction to Solid-State Physics,* Vieweg+Teubner
- 🕮 H. Ibach, H. Lüth, *Festkörperphysik,* Springer

Recommended Prior Knowledge:
- Modules "Mechanics and Heat", "Electricity and Relativity", "Optics, Atomic Physics, Quantum Phenomena", and "Nuclei, Particles and Solids"

Where applicable entrance requirements and/or restricted number of participants:

Applicability:
- Bachelor's Programme in Physics (Specialisation Module)
- Bachelor's Programme in Meteorology (Scientific-technical Elective Area)

Atomic and Molecular Physics (Atom- und Molekülphysik)			1311
Frequency	Winter Semester		
Responsible for Module	C. Ospelkaus, Institute of Quantum Optics		
Type of Course (SH)	Lecture: "Atomic and Molecular Physics" Tutorial: "Atomic and Molecular Physics" Practical Lab "Atomic and Molecular Physics"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutoriales and Labs		
Grade Composition	-		
Credit Points (ECTS): 8	**Study in Class (h):** 105	**Independent Study (h):** 135	

Learning Outcomes:
Students understand fundamental concepts of atomic and molecular physics and can apply these concepts to selected problems. Students are aware of advanced experimental techniques in the field and can apply these under guidance.
A continuous participation is required to achieve the learning outcomes of the Lab Exercise.

Topics:
- Summary H-Atom
- Atoms in electric and magnetic fields
- Fine and hyperfine structure
- Basic atom-light interaction
- Multi-electron systems
- Atomic spectra and spectroscopy
- Vibration and rotation of molecules
- Electronic structure of molecules
- Dissociation and ionization of molecules
- Selected experiments in modern atomic and molecular physics

Reading List:
- 🕮 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 Quantenchemie,* Springer
- 🕮 R. Loudon, *The Quantum Theory of Light*, OUP, 1973
- 🕮 W. Demtröder, *Molekülphysik,* Oldenburg, 2003 ISBN: 3486249746

Recommended Prior Knowledge:
- Modules "Mechanics and Heat", "Electricity and Relativity", "Optics, Atomic Physics, Quantum Phenomena", and "Nuclei, Particles and Solids"

Where applicable entrance requirements and/or restricted number of participants:

Applicability:
- Bachelor's Programme in Physics (Specialisation Module)
- Bachelor's Programme in Meteorology (Scientific-technical Elective Area)

Coherent Optics (Kohärente Optik)			1312
Frequency	Summer Semester		
Responsible for Module	E. M. Rasel, Institute of Quantum Optics		
Type of Course (SH)	Lecture: "Coherent Optics" Tutorial: "Coherent Optics" Lab "Coherent Optics"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutoriales and Labs		
Grade Composition	-		
Credit Points (ECTS): 8	**Study in Class (h):** 105	**Independent Study (h):** 135	

Learning Outcomes:
The students understand the fundamental concepts of coherent optics and can apply them independently to selected problems. They know the relevant advanced experimental methods and can apply them under guidance. A continuous participation is required to achieve the learning outcomes of the Lab Exercise.

Topics:

- 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 and Homodyne measurements

Reading List:

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

Recommended Prior Knowledge:

- Modules "Mechanics and Heat", "Electricity and Relativity", "Optics, Atomic Physics, Quantum Phenomena", and "Nuclei, Particles and Solids"

Where applicable entrance requirements and/or restricted number of participants:
None

Applicability:

- Bachelor's Programme in Physics (Specialisation Module)

Cross-Module Exam in Specialisation Area (Modulübergreifende Prüfung Vertiefungsbereich)	1002
Frequency	Winter and Summer Semester
Responsible for Module	Dean of Studies Office
Type of Course (SH)	Oral exam
Assessment Components for Acquisition of CP	**Exam Performance**: oral exam
Grade Composition	Grade of oral exam

Learning Outcomes:
The students understand the fundamental concepts of two advanced areas of Physics. They know how the areas relate to each other, and are able to apply insights in one area to the other.

Topics:
Two of the modules:

- "Introduction to Solid-State Physics"
- "Atomic and Molecular Physics"
- "Coherent Optics"

Where applicable entrance requirements and/or restricted number of participants:
Cross-Module Exam Experimentalphysics

Applicability:

- Bachelor's Programme in Physics (Specialisation Module)

Bachelor's in Physics -- Elective Area

Modern Aspects of Physics (Moderne Aspekte der Physik)			1601
Frequency	Winter and Summer Semester		
Responsible for Module	Dean of Studies Office		
Type of Course (SH)	Choice of courses worth at least 12 CP according to lecture list or course descriptions (see below.)		
Assessment Components for Acquisition of CP	**Course Achievement:** according to §6 of the exam regulations **Exam Performance:** oral exam		
Grade Composition	Grade of oral exam		
Credit Points (ECTS): 12	**Study in Class (h):** 240	**Independent Study (h):** 240	
Learning Outcomes: Students have a thorough knowledge of selected areas of Physics. They can place acquired knowledge in the logical structure of Physics. Students are able to understand scientific texts in English.			
Topics: Advanced courses in Physics as chosen by the students. Exam performance covers courses worth at least 4 CP as chosen by the students.			
Reading List: To be announced in the lectures.			
Recommended Prior Knowledge: Foundation courses in Physics			
Where applicable entrance requirements and/or restricted number of participants: None			
Applicability: • Bachelor's Programme in Physics (Physics Elective)			

Key Skills (Schlüsselkompetenzen)		????
Frequency	Winter and Summer Semester	
Responsible for Module	Dean of Studies Office	
Type of Course (SH)	Courses offered by the Language Centre or the Centre for Soft Skills, corresponding courses offered by Faculties and computer courses offered by the Computing Centre.	
Assessment Components for Acquisition of CP	**Course Achievement:** according to §6 of the exam regulations	
Grade Composition		
Credit Points (ECTS): 2-4	**Study in Class and Independent Study (h):** 60-120	
Learning Outcomes: • You acquire and master key skills in the area chosen		
Topics: • Depends on the course		
Reading List: • To be announced in the course		
Recommended Prior Knowledge: • None		
Where applicable entrance requirements and/or restricted number of participants: None		
Applicability: • Bachelor's Programme in Physics		

Bachelor's in Meteorology – Core Modules

The descriptions of the core Modules "Mechanics and Heat", "Electricity and Relativity", "Optics, Atomic Physics, Quantum Phenomena", "Cross-Module Exam in Experimental Physics" and "Mathematical Methods in Physics/ Theoretical Electrodynamics" are to be found in the section **Bachelor's in Physics – Core Modules** (from page 4).

Linear Algebra (Linear Algebra)			
Frequency	Winter Semester		
Responsible for Module	Michael Cuntz, Institute of Algebra, Number Theory and Discrete Mathematics, and Institute of Algebraic Geometry		
Type of Course (SH)	Lecture and Tutorial: "Mathematics 1: Linear Algebra"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial exercises on Linear Algebra **Exam Performance:** One ungraded exam		
Grade Composition	-		
Credit Points (ECTS): 8	**Study in Class (h):** 120	**Independent Study (h):** 120	

Learning Outcomes:
Basic understanding of the mathematical way of thinking and its application to a variety of problems. Sound competence in handling systems of linear equations and the corresponding methods for solving them; thorough knowledge of the underlying algebraic structures. Ability to express and present mathematical reasoning, and knowledge of suitable methods for this. Ability to apply theoretical knowledge.

Topics:

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

Reading List:

- 🕮 G. Fischer: *Lineare Algebra*

Recommended Prior Knowledge:

Where applicable entrance requirements and/or restricted number of participants:
None

Applicability:

- Bachelor's Programme in Meteorology (Core Module)

Analysis			2551
Frequency	Summer Semester		
Responsible for Module	Elmar Schrohe, Institute of Analysis		
Type of Course (SH)	Lecture and Tutorial: "Mathematics 2: Analysis"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial exercises on Analysis **Exam Performance:** One ungraded exam		
Grade Composition	-		
Credit Points (ECTS): 10	**Study in Class (h):** 120	**Independent Study (h):** 180	

Learning Outcomes:
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 Tutoriales, the students are familiar with mathematically exact formulations and conclusions in simple contexts and are able to present them.

Topics:
- Real and complex numbers,
- Convergence of sequences and series,
- Continuity and differentiability of functions of one real variable,
- Riemann integral,
- Taylor's formula and power seriesNormed spaces,
- Differentiation of functions of several variables,
- Theorem on implicit and inverse functions,
- Multidimensional Taylor formula,
- Extrema under constraints,
- Basics of vector analysis,
- Ordinary differential equations,
- Multi-dimensional integration.

Reading List:
- 🕮 H. Amann & J. Escher: *Analysis I and II, Birkhäuser Verlag, 2002*
- 🕮 O. Forster: *Analysis 1 and 2, Vieweg+Teubner*
- 🕮 K. Meyberg & P. Vachenauer: *Höhere Mathematik 1, Springer-Verlag 2001*

Recommended Prior Knowledge:

Where applicable entrance requirements and/or restricted number of participants:
None

Applicability:
- Bachelor's Programme in Meteorology (Core Module)

Theoretical Physics A (Theoretische Physik A)			2552
Frequency	Winter Semester		
Responsible for Module	Institute of Theoretical Physics		
Type of Course (SH)	Lecture: „Theoretische Physik A" Tutorial: „Theoretische Physik A"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorials exercises **Exam Performance:** exam		
Grade Composition	Not included in final grade		
Credit Points (ECTS): 7	**Study in Class (h):** 75	**Independent Study (h):** 135	

Learning Outcomes:
The students will understand the mathematical quantities required for the description of physical theories. The participants will be able to mathematically formulate simple physical problems and analyse them both theoretically and numerically via computers.

Topics:
- Accelerated coordinate systems and the kinematics of rigid bodies
- Vectors: scalar and cross product; index notation and determinants
- Space curves: differentiation, chain rule, gradient, Frenet formula
- Ordinary differential equations: solution
- Newtonian mechanics of point masses, systems of point masses
- Tensors: matrices, rotations, inertia tensor
- Harmonic oscillations: normal coordinates, resonance
- Functions: inverse function, power series, Taylor series, complex numbers
- Integration: one- und multidimensional, line and surface integrals
- One dimensional motion: solution via energy considerations
- Curvilinear coordinates: integration, substitution, delta functions

Programming of simple numerical routines and solution and visualisation of physical problems.

Reading List:
- 🕮 Großmann, *Mathematischer Einführungskurs für die Physik*, Teubner 2000
- 🕮 Schilcher, *Theoretische Physik kompakt für das Lehramt*, Oldenburg 2010
- 🕮 Nolting, *Grundkurs Theoretische Physik 1 - Klassische Mechanik*, Springer

Recommended Prior Knowledge:
School knowledge of Mathematics and Physics (gymnasiale Oberstufe)

Where applicable entrance requirements and/or restricted number of participants:
None

Applicability:
- Interdisciplinary Bachelor's Degree
- Teacher Training Course for Grammar Schools, Third Subject
- Bachelor's Programme in Meteorology (Core Module)

Theoretical Physics B (Theoretische Physik B)			2553
Frequency	Summer Semester		
Responsible for Module	Institute of Theoretical Physics		
Type of Course (SH)	Lecture: „Theoretische Physik B" Tutorial: „Theoretische Physik B"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial exercises **Exam Performance:** exam		
Grade Composition	Not included in final grade		
Credit Points (ECTS): 7	**Study in Class (h):** 75	**Independent Study (h):** 135	

Learning Outcomes:
The students know the mathematical quantities required for the description of physical theories. They are able to formulate simple physical problems mathematically and to solve them with analytical methods as well as numerical, computer-aided methods. The students have understood the logical structure of electrodynamics and know the mathematical formulation of the laws of electrodynamics. They know the phenomena of electrodynamics and can derive them from basic equations. The students are able to find analytical solutions for basic and simple problems of electrodynamics as well as to make suitable mathematical and physical approximations for the solution of selected problems.

Topics:
- Vector fields: Vector analysis, integral theorems, Laplace operator
- Maxwell equations: integral form, initial and boundary values, boundary surfaces
- Potentials, gauge freedom, vacuum solution, solution with sources, retarded solutions
- Linear partial differential equations: Separation, Green's function
- Fourier analysis: Fourier series
- Electrostatics: boundary value problems, potential theory
- Magnetostatics: linelike current distributions
- Moving point charges, Lienard-Wiechert potentials,
- Electromagnetic waves: in vacuum, influence of sources
- Field energy, Poynting vector
- Special theory of relativity: Lorentz transformation, time dilation, length contraction, space-time, four-vectors, Minkowski metrics

Programming of simple numerical routines and solution and visualisation of physical problems.

Reading List:
- 🕮 Schilcher, *Theoretische Physik kompakt für das Lehramt*, Oldenburg 2010
- 🕮 J.D. Jackson, *Klassische Elektrodynamik,* Gruyter, Walter de GmbH
- 🕮 Nolting, *Grundkurs Theoretische Physik 3 - Elektrodynamik*, Springer
- 🕮 Schmüser, *Theoretische Physik für Studierende des Lehramts 2 - Elektrodynamik und SRT*, Springer
- 🕮 Griffiths, *Elektrodynamik: Eine Einführun*g, Pearson 2014

Recommended Prior Knowledge:
- „Theoretical Physics A"
- School knowledge of mathematics and physics (gymnasiale Oberstufe)

Where applicable entrance requirements and/or restricted number of participants:
None

Applicability:
- Interdisciplinary Bachelor's Degree
- Teacher Training Course for Grammar Schools, Third Subject
- Bachelor's Programme in Meteorology (Core Module)

Applied Mathematics (Angewandte Mathematik)			2552
Frequency	Winter and Summer Semester		
Responsible for Module	Institute of Mathematical Stochastics, Institute of Applied Mathematics		
Type of Course (SH)	Lecture: "Numerical Mathematics A" Tutorial: "Numerical Mathematics A" Lecture: "Stochastics A" Tutorial: "Stochastics A" It is possible to choose the lecture "Umweltdatenanalyse" instead of the lecture and tutorial to „Stochastik A".		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial exercises on Numerical Mathematics A and Stochastics A **Exam Performance:** One exam each on Numerical Mathematics A and Stochastics A		
Grade Composition	Both exams (equal weighting)		
Credit Points (ECTS): 8	**Study in Class (h):** 90	**Independent Study (h):** 150	

Learning Outcomes:
Knowledge of numerical methods for approximate solution of basic mathematical problems. Ability to assess the suitability of different methods. Awareness of areas of application and limitations of numerical methods. Competence in dealing with stochastic methods and statistical problems.
Knowledge of basics of combinatorics, probability theory and statistical methods. Understanding of models, familiarity with elementary stochastic ways of thinking. Ability to describe mathematical ideas, analyse simple random problems and solve simple tasks and present them in class.

Topics:
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 spaces
- Laplace experiments
- Conditional probabilites and independence,
- Random variables and their distributions,
- Central limit theorem

Reading List:

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

Recommended Prior Knowledge:

Where applicable entrance requirements and/or restricted number of participants:
None

Applicability:

- Bachelor's Programme in Meteorology (Core Module)

Applied Programming (Programmieren)			**2553**
Frequency	Summer Semester		
Responsible for Module	Fechner, Institute of Meteorology and Climatology		
Type of Course (SH)	Lecture: "Applied Programming" Tutorial: "Applied Programming"		
Assessment Components for Acquisition of CP	**Course Achievement:** Class exercises		
Grade Composition	-		
Credit Points (ECTS): 4	**Study in Class (h):** 45	**Independent Study (h):** 75	

Learning Outcomes:
Students have mastered the essentials of a high-level programming language and can apply this knowledge to developing their own programmes to solve simple problems (methodological competence).

Topics:
- Programm modules: Application cycles, loops, alternatives
- Flow charts, structure charts
- Language elements of FORTRAN95: Data types, fields, expressions, field expressions, IF-, CASE-, DO structures
- Formatted and unformatted in-/output, NAMELIST I/O
- Program units: Subroutines, modules, interfaces

Reading List:
- 🕮 Metcalf, M. and J. Reid: *FORTRAN 90/95 Explained*. Oxford University Press.

Recommended Prior Knowledge:
None

Where applicable entrance requirements and/or restricted number of participants:
None

Applicability:
- Bachelor's Programme in Meteorology (Core Module)

Introduction to Meteorology and Climatology (Einführung in die Meteorologie und Klimatologie)			2560
Frequency	Summer and Winter Semester		
Responsible for Module	Seckmeyer, Institute of Meteorology and Climatology		
Type of Course (SH)	Lecture: "Introduction to Meteorology" Tutorial "Introduction to Meteorology" Lecture: "Climatology" Class: "Climatology"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial exercises on Introduction to Meteorology and Climatology **Exam Performance:** One exam		
Grade Composition			
Credit Points (ECTS): 8	**Study in Class (h):** 90	**Independent Study (h):** 150	

Learning Outcomes:
Upon completion of the course, students will have an overview of meteorology and environmental physics so that they are able to benefit from subsequent lectures in atmospheric physics and meteorology. The classes also foster communication skills and methodological competence in the transfer of specialist knowledge.

Topics:
Introduction to Meteorology:
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 vapour, ozone including ozone hole formation mechanisms, greenhouse gases and climate change, the water cycle and the mass circulation of various trace gases.
Basics of aerosols, clouds and rainfall. Mass, impulse, and energy fluxes in the Earth system. Energy conversion, thermodynamic basic equations, meteorological observation systems, international measuring networks, and energy meteorology.
Climatology

- Climate system: Components of the climate system
- Earth climates
- Energy and water balance
- General circulation of the atmosphere and the ocean
- Regional circulation system
- Climate changes
- Climate modelling
- Climate forecasting
- Climate policies

Reading List:

- 🕮 Kraus, *Die Atmosphäre der Erde: Eine Einführung in die Meteorologie*, Springer
- 🕮 Hauf, Seckmeyer, *Lecture Script Einführung in die Meteorologie I+II*
- 🕮 Häckel, *Meteorologie*, UTB, Stuttgart
- 🕮 Roedel, *Physics unserer Umwelt*, Springer
- 🕮 Liljequist, *Allgemeine Meteorologie*, Springer
- 🕮 Kshudiram Saha, The Earth's Atmosphere - Its Physics and Dynamics, Springer
- 🕮 Mahlberg, *Meteorologie und Klimatologie*, Springer Verlag
- 🕮 Peixoto & Oort, *Physics of Climate*, Springer Verlag
- 🕮 Schönwiese, *Klimatologie*, UTB, Stuttgart

Recommended Prior Knowledge:

Where applicable entrance requirements and/or restricted number of participants:
None

Applicability:

- Bachelor's Programme in Meteorology (Core Module)
- Bachelor's in Geography
- Master's in Landscape Architecture
- Bachelor's and Master's in Physics

Radiation (Strahlung)			**2003**
Frequency	Summer Semester and Winter Semester		
Responsible for Module	Seckmeyer, Institute of Meteorology and Climatology		
Type of Course (SH)	Lecture: "Radiation I" Lecture: "Radiation II" Tutorial "Radiation I" Tutorial "Radiation II"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorials on Radiation I and II **Exam Performance:** oral exam		
Grade Composition	Grade of oral exam		
Credit Points (ECTS): 8	**Study in Class (h):** 90	**Independent Study (h):** 150	

Learning Outcomes:
The students have an advanced knowledge of physics and meteorology in the field of solar radiation and can apply it. They are familiar with various measurement techniques in radiation physics of non-ionizing radiation and their quality assurance / quality control. The theoretical and experimental exercises also foster communication skills and methodological competence in the implementation of specialist knowledge.

Topics:
- Basic concepts of radiation physics; radiation processes in the atmosphere
- Measurement methods of radiation physics
- Basics of light technology
- Principles of astronomy, chemistry, biology and medicine
- Methods for calculating radiation transfer in the atmosphere

Reading List:
- 🕮 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 Lecture Strahlung*
- 🕮 Bergmann-Schäfer, Band 3 *Optik,* Gruyter

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

Recommended Prior Knowledge:
- Module "Introduction to Meteorology"
- For the "Radiation II" exercise, successful participation in the "Radiation I" exercise is required.

Where applicable entrance requirements and/or restricted number of participants:
None

Applicability:
- Bachelor's Programme in Meteorology (Core Module)
- Master's Subject Optical Technologies
- Bachelor's and Master's in Physics

Cloud Physics (Wolkenphysik)			2011
Frequency	Summer Semester		
Responsible for Module	Raasch, Institute of Meteorology and Climatology		
Type of Course (SH)	Lecture: "Cloud Physics" Class "Cloud Physics"		
Assessment Components for Acquisition of CP	**Course Achievement:** Class exercises **Exam Performance:** oral exam		
Grade Composition	Grade of oral exam		
Credit Points (ECTS): 4	**Study in Class (h):** 45	**Independent Study (h):** 75	

Learning Outcomes:
Students are familiar with advanced physics in cloud physics processes and can apply this in theoretical examples. Theoretical and experimental exercises, and a presentation foster communication skills and methodological competence in the transfer of specialist knowledge.

Topics:
- Theory of the activation of drops through aerosols
- Diffusional growth
- Collision/coalescence
- The warm rain process
- Principles of ice- and mixed-phase clouds
- Principles of numerical cloud models

Reading List:
- 🕮 Pruppacher and Klett, *Microphysics of Clouds and Precipitation*, Springer
- 🕮 Rogers, *Cloud Physics A*, Butterworth-Heinemann Title; 3rd edition,

Recommended Prior Knowledge:
- Module "Introduction to Meteorology"
- Lecture and Class "Thermodynamics and Statics" (in the Module Theoretical Meteorology)

Where applicable entrance requirements and/or restricted number of participants:
None

Applicability:
- Bachelor's Programme in Meteorology (Core Module)
- Bachelor's and Master's in Physics

Practical Work with Instruments (Instrumentenpraktikum)			**2102**
Frequency	Winter Semester		
Responsible for Module	Gross, Institute of Meteorology and Climatology		
Type of Course (SH)	Practical Work with Instruments		
Assessment Components for Acquisition of CP	**Course Achievement:** Lab practical		
Grade Composition	-		
Credit Points (ECTS): 6	**Study in Class (h):** 90	**Independent Study (h):** 90	

Learning Outcomes:
Students are familiar with basic measuring methods in meteorology and can apply them in practice. Here, the critical appraisal of measurements is of crucial importance regarding their validity and accuracy. Conducting experiments in small groups also fosters the ability to work in teams

Topics:
- Conducting lab and field tests with measurements of the main meteorological variants temperature, pressure, humidity, wind speed and individual components of the radiation and energy balance

Reading List:
Script on Practical Work with Instruments

Recommended Prior Knowledge:
- Module "Introduction to Meteorology"
- Module "Mechanics and Heat", "Electricity and Relativity", "Optics, Atomic Physics, Quantum Phenomena", and "Nuclei, Particles and Solids"
- Module "Radiation"

Where applicable entrance requirements and/or restricted number of participants:
None

Applicability:
- Bachelor's Programme in Meteorology (Core Module)
- Master's in Landscape Sciences
- Bachelor's in Physics

Climatology (Klimatologie)			**2002**
Frequency	Winter Semester		
Responsible for Module	Gross, Institute of Meteorology and Climatology		
Type of Course (SH)	Lecture: "Climatology" Class: "Climatology"		
Assessment Components for Acquisition of CP	**Course Achievement:** class exercises **Exam Performance:** Exam		
Grade Composition	Grade of Exam		
Credit Points (ECTS): 4	**Study in Class (h):** 45	**Independent Study (h):** 75	

Learning Outcomes:
Students gain an overview of Climatology, acquiring skills that can be a called upon later for applying specialist knowledge of Meteorology and Climatology within Climatology. The classes also foster communication skills and methodological competence in the transfer of specialist knowledge.

Topics:
- Climate system: Components of the climate system
- Earth climates
- Energy and water balance
- General circulation of the atmosphere and the ocean
- Regional circulation system
- Climate changes
- Climate modelling
- Climate forecasting
- Climate policies

Reading List:
- 🕮 Mahlberg, *Meteorologie und Klimatologie*, Springer Verlag
- 🕮 Peixoto & Oort, *Physics of Climate*, Springer Verlag
- 🕮 Roedel, *Physics unserer Umwelt*, Springer Verlag
- 🕮 Schönwiese, *Klimatologie*, UTB, Stuttgart

Recommended Prior Knowledge:
- Module Introduction to Meteorology

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:
- Bachelor's Programme in Meteorology (core module)
- Bachelor's in Geography
- Bachelor's and Master's in Physics

Theoretical Meteorology (Theoretische Meteorologie)			2561
Frequency	Winter and Summer Semester		
Responsible for Module	Raasch, Institute of Meteorology and Climatology		
Type of Course (SH)	Lecture: "Thermodynamics and Statics" Class: "Thermodynamics and Statics" Lecture: "Kinematics and Dynamics" Class: "Kinematics and Dynamics" Lecture: "Turbulence and Diffusion" Class: "Turbulence and Diffusion"		
Assessment Components for Acquisition of CP	**Course Achievement:** Class exercises on "Thermodynamics and Statics, Kinematics and Dynamics" and "Turbulence and Diffusion" **Exam Performance:** one exam each on "Thermodynamics and Statics, Kinematics and Dynamics" and "Turbulence and Diffusion"		
Grade Composition	Grades of all 3 exams (equal weighting)		
Credit Points (ECTS): 12	**Study in Class (h):** 135	**Independent Study (h):** 225	

Learning Outcomes:
Students learn the principles of theoretical meteorology and are able to apply them in exercises (methodological competence).

Topics:
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

Kinematics and Dynamics
- 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 turbulent kinetic energy, Richardson-flux-number
- vertical wind profiles and processes in the atmospheric boundary layer: constant-flux layer, Ekman layer

Reading List:
- 🕮 Etling, *Theoretische Meteorologie*, Springer Verlag
- 🕮 Bohren and 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 Prior Knowledge:
- Module "Introduction to Meteorology"
- Module "Mechanics and Heat"
- Lecture and Tutoriales on "Mathematical Methods in Physics"

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:
- Bachelor's Programme in Meteorology (more module)
- Bachelor's and Master's in Physics (also parts of this module)
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Synoptic Meteorology (Synoptische Meteorologie)			2104
Frequency	Winter and Summer Semester		
Responsible for Module	Gryschka, Institute of Meteorology and Climatology		
Type of Course (SH)	Lecture: "Synoptic Meteorology I" Class: Exercises on Operational Synoptics Lecture: "Synoptic Meteorology II" Seminar "Weather Briefing" Class: "Introduction to Working with NINJO"		
Assessment Components for Acquisition of CP	**Course Achievement:** Class exercises on the lectures and seminar performance Weather Briefing		
Grade Composition	-		
Credit Points (ECTS): 8	**Study in Class (h):** 164	**Independent Study (h):** 76	

Learning Outcomes:
Students understand the principles of weather analysis and forecasting; they analyse and forecast weather under supervision and with existing information systems, and present their findings in written and oral form with subsequent discussion. Apart from gaining specialised knowledge they thus develop media competence and the skills for critical discussion, presentation to a specialist audience, and also customer-oriented preparation/presentation of specialised knowledge.

Topics:
- Use of modern meteorological information systems
- Analysis of atmospheric conditions
- Forecasting weather development
- Presentation of results
- Own contributions to scientific discussion of weather analysis and forecasting

Reading List:
- 🕮 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 Prior Knowledge:
- Module "Introduction to Meteorology"
- Lectures and classes on "Thermodynamics and Statics" and "Kinematics and Dynamics"

Where applicable entrance requirements and/or restricted number of participants:
None

Applicability:
- Bachelor's Programme in Meteorology (core module)
- Master's in Landscape Sciences

Studies and Profession (Studium und Beruf)		2105
Frequency	Winter Semester, lecture-free period (Internship), following Winter Semester (Lecture)	
Responsible for Module	Gross, Institute of Meteorology and Climatology	
Type of Course (SH)	Seminar "Introduction to Studying Meteorology" Internship	
Assessment Components for Acquisition of CP	**Course Achievement:** Internship with report	
Grade Composition	-	
Credit Points (ECTS): 5	**Study in Class and Independent Study (h):** 150	

Learning Outcomes:
First semester students receive an introduction to studying meteorology, become familiar with specific subject and methodological requirements, and become acquainted with lecturers and research at the institute and the professional environment concerning their own studies and career.

Topics:
- Introduction to university institutions and everyday student life
- Introduction to research at the institute
- 4-week practical work in research, authorities or industry under meteorological supervision individual study guidance/mentoring

Reading List:
- 🕮 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 Prior Knowledge:

Where applicable entrance requirements and/or restricted number of participants:
None

Applicability:
- Bachelor's Programme in Meteorology (core module)

Meteorological Field Trip I (Meteorologische Exkursion I)		2106
Frequency	Summer Semester, lecture-free period (Internship)	
Responsible for Module	Seckmeyer, Institute of Meteorology and Climatology	
Type of Course (SH)	Field trip Meteorological Field Trip I	
Assessment Components for Acquisition of CP	**Course Achievement:** Field trip report	
Grade Composition	-	
Credit Points (ECTS): 2	**Study in Class and Independent Study (h):** 60	

Learning Outcomes:
Before the field trip, students work independently on a thematic aspect of the field trip and present this during the field trip. They are available for discussion and consultation; they write a contribution to the field trip report, and after a discussion with their supervisor present this in the concluding seminar. A thematic aspect is thus studied in depth. The presentation also serves to train presentation skills o

Topics:
- Participation in a one or two-week field trip, usually on a specific topic area (e.g. maritime or alpine)
- Preparation of a thematic aspect of the field trip followed by written contribution to the field trip report. Lecture (10 min.) in the concluding seminar.

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

Recommended Prior Knowledge:
- Module "Studies and Profession"
- Lecture "Introduction to Meteorology I"

Where applicable entrance requirements and/or restricted number of participants:
None

Applicability:
- Bachelor's Programme in Meteorology (core module)

Bachelor's in Meteorology – Elective Area

Turbulence II (Turbulenz II)				**2210**
Frequency	Winter Semester			
Responsible for Module	Raasch, Institute of Meteorology and Climatology			
Type of Course (SH)	Lecture: **"**Turbulence **II"**			
Assessment Components for Acquisition of CP	**Course Achievement:** according to §6 of the exam regulations **Exam Performance:** oral exam			
Grade Composition	Grade of oral exam			
Credit Points (ECTS): 4	**Study in Class (h):** 45		**Independent Study (h):** 75	

Learning Outcomes:
Expanding specialist knowledge.

Topics:
- turbulence features, ensemble averaged equations,
- spatially averaged equations
- turbulent fluxes
- energy cascade, Kolmogorov spectrum

Reading List:
- 🕮 Wyngaard, Turbulence in the Atmosphere, Cambridge University Press

Recommended Prior Knowledge:
- „Kinematics and Dynamics"
- „Turbulence and Diffusion"

Where applicable entrance requirements and/or restricted number of participants:
See course list

Applicability:
- Bachelor's Programme in Meteorology (Elective Area Meteorology)

Atmospheric Convection (Atmosphärische Konvektion)		**2211**
Frequency	Winter Semester	
Responsible for Module	Raasch, Institute of Meteorology and Climatology	
Type of Course (SH)	Lecture: "Atmospheric Convection"	
Assessment Components for Acquisition of CP	**Course Achievement:** according to §6 of the exam regulations **Exam Performance:** oral exam (Exam covers at least 8CP)	
Grade Composition	Grade of oral exam	
Credit Points (ECTS): 4	**Study in Class and Independent Study (h):** 45 and 75	

Learning Outcomes:
Expanding specialist knowledge.

Topics:
- Basics of thermal convection: Rayleigh number, convection between plates, molecular /convective heat transport, Nusselt number, analytical derivation oft he critical Rayleigh number
- Atmospheric convection: boundary layer growth, entrainment, forming of coherent structures

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

Recommended Prior Knowledge:
- "Thermodynamics"
- "Kinematics and Dynamics"
- "Turbulence and Diffusion"

Where applicable entrance requirements and/or restricted number of participants:
See course list

Applicability:
- Bachelor's Programme in Meteorology (Elective Area Meteorology)

Simulation of Turbulent Flows with LES Models (Simulation turbulenter Strömungen mit LES-Modellen)	**2212**
Frequency	Summer Semester
Responsible for Module	Raasch, Institute of Meteorology and Climatology
Type of Course (SH)	See course list
Assessment Components for Acquisition of CP	**Course Achievement:** according to §6 of the exam regulations **Exam Performance:** oral exam (Exam covers at least 8CP)
Grade Composition	Grade of oral exam
Credit Points (ECTS): 4	**Study in Class and Independent Study (h):** 45 and 75

Learning Outcomes:
Expanding specialist knowledge.

Topics:

- 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

Reading List:

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

Recommended Prior Knowledge:

- "Turbulence and Diffusion"
- "Numerical Weather Prediction"
- "Atmospheric Convection"
- "Laboratory for Numerical Weather Prediction"

Where applicable entrance requirements and/or restricted number of participants:
See course list

Applicability:

- Bachelor's Programme in Meteorology (Elective Area Meteorology)

Agrometeorology (Agrarmeteorologie)				**2213**
Frequency	Summer Semester			
Responsible for Module	Raasch, Institute of Meteorology and Climatology			
Type of Course (SH)	Lecture: "Agrometeorology" Tutorial: "Agrometeorology"			
Assessment Components for Acquisition of CP	**Course Achievement:** according to §6 of the exam regulations **Exam Performance:** oral exam			
Grade Composition	Grade of oral exam			
Credit Points (ECTS): 4	**Study in Class (h):** 45		**Independent Study (h):**	75

Learning Outcomes:
Basic understanding of the interactions between soil, plants and the atmosphere. Sound knowledge of energy transfer and the physical elements of evapotranspiration. Ability to describe plant growth depending on atmospheric conditions including meteorological dangers and protective measures.

Topics:
- Energy and water balance of plants;
- Characteristic measures of plants (LAI);
- Measurements and calculating evapotranspiration;
- Specific plant climates;
- Phenology
- Atmospheric Dangers and countermeasures.
- Agrometeorology and changing climate

Reading List:
- 🕮 Van Eimern, *Wetter und Klimakunde für Landwirte*, Ulmer Verlag
- 🕮 Seeman et al., *Agrometeorology*, Springer Verlag

Recommended Prior Knowledge:
- „Introduction to Meteorology"

Where applicable entrance requirements and/or restricted number of participants:
See course list

Applicability:
- Bachelor's Programme in Meteorology (Elective Area Meteorology)

Local Climates (Lokalklimate)				2214
Frequency	Winter Semester			
Responsible for Module	Gross, Institute of Meteorology and Climatology			
Type of Course (SH)	Lecture: "Local Climates" Tutorial: "Local Climates"			
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial exercises **Exam Performance:** oral exam			
Grade Composition	Grade of oral exam			
Credit Points (ECTS): 4	**Study in Class (h):** 45		**Independent Study (h)**	75

Learning Outcomes:
Basic understanding of physical principles of the local distribution of meteorological parameter depending on land use. Sound knowledge of energy balances and diurnal variation of temperature humidity and wind. Ability to describe the evolution of local climates depending on soil and surface characteristics and geographical parameter.

Topics:
- Climate of the near surface;
- Urban climate;
- Forest climate
- Climate near water surfaces;
- Phenology
- Climate and orography

Reading List:
- 🕮 Geiger, climate near the ground, Vieweg Verlag
- 🕮 Hupfer et al., Witterung und Klima, Teubner Verlag

Recommended Prior Knowledge:
- „Introduction to Meteorology"

Where applicable entrance requirements and/or restricted number of participants:
None

Applicability:
- Bachelor's Programme in Meteorology (Elective Area Meteorology)

Numerical Weather Prediction (Numerische Wettervorhersage)				**2215**
Frequency	Winter Semester			
Responsible for Module	Gross, Institute of Meteorology and Climatology			
Type of Course (SH)	Lecture: "Numerical weather prediction" Tutorial: "Numerical weather prediction"			
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial exercises **Exam Performance:** oral exam			
Grade Composition	Grade of oral exam			
Credit Points (ECTS): 4	**Study in Class (h):** 45		**Independent Study (h):** 75	

Learning Outcomes:
Basic understanding of the mathematical basis of weather prediction models including coordinate transformations and simplifications. Sound knowledge of numerical methods to solve the equation system. Ability to express and present mathematical reasoning, and knowledge of suitable methods for numerical models.

Topics:
- Basic equations;
- Meteorological coordinate systems;
- Filtered and unfiltered prediction models;
- Initialization;
- Numerical methods to solve the equations;
- Prediction models of the German weather service.

Reading List:
- 🕮 Roache, *Computational Fluid Dynamics*, Hermosa Publishers

Recommended Prior Knowledge:
- "Introduction to Meteorology"
- "Theoretical Meteorology"

Where applicable entrance requirements and/or restricted number of participants:
See course list

Applicability:
- Bachelor's Programme in Meteorology (Elective Area Meteorology)

Remote Sensing I (Fernerkundung I)		2107
Frequency	Winter Semester	
Responsible for Module	Gross, Institute of Meteorology and Climatology	
Type of Course (SH)	See course list	
Assessment Components for Acquisition of CP	**Course Achievement:** according to §6 of the exam regulations **Exam Performance:** oral exam (Exam covers at least 8CP)	
Grade Composition	Grade of oral exam	
Credit Points (ECTS): 4	**Study in Class and Independent Study (h):**	

Learning Outcomes:
Expanding specialist knowledge.

Topics:
- Satellite measurements and their applications for recording atmospheric processes
- Remote sensing with satellite instruments. Derivation of temperature, cloud and trace gas measurements using remote-sensing instruments from satellites and the ground.
- Derivation of radiation measurements from satellite data

Reading List:
- 🕮 Kidder and Vonder Haar: *Satellite Meteorology: An Introduction, Academic Press*

Recommended Prior Knowledge:
- "Introduction to Meteorology"
- "Radiation"

Where applicable entrance requirements and/or restricted number of participants:
See course list

Applicability:
- Bachelor's Programme in Meteorology (Elective Area Meteorology)

Remote Sensing II (Fernerkundung II)		2107
Frequency	Summer Semester	
Responsible for Module	Gross, Institute of Meteorology and Climatology	
Type of Course (SH)	See course list	
Assessment Components for Acquisition of CP	**Course Achievement:** according to §6 of the exam regulations **Exam Performance:** oral exam (Exam covers at least 8CP)	
Grade Composition	Grade of oral exam	
Credit Points (ECTS): 4	**Study in Class and Independent Study (h):**	

Learning Outcomes:
Expanding specialist knowledge.

Topics:
- The contribution of ground and satellite-assisted remote sensing procedures to current research topics on climate, weather and global change.
- Presenting methods and their results

Reading List:
- 🕮 Kidder and Von der Haar: *Satellite Meteorology: An Introduction, Academic Press*

Recommended Prior Knowledge:
- "Introduction to Meteorology"
- "Radiation"
- "Remote Sensing I"

Where applicable entrance requirements and/or restricted number of participants:
See course list

Applicability:
- Bachelor's Programme in Meteorology (Elective Area Meteorology)

Atmospheric air pollution (Schadstoffausbreitung)				2218
Frequency	Summer Semester			
Responsible for Module	Gross, Institute of Meteorology and Climatology			
Type of Course (SH)	Lecture: "atmospheric air pollution" Tutorial: "atmospheric air pollution"			
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial exercises **Exam Performance:** oral exam			
Grade Composition	Grade of oral exam			
Credit Points (ECTS): 4	**Study in Class (h):** 45		**Independent Study (h)**	75

Learning Outcomes:
Basic understanding of the interactions between emission, transmission and immission of various atmospheric pollutants. Sound knowledge of mathematical models to describe the dispersion of air pollutants, depending of meteorological parameter. Ability to assess atmospheric concentrations with respect to thresholds prescribed in laws and guidelines..

Topics:
- Effects of atmospheric pollutants;
- Atmospheric dispersion: emission-transmission-immission;
- Types of dispersion models: Gauss, Euler, Lagrange;
- Clean air: laws and guidelines;
- Selected problems: smog, acid rain, urban pollution.

Reading List:
- 🕮 Helbig et al., *Stadtklima und Luftreinhaltung,* Springer Verlag, Berlin.
- 🕮 Zenger, *Atmosphärische Ausbreitungsmodellierung*. Springer Verlag, Berlin
- 🕮 Van Dop, *air pollution modelling and its application*, Plenum press

Recommended Prior Knowledge:
- "Introduction to Meteorology"
- "Theoretical Meteorology"

Where applicable entrance requirements and/or restricted number of participants:
None

Applicability:
- Bachelor's Programme in Meteorology (Elective Area Meteorology)

Laboratory for Numerical Weather Prediction (Programmierpraktikum zur Numerischen Wettervorhersage)	**2107**
Frequency	Winter Semester
Responsible for Module	Raasch, Institute of Meteorology and Climatology
Type of Course (SH)	"Laboratory for Numerical Weather Prediction"
Assessment Components for Acquisition of CP	**Course Achievement:** according to §6 of the exam regulations **Exam Performance:** oral exam (Exam covers at least 8CP)
Grade Composition	Grade of oral exam
Credit Points (ECTS): 4	**Study in Class and Independent Study (h):** 45 and 75

Learning Outcomes:
Expanding specialist knowledge.

Topics:
- 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

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

Recommended Prior Knowledge:
- "Applied Programming"
- "Numerical Weather Prediction"
- "Kinematics and Dynamics"

Where applicable entrance requirements and/or restricted number of participants:
See course list

Applicability:
- Bachelor's Programme in Meteorology (Elective Area Meteorology)

Laboratory for Simulation of Turbulent Flows with LES Models (Numerisches Praktikum zur Simulation turbulenter Strömungen mit LES-Modellen)	**2107**
Frequency	Block course at the end of Summer Semester
Responsible for Module	Raasch, Institute of Meteorology and Climatology
Type of Course (SH)	**"Laboratory for Simulation of Turbulent Flows with LES Models"**
Assessment Components for Acquisition of CP	**Course Achievement:** according to §6 of the exam regulations **Exam Performance:** oral exam (Exam covers at least 8CP)
Grade Composition	Grade of oral exam
Credit Points (ECTS): 4	**Study in Class and Independent Study (h):** 45 and 75

Learning Outcomes:
Expanding specialist knowledge.

Topics:
- Installation of LES model PALM
- Performing simulations of the convective atmospheric boundary layer and analysis of data
- Simulation of turbulent flow around buildings including dispersion modeling

Reading List:
- 🕮 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 Prior Knowledge:
- „Turbulence and Diffusion"
- „Atmospheric Convection"
- "Simulation of Turbulent Flows wiht LES Models"
- "Laboratory for Numerical Weather Prediction"

Where applicable entrance requirements and/or restricted number of participants:
See course list

Applicability:
- Bachelor's Programme in Meteorology (Elective Area Meteorology)

Laboratory Simulation of the Atmospheric Boundary Layer (Programmierpraktikum zur Simulation der atmosphärischen Grenzschicht)	**2107**
Frequency	Winter or Summer Semester
Responsible for Module	Raasch, Institute of Meteorology and Climatology
Type of Course (SH)	See course list
Assessment Components for Acquisition of CP	**Course Achievement:** according to §6 of the exam regulations **Exam Performance:** oral exam (Exam covers at least 8CP)
Grade Composition	Grade of oral exam
Credit Points (ECTS): 4	**Study in Class and Independent Study (h):** 45 and 75

Learning Outcomes:
Expanding specialist knowledge.

Topics:
- 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)

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

Recommended Prior Knowledge:
- "Applied Programming"
- "Kinematics and Dynamics"
- "Turbulence and Diffusion"
- "Numerical Weather Prediction"
- "Atmospheric Convection"

Where applicable entrance requirements and/or restricted number of participants:
See course list

Applicability:
- Bachelor's Programme in Meteorology (Elective Area Meteorology)

Bachelor's in Meteorology – Scientific-Technical Elective Area

Scientific-Technical Elective Area (Naturwissenschaftlich-technischer Wahlbereich)		2108
Frequency	Winter Semester or Summer Semester	
Responsible for Module	Seckmeyer, Institute of Meteorology and Climatology	
Type of Course (SH)	Courses worth at least 12 CP at the Faculty of Mathematics and Physics, the Faculty of Electrical Engineering and Computer Science, the Faculty of Mechanical Engineering and the Faculty of Natural Sciences or, on application, modules at other faculties	
Assessment Components for Acquisition of CP	**Course Achievement:** according to the exam regulations of the faculty in question If the exam regulations of the faculty in question require an exam rather than a course achievement, the exam performance will be treated as a course achievement and recognised	
Grade Composition	-	
Credit Points (ECTS): 12	**Study in Class and Independent Study (h):** 360	
Learning Outcomes: Acquisition of interdisciplinary knowledge in other scientific or technical disciplines.		
Topics: • See course list		
Reading List:		
Recommended Prior Knowledge:		
Where applicable entrance requirements and/or restricted number of participants:		
Applicability: • Bachelor's Programme in Meteorology (Scientific-Technical Elective Area)		

Bachelor's in Meteorology – Key Skills

Key Skills (Schlüsselkompetenzen)		2570
Frequency	Winter and Summer Semester	
Responsible for Module	Seckmeyer, Institute of Meteorology and Climatology	
Type of Course (SH)	Courses offered by the Language Centre or the Centre for Soft Skills, corresponding courses offered by faculties and computer courses offered by the Computing Centre. A course on scientific writing worth 2CP must be taken.	
Assessment Components for Acquisition of CP	**Course Achievement:** according to §6 of the exam regulations	
Grade Composition		
Credit Points (ECTS): 2-4	**Study in Class and Independent Study (h):** 60-120	

Learning Outcomes:

- Students are able to write scientific texts and have mastered the principles of correct quoting and verifying of sources
- Students acquire key skills in the field covered by the chosen course

Topics:

- Introduction to scientific writing
- Dealing with specialist literature
- Correct quoting and verifying of sources
- Further contents according to the chosen course

Reading List:

- To be announced in the course

Recommended Prior Knowledge:

- None

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:

- Bachelor's Programme in Meteorology (Core Module)

Master Physics – Advanced Specialisation Phase

Advanced Solid-State Physics (Fortgeschrittene Festkörperphysik)				**1221**
Frequency	Winter Semester			
Responsible for Module	F. Ding, Institute of Solid-State Physics, Abt. ATMOS			
Type of Course (SH)	Lecture: „Advanced Solid-State Physics" Tutorial: „Advanced Solid-State Physics"			
Assessment Components for Acquisition of CP	**Course Achievement:** short tests and/or solving problems **Exam Performance:** oral or written exam (lecturer's choice)			
Grade Composition	Grade of exam			
Credit Points (ECTS): 5	**Study in Class (h):** 60		**Independent Study (h):** 90	

Learning Outcomes:
Students acquire in-depth knowledge of theoretical models and experimental results in solid state physics. They are able to classify selected phenomena and to develop models at their level of understanding. They get to know important developments in the field that have evolved over the last decades and have a clear impression of current unsolved problems in solid state physics. The students are able to judge advantages and disadvantages of certain experimental techniques and acquire knowledge about the complementarity of various experimental options.

Topics:
- Dielectric properties
- Quantum optics in solids
- Magnetism
- Superconductivity
- Emerging topics in solid state physics (phase transitions, low dimensional systems, quantum computing, topological states)

Reading List:
- 🕮 R. Gross und A. Marx, Festkörperphysik, De Gruyter
- 🕮 D. Snoke, Solid State Physics: Essential Concepts, Cambridge University Press

Recommended Prior Knowledge:
- Festkörperphysik II (Solid State Physics 2)

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:
- Master's Programme in Physics (Advanced Specialisation Phase)
- Master's Programme in Nanotechnology (Elective Area)

Gravitational Physics (Gravitationsphysik)			1421
Frequency	Summer Semester		
Responsible for Module	B. Wilke, AEI		
Type of Course (SH)	Lecture: "Gravitationsphysik" Tutorial: "Gravitationsphysik"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial exercises **Exam Performance:** oral or written exam as chosen by the lecturer		
Grade Composition	Grade of exam		
Credit Points (ECTS): 5	**Study in Class (h):** 60	**Independent Study (h):** 90	

Learning Outcomes:
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.

Topics:

General relativity

- Equivalence principle, Lense–Thirring effect
- Cosmology
- Astrophysics
- Sources and propagation of gravitational waves
- Noise sources in laser interferometer
- Seismic isolation
- Mechanical quality factor and thermal noise
- Quantum noise in interferometer
- Interferometer-recycling-technics

Reading List:
To be announced in lecture

Recommended Prior Knowledge:

- Basics of "Special Relativity Theory"
- Modul „Coherent Optics"

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:

- Master's Programme in Physics (Advanced Specialisation Phase)

Quantum optics (Quantenoptik)			1321
Frequency	Winter Semester		
Responsible for Module	P. Schmidt, Institute of Quantum Optics		
Type of Course (SH)	Lecture: „Quantum Optics" Tutorial: „Quantum Optics"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial exercises **Exam Performance:** oral or written exam as chosen by the lecturer		
Grade Composition	Grade of exam		
Credit Points (ECTS): 5	**Study in Class (h):** 60	**Independent Study (h):** 90	

Learning Outcomes:
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.

Topics:
- Quantization of the em field & Fock, Glauber, squeezed states
- Heisenberg uncertainty relation, photon statistics, quantum noise
- Generation of non-classical light: squeezing and entanglement
- Bell's inequality and nonlocality
- Atom-field interaction with coherent fields, Rabi model, optical Bloch equations, Jaynes-Cummings model
- Spontaneous emission, Lamb shift, Casimir effect
- Experiments in modern quantum optics
- Resonance fluorescence, laser cooling, optical traps, coherent manipulation of atoms

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

Recommended Prior Knowledge:
- Modul „Coherent Optics"
- Modul „Introduction to Quantum Theory"

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:
- Master's Programme in Physics (Advanced Specialisation Phase)

Quantum Field Theory (Quantenfeldtheorie)			1121
Frequency	Winter or Summer Semester		
Responsible for Module	O. Lechtenfeld, Institute of Theoretical Physics		
Type of Course (SH)	Lecture: „Quantum Field Theory" Tutorial: „Quantum Field Theory"		
Assessment Components for Acquisition of CP	**Course Achievement:** Tutorial exercises **Exam Performance:** oral or written exam as chosen by the lecturer		
Grade Composition	Grade of exam:		
Credit Points (ECTS): 5	**Study in Class (h):** 60	**Independent Study (h):** 90	

Learning Outcomes:
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.

Topics:
- 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

Reading List:

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

Recommended Prior Knowledge:
- Lecture „Advanced Quantum Theory"

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:
- Master's Programme in Physics (Advanced Specialisation Phase)

Elektronics and Metrology (Elektronik und Messtechnik)			1222
Frequency	Winter or Summer Semester		
Responsible for Module	T. Block, Institute of Solid-State Physics		
Type of Course (SH)	Lecture: „Electronics" Lecture: „Metrology" Lab Electronics		
Assessment Components for Acquisition of CP	**Course Achievement:** Laboratory work **Exam Performance:** oral or written exam as chosen by the lecturer		
Grade Composition	Grade of Exam		
Credit Points (ECTS): 8	**Study in Class (h):** 120	**Independent Study (h):** 120	

Learning Outcomes:
Students learn experimental and numerical methods, apply these independently and develop models to explain experimental and numerical results. They become familiar with the function of electronic components and can apply these to measurement data acquisition.

Topics:
- Introduction to Electronics
- Passive components
- Transistors
- Basic analogue circuits (Filters)
- Operational amplifiers
- Static and dynamic OP circuitry
- Introduction to High frequency technology
- Signal generators/ Phase shifters
- Electronic controllers
- DAAD conversion
- Practical work: selected experiments on topics covered by the lectures

Reading List:
- 🕮 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 Prior Knowledge:
- Modules „Mechanics and Heat", „Electricity and Relativity", „Optics, Atomic Physics, Quantum Phenomena" and „Nuclei, Particles and Solids"

Where applicable entrance requirements and/or restricted number of participants:
None

Applicability:
-

Master Physics – Specialisation Phase

Selected Topics in Modern Physics A (Ausgewählte Themen moderner Physik A)		1621
Frequency	Winter or Summer Semester	
Responsible for Module	Dean of Studies Office	
Type of Course (SH)	Courses worth at least 27 Credit points according to lecture list	
Assessment Components for Acquisition of CP	**Course Achievement:** according to §6 of exam regulations **Exam Performance:** oral exam	
Grade Composition	Grade of oral exam	
Credit Points (ECTS): 27	**Study in Class (h):**	**Independent Study (h):**

Learning Outcomes:
Students acquire a broad overview of modern physics at an advanced level, and are able to classify this knowledge within the general context of physics. They go into greater depth in a selected branch of physics, which will enable them to join a research group working in this field.

Topics:
Advanced courses in physics chosen by the student.
The exam covers the contents of thematically connected courses to the value of at least 12 CP.

Reading List:
To be announced in class

Recommended Prior Knowledge:
Description of each course in the module catalogue

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:
- Master's Programme in Physics (Specialisation Phase)

Selected Topics in Modern Physics B (Ausgewählte Themen moderner Physik B)			1622
Frequency	Winter Semester or Summer Semester		
Responsible for Module	Dean of Studies Office		
Type of Course (SH)	Courses worth at least minimum 17 Credit points according to lecture list.		
Assessment Components for Acquisition of CP	**Course Achievement:** according to §6 of exam regulations **Exam Performance:** oral exam		
Grade Composition	Grade of oral exam		
Credit Points (ECTS): 17	**Study in Class (h):**	**Independent Study (h):**	

Learning Outcomes:
Students acquire a broad overview of modern physics at an advanced level, and are able to classify this knowledge within the general context of physics. They go into greater depth in a selected branch of physics, which will enable them to join a research group working in this field.

Topics:
Advanced courses in physics chosen by the student.
The exam covers the contents of thematically connected courses to the value of at least 12 CP.

Reading List:
To be announced in class

Recommended Prior Knowledge:
According to course descriptions

Where applicable entrance requirements and/or restricted number of participants:
to be selected together with the module External Internship

Applicability:
- Master's Programme in Physics (Specialisation Phase)

Seminar			1622
Frequency	Winter Semester or Summer Semester		
Responsible for Module	Dean of Studies Office		
Type of Course (SH)	Seminar		
Assessment Components for Acquisition of CP	**Exam Performance:** Seminar performance		
Grade Composition	Grade of Seminar performance		
Credit Points (ECTS): 3	**Study in Class (h):** 30	**Independent Study (h):** 60	

Learning Outcomes:

- 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's own and their's classmates as well).
- Students are able to communicate fluently in German and English.

Topics:
Advanced topics of physics

Reading List:
To be announced in class

Recommended Prior Knowledge:

Where applicable entrance requirements and/or restricted number of participants:
None

Applicability:

- Master's Programme in Physics (Specialisation Phase)

Key skills for the englisch path of the Physics Master (Schlüsselkompetenzen)		1970
Frequency	Winter and Summer Semester	
Responsible for Module	Dean of Studies Office	
Type of Course (SH)	Courses offered from the ‚Applied linguistic and special languages' or the ‚center for quality enhancement in teaching and learning', the advertised offeres from the faculties, and the computer courses from the ‚Data Center'.	
Assessment Components for Acquisition of CP	**Course Achievement:** according to §6 of exam regulations	
Grade Composition		
Credit Points (ECTS): 4 -18	**Study in Class and Independent Study (h):**	120 -540

Learning Outcomes:

- The students learn exemplary key skills in the area chosen

Topics:

Topics according to the chosen class

Reading List:

To be announced in class

Recommended Prior Knowledge:

None

Where applicable entrance requirements and/or restricted number of participants:

None

Applicability:

- Master's Programme in Physics
- Students of the english path of the Physics Master complete German Language Courses in an amount of up to 10 CP for this module. This depends on the result of the mandatory consultation.

For all other students this module is worth 4 CP

Industrial Internship (Industriepraktikum)			**1831**
Frequency	Winter Semester or Summer Semester		
Responsible for Module	Internship coordinator		
Type of Course (SH)	-		
Assessment Components for Acquisition of CP	**Course Achievement:** Internship report		
Grade Composition	-		
Credit Points (ECTS): 10	**Study in Class (h):**	**Independent Study (h):**	
Learning Outcomes: 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.			
Topics: Internship in an industrial enterprise. Institutes of the university are excluded, in exceptional cases the internship can also take place in a non-university research institute. The Internship should take place in a typical occupation of a physicist. Within the Internship the student should work on a defined (small) projekt. The duration of the internship is minimum 8 weeks.			
Reading List:			
Recommended Prior Knowledge:			
Where applicable entrance requirements and/or restricted number of participants: The internship requires approval in advance of the head of examining commitee.			
Applicability: Master's Programme in Physics (Modul Selected Topics in Modern Physics B)			

Master Meteorology – Advanced Meteorology

Seminars on Advanced Meteorology (Seminare zur Fortgeschrittene Meteorologie)				**2301**
Frequency	Winter and Summer Semester			
Responsible for Module	Günther Gross, Institute of Meteorology and Climatology			
Type of Course (SH)	2 seminars from different fields in meteorology			
Assessment Components for Acquisition of CP	**Course Achievement:** 2 Seminars			
Grade Composition	-			
Credit Points (ECTS): 10	**Study in Class (h):** 56		**Independent Study (h):** 244	

Learning Outcomes:

- The students are able to independently research literature on a given current topic from modern meteorology, which is still partly the subject of research. Students are able to independently develop a current area of knowledge.
- Students can structure and give a lecture on a complex topic of modern meteorology that can be easily followed by a meteorologically educated audience.
- By designing the lecture, they 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 (on topics of their own and of fellow students).

Students are able to speak German or English in a free speech

Topics:

- Advanced Topics in Meteorology

Reading List:

To be announced during the lecture.

Recommended Prior Knowledge:

To be announced during the lecture.

Where applicable entrance requirements and/or restricted number of participants:

None

Applicability:

- Master's Programme in Meteorology (Advanced Meteorology)

Advanced Practical Work (Fortgeschrittenenpraktikum)		**2304**
Frequency	Lecture free time between Winter and Summer Semester	
Responsible for Module	Gross, Institute of Meteorology and Climatology	
Type of Course (SH)	Advanced practical and experimental work	
Assessment Components for Acquisition of CP	**Course Achievement:** practical work and report	
Grade Composition	-	
Credit Points (ECTS): 6	**Study in Class and Independent Study (h):** 180	

Learning Outcomes:
Students become familiar with advanced measuring systems in e.g. radiation or aviation meteorology. Participation in field experiments and working in small groups prepare the students for their future career in applied meteorology.

Topics:
- Practical experiments in various field in meteorology.

Reading List:
Script on Practical Work with Instruments

Recommended Prior Knowledge:
- "Introduction to Meteorology"
- Practical work with instruments

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:
- Master's Programme in Meteorology (Advanced Meteorology)

Key Skills (Meteorology) (Schlüsselkompetenzen)		2670
Frequency	Winter and Summer Semester	
Responsible for Module	Seckmeyer, Institute of Meteorology and Climatology	
Type of Course (SH)	Courses offered from the ‚Applied linguistic and special languages' or the ‚center for quality enhancement in teaching and learning', the advertised offeres from the faculties, and the computer courses from the ‚Data Center'.	
Assessment Components for Acquisition of CP	**Course Achievement:** according to §6 of the exam regulations	
Grade Composition	--	
Credit Points (ECTS): 4	**Study in Class and Independent Study (h):** 120	
Learning Outcomes: The students learn the exemplary key skills in the area chosen		
Topics: Topics according to the class chosen		
Reading List: To be announced in class		
Recommended Prior Knowledge: None		
Where applicable entrance requirements and/or restricted number of participants: None		
Applicability: • Master's Programme in Meteorology (Key Competencies)		

Master Meteorology – Elective Area

Selected topics of Modern Meteorology A (Ausgewählte Themen moderner Meteorologie A)		2202
Frequency	Winter and Summer Semester	
Responsible for Module	Günther Gross, Institute of Meteorology and Climatology	
Type of Course (SH)	Courses worth at least 8 CP from the meteorology course descriptions	
Assessment Components for Acquisition of CP	**Course Achievement:** as chosen by lecturer **Exam Performance:** oral exam	
Grade Composition	Grade of oral exam	
Credit Points (ECTS): 8	**Study in class and Independent Study (h):** 240	

Learning Outcomes:
Expanding knowledge of the subject and, depending on the course chosen, extension or acquisition of new methodological expertise in practical work e.g. in programming models, applying complex models or in conducting experiments.

Topics:
Choice of courses worth at least 8 CP according to lecture list or course descriptions (see below.)
The exam covers the contents of thematically connected courses to the value of at least 8 CP.

Reading List:
See course catalogue/descriptions

Recommended Prior Knowledge:
See course catalogue

Where applicable entrance requirements and/or restricted number of participants:
See course catalogue

Applicability:
- Master's Programme in Meteorology (Elective Area Meteorology)

Selected Topics of Modern Meteorology B (Ausgewählte Themen moderner Meteorologie B)		2650
Frequency	Winter Semester and Summer Semester	
Responsible for Module	Gross, Institute of Meteorology and Climatology	
Type of Course (SH)	Lectures and exercises in meteorology in the amount of 8CP	
Assessment Components for Acquisition of CP	**Course Achievement:** lectures and class exercises as defined by the lecturer at the beginning of the module **Exam Performance:** oral exam	
Grade Composition	Grade of oral exam	
Credit Points (ECTS): 8	**Study in Class and Independent Study (h):** 240	

Learning Outcomes:
Expanding knowledge of the subject and, depending on the course chosen, extension or acquisition of new methodological expertise in practical work e.g. in programming models, applying complex models or in conducting experiments.

Topics:
Choice of courses worth at least 8 CP according to lecture list or course descriptions (see below.)
The exam covers the contents of thematically connected courses to the value of at least 8 CP.

Reading List:
See course catalogue/descriptions

Recommended Prior Knowledge:
See course catalogue/descriptions

Where applicable entrance requirements and/or restricted number of participants:
See course catalogue/descriptions

Applicability:
- Master's Programme in Meteorology (Elective Area Meteorology)

Selected Topics of Modern Meteorology C (Ausgewählte Themen moderner Meteorologie C)		2651
Frequency	Winter Semester and Summer Semester	
Responsible for Module	Seckmeyer, Institute of Meteorology and Climatology	
Type of Course (SH)	Courses of at least 8 CP from the catalogue of events of meteorology	
Assessment Components for Acquisition of CP	**Course Achievement:** at the teacher's decision **Exam Performance:** -	
Grade Composition	Module is not graded	
Credit Points (ECTS): 8	**Study in Class and Independent Study (h):** 240	

Learning Outcomes:
Extension of professional competence as well as, depending on the choice of events, deepening or acquisition of new methodological competences within the framework of internships, e.g. in programming models, applying complex models or in experiments.

Topics:
Courses comprising 8 credit points according to the course catalogue.
A maximum of one further seminar on advanced meteorology (5LP) can also be included (see course catalogue).
In consultation with a lecturer in meteorology, a written paper of 3 LP can be included in the module instead of a course.

Reading List:
See course catalogue/descriptions

Recommended Prior Knowledge:
See course catalogue/descriptions

Where applicable entrance requirements and/or restricted number of participants:
See course catalogue/descriptions

Applicability:
- Master's Programme in Meteorology (Elective Area Meteorology)

Thesis and Research Phase

Bachelor's Projekt (Bachelorprojekt)		**9001**
Frequency	Start at any time	
Responsible for Module	Dean of Studies Office	
Type of Course (SH)	Projekt: „Bachelorarbeit" Seminar: „Arbeitsgruppenseminar"	
Assessment Components for Acquisition of CP	**Exam Performance:** Bachelor's thesis **Course Achievement:** Seminar achievement	
Grade Composition		
Credit Points (ECTS): 15	**Study in Class and Independent Study (h):** 450	

Learning Outcomes:
Students are able to work independently to familiarise themselves with a research topic. They can acquire knowledge from books and journals, including some in English. They are capable of planning realistically, managing their time and conducting a scientific project using scientific methods under instruction. They are able to write a text according to scientific standards. They can present a scientific topic using suitable media and are able to conduct a scientific discussion on their own work with fellow students and lecturers. They can use specialised German and partly also English fluently, in both written and spoken form.

Topics:
- Introduction to scientific work
- Independent project work under instruction
- Academic writing
- Presentation techniques
- Scientific talk
- Conducting discussions

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

Recommended Prior Knowledge:
Core modules in the respective bachelor's programme

Where applicable entrance requirements and/or restricted number of participants:
- **Physics:** completed module "Mathematics for Physicists" and successfully passed cross-module exams in "Experimental Physics" and "Theoretical Physics I"
- **Meteorology:** minimum 90 CP

Applicability:
- Bachelor's Programme in Physics (Modul Bachelorprojekt)
- Bachelor's Programme in Meteorology (Modul Bachelorprojekt)

Exam procedure: The topic of the bachelor's thesis is determined by the examiner in consultation with the candidate. The date of the assignment is to be officially recorded and both the exam candidate and the Dean of Studies office to be informed in writing. The examiner is appointed when the topic is assigned. While writing the thesis, the candidate is to be supervised by the examiner.

Research Internship / Project Planning (Forschungspraktikum /Projektplanung)		9031	
Frequency		Winter and Summer Semester	
Responsible for Module		Dean of Studies Office	
Type of Course (SH)		Internship „Forschungspraktikum" Project: Project planning for Master thesis Class: Working group class	
Assessment Components for Acquisition of CP		**Course Achievement:** Seminar achievement	
Grade Composition		Not included in final grade	
Credit Points (ECTS):	30	**Study in Class and Independent Study (h):**	900

Learning Outcomes:
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.
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.
The students are able to gain an overview of current literature. They are able to give a scientific talk and to present their own results in the context of the current state of science.

Topics:
- Literature research
- Getting acquainted with theoretical and experimental methods
- Discussion of current research topics in the research group seminar
- Definition of a scientific problem
- Methods of project management
- Conceiving, presenting and discussing a project plan

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

Recommended Prior Knowledge:
- Advanced specialisation modules in the relevant master's programme

Where applicable entrance requirements and/or restricted number of participants: None

Applicability:
- Master's Programme in Physics (Modules in Research Phase)
- Master's Programme in Meteorology (Modules in Research Phase)

Master Thesis (Masterarbeit)		9021
Frequency	Winter and Summer Semester	
Responsible for Module	Dean of Studies Office	
Type of Course (SH)		
Assessment Components for Acquisition of CP	**Exam Performance:** Masterthesis	
Grade Composition	Grade of Master's thesis	
Credit Points (ECTS): 30	**Study in Class and Independent Study (h):**	900

Learning Outcomes:
Students are able to work independently on a research project. They can structure, prepare and conduct scientific projects under guidance. They are able to gain an overview of current literature, analyse and solve complex problems. Students are able to conduct critical discussions on their own and other research results, and they can deal constructively with questions and criticism. Students are fluent in technical German and English. They are able to give a scientific talk and to present their own results in the context of the current state of science.

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

Reading List:
- 🕮 Current Literatur on the relevant research area
- 🕮 Day, *How to write & publish a scientific paper.* Cambridge University Press
- 🕮 Walter Krämer, *Wie schreibe ich eine Seminar- oder Examensarbeit?*, 1999, ISBN: 3-593-36268-6, Gruppe: Studienratgeber, Reihe: campus concret, Band: 47.

Recommended Prior Knowledge:
-

Where applicable entrance requirements and/or restricted number of participants:
- Physics: Project planning and 40 CP minimum from the master's programme
- Meteorology: Cross-module exam in research training / project planning

Applicability:
- Master's Programme in Physics
- Master's Programme in Meteorology

Exam procedure: The topic of the master's thesis is determined by the first examiner in consultation with the candidate. The date of the assignment is to be officially recorded and both the exam candidate and the Dean of Studies office to be informed in writing. The first and second examiners are appointed when the topic is assigned. While writing the thesis, the candidate is to be supervised by the first examiner.

Course catalogue

Table of the assignment of courses

	Bachelor Physics	Bachelor Meteorology	Master Physics		Master Meteorology		
Name of module / Type of course	Modern Aspects of Physics	Elective Module Meteorology	Selected Topics in Modern Physics	Seminar	Selected Topics of Modern Meteorology A	Selected Topics of Modern Meteorology B	Selected Topics of Modern Meteorology C
Advanced Quantum Theory	X		X				
Seminar Advanced Quantum Theory	X		X	X			
Theoretical Quantum Optics and Quantum dynamics	X		X				
Computational Physics	X		X				
Theoretical solid-state physics			X				
Statististical field theory			X				
Seminar: Condensed Matter Theory			X	X			
Advanced Computational Physics	X		X				
Current Problems in Condensed matter theory			X				
Theory of Fundamental Interactions			X				
Seminar: Theory of fundamental interactions			X	X			
Advanced topics in classical physics	X		X				
Introduction to Particle Physics	X		X				
Solid-state physics in lower dimensions	X		X				
Surface and interface physics			X				
From Atoms to Solids	X		X				
Seminar: From Atoms to Solids			X	X			
Fundamentals of Semiconductor Physics			X				
Semiconductor characterization techniques for photovoltaics	X		X				

	Bachelor Physics	Bachelor Meteorology	Master Physics		Master Meteorology		
Name of module / Type of course	Modern Aspects of Physics	Elective Module Meteorology	Selected Topics in Modern Physics	Seminar	Selected Topics of Modern Meteorology A	Selected Topics of Modern Meteorology B	Selected Topics of Modern Meteorology C
Scanning Probe Technology	X		X				
Molecular Elektronics	X		X				
Methods of surface analysis	X		X				
Lab Cours: Practical Methods of Surface Analysis	X		X				
Physics in nanostructures			X				
Optical Spectroscopy of solids			X				
Quantum Devices			X				
Physics of Solar cells	X		X				
Seminar: „Current Research Questions Of Photovoltaics“	X						
Introduction to electronic measurement data acquisition and processing with Labview	X		X				
Lab Course: Solid-State Physics			X				
Thermodynamics, kinetics and structure of defects in semiconductors			X				
Physics in nanostructures	X		X				
Nonlinear Optics	X		X				
Photonics			X				
Seminar: Photonics			X				
Atom optics			X				
Lab Course: Optics	X		X				
Solid-State Lasers			X				

	Bachelor Physics	Bachelor Meteorology	Master Physics		Master Meteorology		
Name of module / Type of course	Modern Aspects of Physics	Elective Module Meteorology	Selected Topics in Modern Physics	Seminar	Selected Topics of Modern Meteorology A	Selected Topics of Modern Meteorology B	Selected Topics of Modern Meteorology C
Optical Coatings			X				
Fundamentals of Laser Medicine and Biomedical Optics	X						
Physics of Life	X		X				
Bionic Surfaces through Laser Radiation			X				
Data Analysis			X				
Lab Course: Data Analysis	X		X				
Neutron Stars and Black Holes			X	X			
Seminar: Gravitational waves			X	X			
Seminar: Gravitational Physics			X	X			
Laser Interferometry			X				
Lab Course: Laser Interferometry			X				
Laser stabilization and control of optical experiments			X				
Non-classical Light			X				
Non-classical Laser Interferometry			X				
Elektronic Metrology in the Optics Lab			X				
Nuclear Energy and Fuel Cycle, Technical Aspects and Public Discourse	X		X				
Radioaktive Contaminations in the Environment and Risk to Human Health	X		X				
Radiation Protection and Radioecology	X		X				
Chemistry and physical analysis of radionuclides	X		X				

	Bachelor Physics	Bachelor Meteorology	Master Physics		Master Meteorology		
Name of module / Type of course	Modern Aspects of Physics	Elective Module Meteorology	Selected Topics in Modern Physics	Seminar	Selected Topics of Modern Meteorology A	Selected Topics of Modern Meteorology B	Selected Topics of Modern Meteorology C
Introduction to Mass Spectrometry			X				
Seminar: Radiation Protection and Radioecology	X		X				
Knowledge in Radiation Protection	X		X				
Numerical Weather Prediction		X			X	X	X
Lab Course: Numerical Weather Forecasting		X			X	X	X
Pollutant Dispersal in the Atmosphere		X			X	X	X
Turbulence II		X			X	X	X
Atmospheric Convection		X			X	X	X
Lab Course: Simulation of the Atmospheric Boundary Layer		X			X	X	X
Simulation of Turbulent Flows wiht LES Models		X			X	X	X
Lab Course: Simulation of Turbulent Flows with LES Models		X			X	X	X
Agrometeorology		X			X	X	X
Local Climates		X			X	X	X
Remote Sensing I		X			X	X	X
Remote Sensing II		X			X	X	X
Seminar: Advanced Meteorology							X
Meteorological Field Trip II							X
Seminar: Radiation and Remote Sensing							X
What do you need mathematics and physics for or in meteorology studies? WOMA		X					

	Bachelor Physics	Bachelor Meteorology	Master Physics		Master Meteorology		
Name of module / Type of course	Modern Aspects of Physics	Elective Module Meteorology	Selected Topics in Modern Physics	Seminar	Selected Topics of Modern Meteorology A	Selected Topics of Modern Meteorology B	Selected Topics of Modern Meteorology C
External intershio (domestic)							X
External intership (international)							X

Courses in Physics

Institute of Theoretical Physics

Advanced Quantum Theory
(Fortgeschrittene Quantentheorie)

SH	Credit points :	Responsible for Module
3+1	5	Institute of Theoretical Physics

Frequency: Summer Semester

Topics:
- 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, tunnelling, path integral
- Relativistic quantum mechanics: space-time symmetries, Dirac equation
- Scattering theory

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

Recommended Prior Knowledge:
- Mathematics for Physicists
- Introduction to Quantum Theory

Applicability:
- Modern Aspects of Physics
- Selected Topics in Modern Physics

Seminar Advanced Quantum Theory

(Seminar zu Fortgeschrittene Quantentheorie)

SH	Credit points :	Responsible for Module
2	3	Institute of Theoretical Physics

Frequency: Summer Semester

Topics:
In consultation with the lecturer. The seminar must be taken in conjunction with the lecture course Advanced Quantum Theory.

Reading List:

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

Recommended Prior Knowledge:

- „Mathematics for Physicists"
- „Introduction to Quantum Theory"

Applicability:

- Modern Aspects of Physics
- Selected Topics in Modern Physics
- Seminar

Theoretical Quantum Optics and Quantum dynamics

(Theoretische Quantenoptik und Quantendynamik)

SH	Credit points:	Responsible for Module
3+1	5	Institute of Theoretical Physics

Frequency: Winter or Summer Semester

Topics:

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

Reading List:

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

Recommended Prior Knowledge:

- "Theoretical Electrodynamics"
- „Introduction to Quantum Theory"

Applicability:

- Modern Aspects of Physics
- Selected Topics in Modern Physics

Computational Physics

(Computerphysik)

SH	Credit points:	Responsible for Module
2+2	6	Institute of Theoretical Physics

Frequency: Summer Semester

Topics:

- 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, thermodynamics and quantum mechanics
- 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

Reading List:

- 🕮 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 Prior Knowledge:

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

Applicability:

- Modern Aspects of Physics
- Scientific-Technical Elective Area
- Selected Topics in Modern Physics

Theoretical solid-state physics

(Theoretische Festkörperphysik)

SH	Credit points:	Responsible for Module
3+1	5	Institute of Theoretical Physics

Frequency: Winter or Summer Semester (alternating with Statistical Field Theory)

Topics:

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

Reading List:

- 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 Prior Knowledge:

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

Applicability:

- Selected Topics in Modern Physics

Statistical Field Theory

(Statistische Feldtheorie)

SH	Credit points:	Responsible for Module
3+1	5	Institute of Theoretical Physics

Frequency: Winter or Summer Semester (alternating with theoretical solid-state physics)

Topics:

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

Reading List:

- 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 Prior Knowledge:

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

Applicability:

- Selected Topics in Modern Physics

Seminar: Condensed matter theory

(Seminar zur Theorie der kondensierten Materie)

SH	Credit points:	Responsible for Module
2	3	Institute of Theoretical Physics

Frequency: Winter and Summer Semester

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

Reading List:

- 🕮 See courses "Theoretical solid-state physics" and "Statistical field theory"

Recommended Prior Knowledge:

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

Applicability:

- Selected Topics in Modern Physics
- Seminar

Advanced computational physics

(Fortgeschrittene Computerphysik)

SH	Credit points:	Responsible for Module
4+2	8	Prof. Jeckelmann, Institute of Theoretical Physics

Frequency: Winter or Summer Semester

Topics:

- Exact diagonalizations
- Monte Carlo simulations
- Numerical renormalization group methods
- Density functional theory
- Molecular dynamics
- Quantum dynamics
- Quantum computing
- Artificial intelligence/ Machine learning

Reading List:

- 🕮 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

Recommended Prior Knowledge:

- "Introduction to Quantum Theory"
- "Statistical Physics"
- "Computational Physics"

Applicability:

- Selected Topics in Modern Physics
- Modern Aspects of Physics

Current problems in Condensed Matter Theory

(Aktuelle Probleme der Theorie der kondensierten Materie)

SH	Credit points:	Responsible for Module
2	2	Institute of Theoretical Physics

Frequency: Winter or Summer Semester

Topics:

Current topics selected by the lecturer:

- Theory of Magnetism
- Theory of Superconductivity
- Theory of the Quantum Hall Effect
- Theory of Strongly Correlated Electrons
- Integrable Quantum Systems
- Systems out of Equilibrium

Reading List:

to be announced by the lecturer

Recommended Prior Knowledge:

- "Advanced Quantum Theory"
- "Advanced Solid-State Physics"

Applicability:

- Selected Topics in Modern Physics

Theory of Fundamental Interactions

(Theorie der fundamentalen Wechselwirkungen)

SH	Credit points :	Responsible for Module
3+1	5	Institute of Theoretical Physics

Frequency: Winter or Summer Semester

Topics:

The Standard Model of Particle Physics

- a heuristic representation of the theory and applications
- Lagrange densities in field theory
- Gauge invariance, nonabelian gauge theory
- Dirac fermions
- the electroweak theory
- Masses and Higgs mechanism
- QCD, quark confinement, jets, glueballs
- Flavor physics, SU(3), heavy quarks
- Cross sections, decay widths, lifetimes
- Testing the Standard Model
- further topics

Reading List:

- 🕮 G. Kane, *Modern Elementary Particle Physics*, Perseus Publishing 1993

Recommended Prior Knowledge:

- "Advanced Quantum Theory"

Applicability:

- Selected Topics in Modern Physics

Seminar: Theory of Fundamental Interactions

(Seminar zu Theorie der fundamentalen Wechselwirkungen)

SH	Credit points :	Responsible for Module
2	3	Institute of Theoretical Physics

Frequency: Winter or Summer Semester

Topics:
In consultation with the lecturer. The seminar must be taken in conjunction with the lecture course "Theory of Fundamental Interactions".

Reading List:

- 🕮 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 Prior Knowledge:

- "Advanced Quantum Theory"

Applicability:

- Selected Topics in Modern Physics
- Seminar

Advanced topics in classical physics

(Ergänzungen zur klassischen Physik)

SH	Credit points :	Responsible for Module
3+1	5	Institute of Theoretical Physics

Frequency: Winter or Summer Semester

Topics:

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

Reading List:

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

Recommended Prior Knowledge:

- "Analytical Mechanics and Special Relativity"

Applicability:

- Moderne Aspects of Physics
- Selected Topics in Modern Physics

Introduction to Particle Physics

(Einführung in die Teilchenphysik)

SH	Credit points :	Responsible for Module
3+1	5	Institute of Theoretical Physics

Frequency: Summer Semester

Topics:

- Fundamental articles 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

Reading List:

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

Recommended Prior Knowledge:

Applicability:

- Modern Aspects of Physics
- Selected Topics in Modern Physics

Institute of Solid-State Physics

Solid-State Physics in Low Dimensions

(Festkörperphysik in niedrigen Dimensionen)

SH	Credit points :	Responsible for Module
3+1	5	Institute of Solid-State Physics

Frequency: Summer Semester

Topics:

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

Reading List:

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

Recommended Prior Knowledge:

- "Introduction to the Solid-State physics"

Applicability:

- Modern Aspects of Physics
- Selected Topics in Modern Physics

Surface and Interface Physics

(Oberflächenphysik)

SH	Credit points :	Responsible for Module
3+1	5	Institute of Solid-State Physics

Frequency: Summer Semester

Topics:

- 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

Reading List:

- 🕮 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

Recommended Prior Knowledge:

- "Introduction to Solid-State Physics"
- "Advanced Solid-State Physics"

Applicability:

- Selected Topics in Modern Physics

From Atoms to Solids

(Vom Atom zum Festkörper)

SH	Credit points :	Responsible for Module
3+1	5	Institute of Solid-State Physics

Frequency: Summer Semester

Topics:

- 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

Reading List:

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

Recommended Prior Knowledge:

- "Introduction to Solid-State Physics"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics of Nanoelectronics
- Modern Aspects of Physics

Seminar: "From Atoms to Solids"

SH	Credit points :	Responsible for Module
2	3	Institute of Solid-State Physics

Frequency: Summer Semester

Topics:
In consultation with the lecturer. The seminar must be taken in conjunction with the lecture course "From Atoms to Solids".

Reading List:

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

Recommended Prior Knowledge:

- "Introduction to Solid-State Physics"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics of Nanoelectronics
- Seminar

Characterization of Semiconductors and Solar Cells

(Charakterisierung von Halbleitern und Solarzellen)

SH	Credit points:	Responsible for Module
2	2	Institute of Solid-State Physics

Frequency: Summer Semester (irregular)

Topics:

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

References:

🕮 Will be announced in the lecture

Recommended prerequisites:

- Lecture "Introduction to Solid State Physics"

Applicability:

- Modern aspects of physics
- Selected topics of modern physics
- Selected topics of nanoelectronics

Fundamentals of Semiconductor Physics

(Grundlagen der Halbleiterphysik)

SH	Credit points:	Responsible for Module
2	2	Institute of Solid-State Physics

Frequency: Winter Semester

Topics:

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

- Bändertheorie
- Eigen- und Störstellenleitung
- Defekte in Halbleitern
- p-n-Übergänge
- Rekombinationsprozesse
- Ladungsträgertransport
- Heteroübergänge
- Metall-Halbleiter-Kontakte
- Halbleiterbauelemente (Dioden, Transistoren, Photodioden)

Reading List:

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

Recommended Prior Knowledge:

- "Introduction to Solid-State Physics"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics of Nanoelectronics

Semiconductor Characterization Techniques for Photovoltaics

(Halbleitermesstechnik in der Photovoltaik)

SH	Credit points:	Responsible for Module
2	3	Institute of Solid-State Physics

Frequency: Winter Semester

Topics:

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, such characterization techniques as:

- Materials characterization: conductivity, , (, photoconductivity,), 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))

Reading List:

- 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 Prior Knowledge:

- "Introduction to Solid-State Physics"
- "Semiconductor Physics"
- "Physics of Solar Cells"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics of Nanoelectronics
- Modern Aspects of Physics

Scanning Probe Technology

(Rastersondentechnik)

SH	Credit points:	Responsible for Module
2+1	2	Institute of Solid-State Physics

Frequency: Winter Semester

Topics:

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

Reading List:

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

Recommended Prior Knowledge:

- "Introduction to Solid-State Physics"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics of Nanoelectronics
- Modern Aspects of Physics

Molecular Electronics

(Molekulare Elektronik)

SH	Credit points:	Responsible for Module
2+1	2	Institute of Solid-State Physics

Frequency: Summer Semester

Topics:

- Geometric and electronic structure of molecules
- molecular crystals
- Organic films, doping, electronic transport in organic material, OLED
- Molecules on surfaces
- One-dimensional conductors
- Contacts in the quantum regime

Reading List:

- J. Tour, *Molecular electronics*, World scientific 2002
- Schwoerer, Wolf, *Organische Festkörper*, Wiley

Recommended Prior Knowledge:

- "Introduction to Solid-State Physics"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics of Nanoelectronics
- Modern Aspects of Physics

Methods of Surface Analysis

(Methoden der Oberflächenanalytik)

SH	Credit points:	Responsible for Module
2	2	Institute of Solid-State Physics

Frequency: Summer Semester

Topics:

- Vakuum techniques and sample preparation
- Methods of chemical 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

Reading List:

- 🕮 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 Prior Knowledge:

- "Introduction to Solid-State Physics"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics of Nanoelectronics
- Modern Aspects of Physics

Lab course: Practical Methods of Surface Analysis

(Laborpraktikum Methoden der Oberflächenanalytik)

SH	Credit points:	Responsible for Module
3	3	Institute of Solid-State Physics

Frequency: Summer Semester

Topics:

Appropriate experiments, e.g. XPS, UPS, LEED, EELS, STM, AFM. The lab course must be taken in conjunction with the Surface Science lecture.

Reading List:

- 🕮 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 Prior Knowledge:

- "Introduction to Solid-State Physics"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics of Nanoelectronics
- Modern Aspects of Physics

Physics of Nanostructures

(Physik der Nanostrukturen) Status: Modulkatalog 2018

SH	Credit points:	Responsible for Module
2+1	5	Institute of Solid-State Physics

Frequency: at irregular intervals

Topics:

- Grundlagen Nanostrukturen
- Moderne ein- und zweidimensionale Strukturen
- Spektroskopiemethoden

Reading List:

🕮 To be announced in the lecture

Recommended Prior Knowledge:

- "Introduction to Solid-State Physics"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics of Nanoelectronics

Optical Spectroscopy of Solids

(Optische Spektroskopie von Festkörpern)

SH	Credit points:	Responsible for Module
2	2	Institute of Solid-State Physics

Frequency: Winter Semester

Topics:

- 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

Reading List:

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

Recommended Prior Knowledge:

- "Introduction to Solid-State Physics"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics of Nanoelectronics

Quantum Devices

(Quantenstrukturbauelemente)

SH	Credit points:	Responsible for Module
3+1	5	Institute of Solid-State Physics

Frequency: Summer Semester

Topics:

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

Reading List:

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

Recommended Prior Knowledge:

- "Introduction to Solid-State Physics"
- "Advanced Solid-State Physics"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics of Nanoelectronics
- Quantum devices ('Pflichtbereich' Master Nanotechnology)

Physics of Solar Cells

(Physik der Solarzelle)

SH	Credit points:	Responsible for Module
2+2	5	Institute of Solid-State Physics

Frequency: Summer Semester

Topics:

- 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

Reading List:

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

Recommended Prior Knowledge:

- "Introduction to Solid-State Physics"

Applicability:

- Modern Aspects of Physics
- Selected Topics in Modern Physics
- Selected Topics of Nanoelectronics
- „Wahlveranstaltung" of Master's Programme in Nanotechnology

Seminar „Current Research Questions Of Photovoltaics“

(Seminar „Aktuelle Forschungsfragen der Photovoltaik“)

SH	Credit points:	Responsible for Module
2	3	Institute of Solid-State Physics

Frequency: Winter Semester

Topics:

- Current research topics of photovoltaics

Reading List:

🕮 To be announced in seminar.

Recommended Prior Knowledge:

- „Introduction to Solid-State Physics“
- „Physics of Solar Cells“

Applicability:

- Modern Aspects of Physics

Introduction to electronic measurement Data acquisition and processing with LabView

(Einführung in die elektronische Messdatenerfassung und -verarbeitung mit LabView)
(course held in German)

SH	Credit points:	Responsible for Module
4	5	Institute of Solid-State Physics

Frequency: Winter Semester

Learning Outcomes:

The students learn experimental methods of computer-aided electronic measurement data acquisition as well as the further processing of these data with the graphical programming environment LabView, which is often used in research and industry. They are familiar with the physical functional principles of the sensors used and are able to solve measurement tasks independently, process the data with a computer and analyse the uncertainty of the results.

Topics:

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

Reading List:

- 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 Prior Knowledge:

- lectures „Mechanics and Heat" and „Electricity and Relativity"

Recommended Prior Knowledge / Participants limit:
20 participants, Registration via Stud.IP

Applicability:

- Modern Aspects of Physics
- Selected Topics in Modern Physics
- Elektronics and Metrology
- Scientific-Technical Elective Area Meteorology

Lab Course: Solid-State Physics

(Laborpraktikum Festkörperphysik)

SH	Credit points:	Responsible for Module
6	6	Institute of Solid-State Physics

Frequency: Winter and Summer Semester

Topics:

- 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

Reading List:

To be announced during the course

Recommended Prior Knowledge:

- "Introduction to Solid-State Physics"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics of Nanoelectronics

Physics in Nanostructures

(Physik in Nanostrukturen) Status: Modulkatalog 2018

SH	Credit points:	Responsible for Module
2+1	4	Institute of Solid-State Physics

Frequency: Summer Semester

Topics:

- Production of nanostructures through lithography and self-organisation
- Electronic structures, interface states
- Quantum size effects
- Transport signatures in mesoscopic systems
- Magnetoresistance
- Quantum Hall effect, e.g. in graphs
- Instabilities 1-dimensional structures
- Lone electron transistors
- Molecular electronics
- Experimental methods

Reading List:

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

Recommended Prior Knowledge:

- "Introduction to Solid-State Physics"
- "Surface and interface physics"

Applicability:

- Modern Aspects of Physics
- Selected Topics in Modern Physics

Energy Storage materials and devices

SH	Credit points:	Responsible for Module
2+1	4	Zhang, Institute of Solid-State Physics

Frequency: Winter Semester

Topics:

- Introduction (energy crisis, different types of energy storage devices)
- Review of Introduction to Nanophysics (basic knowledge about materials characterization and device fabrication)
- Pumped hydro, thermal, gravity, solar energy
- Batteries and capacitors
    - Introduction to electrochemical energy storage devices
    - Lithium ion battery
    - Lithium sulphur battery
    - Lithium air battery
    - Other emerging technologies
    - Super-capacitor
- Outlook (micro-batteries, on-chip integration, etc)

For practical training, the students are encouraged to visit the laboratory courses in close relation to the topics covered by the lecture.

Reading List:

- Important literatures will be announced at the beginning of the lecture

Recommended Prior Knowledge:

- "Introduction to Nanophysics"

Applicability:

- Modern Aspects of Physics
- Selected Topics in Nanoelectronics

Institute of Quantum Optics

Nonlinear Optics

(Nichtlineare Optik)

SH	Credit points:	Responsible for Module
3+1	5	Institute of Quantum Optics

Frequency: Summer Semester

Topics:

- 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

Reading List:

- 🕮 Agrawal, *Nonlinear Fiber optics*, Academic Press
- 🕮 Boyd, *Nonlinear Optics*, Academic Press
- 🕮 Shen, *Nonlinear Optics*, Wiley-Interscience
- 🕮 Dmitriev, *Handbook of nonlinear crystals*, Springer
- 🕮 Original literature

Recommended Prior Knowledge:

- Atom and Molecular Physics

Applicability:

- Modern Aspects of Physics
- Selected Topics in Modern Physics
- Selected Topics in Photonics

Photonics

(Photonik)

SH	Credit points:	Responsible for Module
2+1	4	Institute of Quantum Optics

Frequency: Winter Semester

Topics:

- Waves in Media
- Dielectric Waveguides (planar, fiber), Integrated Waveguides
- Photonic Crystals
- Waveguide Modes
- Nonlinear Fibre Optics
- Fibre optical components (Circulators, AWG, Fiber-Bragg-Gratings, Modulators)
- Fibre laser
- Laserdiods, Photodetectors
- Optical Communication (RZ, NRZ, WDM/TDM)
- Networks

Reading List:

- 🕮 Reider, *Photonik*, Springer
- 🕮 Menzel, *Photonik,* Springer
- 🕮 Agrawal, *Nonlinear Fiber optics*, Academic Press
- 🕮 Original literature

Recommended Prior Knowledge:

- Coherent Optics
- „Nonlinear Optics"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics in Photonics

Seminar: Photonics

(Seminar zu Photonik)

SH	Credit points:	Responsible for Module
2	3	Institute of Quantum Optics

Frequency: Winter Semester

Topics:
In consultation with the lecturer. The seminar must be taken in conjunction with the lecture course "Photonics".

Reading List:

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

Recommended Prior Knowledge:

- Coherent Optics
- „Nonlinear Optics"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics in Photonics
- Seminar: Photonics (Elective Area Master Nanotechnology)

Atom Optics

(Atomoptik)

SH	Credit points:	Responsible for Module
2+1	4	Institute of Quantum Optics

Frequency: Summer Semester

Topics:

- Atom-light interaction
- Radiation pressure forces
- Neutral atom and ion traps
- Evaporative cooling
- Bose-Einstein condensation
- Ultracold Fermi Gases
- Experiments with ultracold and quantum degenerate gases
- Atoms in optical lattices
- Modern matter wave optics experiments

Reading List:

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

Recommended Prior Knowledge:

- „Atomic and Molecular Physics"
- Quantum Optics

Applicability:

- Selected Topics in Modern Physics
- Selected Topics in Photonics

Lab Course: Optics

(Laborpraktikum Optik)

SH	Credit points:	Responsible for Module
6 (Praktikum)	6	Institute of Quantum Optics

Frequency: Winter and Summer Semester

Topics:

- 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

Reading List:

To be specified in the lab course

Recommended Prior Knowledge:

- Coherent Optics

Applicability:

- Modern Aspects of Physics
- Selected Topics in Modern Physics

Solid-State Lasers

(Festkörperlaser)

SH	Credit points:	Responsible for Module
2	2	Institute of Quantum Optics

Frequency: Summer Semester

Topics:

- 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

Reading List (Literaturempfehlung):

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

Recommended Prior Knowledge:

- Lectures "Coherent Optics" or "Nonlinear Optics"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics in Photonics

Optical Coatings

(Optische Schichten)

SH	Credit points:	Responsible for Module
2 + 1	4	Institute of Quantum Optics

Frequency: Winter Semester

Topics:

- 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)

Reading List:

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

Recommended Prior Knowledge:

- Lectures "Coherent Optics" or "Nonlinear Optics"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics in Photonics

Fundamentals of Laser Medicine and Biomedical Optics

(Grundlagen der Lasermedizin und Biomedizinischen Optik)

SH	Credit points:	Responsible for Module
2	4	Alexander Heisterkamp, Holger Lubatschowski, Institute of Quantum Optics

Frequency: Winter Semester

Topics:

- Lasersystems for application in medicine and biology
- Beam guding and optical medical devices
- Tissue optics
- Thermal properties of tissue
- Photochemical interactions
- Vaporisation/Coagulation
- Photoablation, optoacoustics
- Photodisruption, nonlinear optics
- Applications in Ophthalmology, refractive surgery
- Laser-based diagnostics, optical biopsy
- Optical coherence tomography, theragnostics
- clinical examples

The students will be introduced to the fundamentals of laser medicine and biomedical optics. This will be accompanied by examples from clinical relevant applications. In tutorials and a block seminar (at the end of the semester), recent publications and developments of the field will be discussed.
At the end of the lecture series an excursion to a biomedical optics company (Rowiak) and the LZH or NIFE will be offered.

Reading List:

- 🕮 Eichler, Seiler: "La*sertechnik 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
- 🕮 Originalliterature

Recommended Prior Knowledge:

- Modul „Coherent Optics"

Applicability:

- Bachelor's Programme in Physics (Area of Specialisation, Modern Aspects of Physics)

ster's Programme in Physics (Advanced Specialisation Phase, Modern Aspects of Physics)

Where applicable entrance requirements and/or restricted number of participants: limited places for talks in block seminar (20 talks, 5 ECTS), participation in lecture and seminar not limited (4ECTS)

Physics of Life

SH	Credit points:	Responsible for Module
2	2	Institute of Quantum Optics

Frequency: Summer Semester

Learning Outcomes:

Students acquire a multi-disciplinary knowledge of complex physical and chemical processes in living objects. They will develop the ability to observe and analyze biological processes taken from different scientific perspectives. They will be able to combine increasingly important role of biology in research with other scientific disciplines.

Topics:

The lecture is directed to students interested to know what happens at the interface between physics, biology, and medicine. The classical disciplines (physics, chemistry) get growing interdisciplinary connections to life sciences. This requires to view beyond the horizon of the individual disciplines. This special lecture offers insights into the physics of living matter and presents existing and future interdisciplinary research objectives.

Reading List:

be announced during the lecture.

Recommended Prior Knowledge:

- Lectures of Experimental Physics

Applicability:

- Selected Topics in Modern Physics
- Modern Aspects of Physics

Bionic Surfaces through Laser Radiation

(Bionische Oberflächen durch Laserstrahlung)

SH	Credit points:	Responsible for Module
2+1	4	Fadeeva, Institute of Quantum Optics

Frequency: Winter Semester

Topics:

- Introduction to Bionics: Nature of Bionics, Distinction between bionic and conventional techniques, bionic products and procedures
- Procedures of bionic working: development of ideas, Analysis, Abstraction and Analogy, From planning to invention
- Bionic Surfaces: focused fluid transport, *'Benetzungsoptimierung'*, adhesion, optical effects
- Laser based methods for the production of bionic surfaces: ablation, two photon polymerisation, Laser Induced Forward Transfer (LIFT), Nanoparticles generation
- Application of bionic surfaces in biomedical technology: Optimisation of interfacial tissue/Implants.

Reading List:

To be announced during the lecture.

Recommended Prior Knowledge / Participants limit:

Restricted number of presentations in block seminar (20 Spots for participants),

Participation in lecture and block seminar is unrestricted

Applicability:

- Selected Topics in Modern Physics
- Scientific-Technical Elective Area (Meteorology)

Ultrashort Laser Pulses

(Ultrakurze Laserpulse)

SH	Credit points:	Responsible for Module
2	2	Institute of Quantum Optics

Frequency: Summer Semester

Topics:

- General Basics in linear and non-linear interaction between matter and fields
- Non-linear pulse propagation
- Laser dynamics
- Mode coupling of lasers; types of modern short pulse lasers
- Applications of ultrashort pulses in physics, chemistry and the life sciences
- High energy laser systems
- Generation of harmonics and attosecond pulses

- Relativistic optics

Reading List:

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

Recommended Prior Knowledge:

- Basic knowledge of optics, laser physics, atomic physics

Institute of Photonics

Fracture of Materials and Fracture Mechanics

SH	Credit points:	Responsible for Module
2+2	6	Zhuang, Institute of Photonics

Frequency: Summer Semester

Topics:

The following aspects of fractur emechanics:

1. Introduciton: Review of the history of materials failure and fracture mechanics including historial cases and state of the art
2. Fracutre modes and characteristics: mode I, II and III cracks
3. Brittle and ductile fractures in different materials
4. Characterization of fracture toughness
5. Solution of elastic stress around the crack tip: Kolosov-Muskhelishvili formulus and Westergaard solution
6. Stress intensity factor in 2D and 3D problems and crack handbook
7. Computation of Stress intensity factor: J-integral and a general Eshelby's energy momentum tensor for crack enegy release
8. Introduction and overview of Computational methods for fractue modelling: meshless methods, XFEM and peridynamics and commercial software for fracture modelling
9. Introduction and overview of multiscale approach for fracture modelling

Students are also guided by practical exercises in the computer lab, assigning also specific projects to be solved through the implementation of numerical codes. The codes will be written in Mathematical/Matlab language at the continuum level and in Mathematica/FEAP language when FE discretization are needed. An introduction and examples to using commercial software ABAQUS for crack modelling will be demonstrated

Reading List:

Subject specific recommendation of textbooks and journal articles

Recommended Prior Knowledge:

- Engineering Mechanics, Continuum Mechanics

Applicability:

- Selected Topics in Modern Physics (Master)

Introduction to Multiscale and Multiphysics Modelling

SH	Credit points:	Responsible for Module
2+2	6	Zhang, Institute of Photonics

Frequency: Winter Semester

Topics:

The following aspects of fractur emechanics:

1. Introduction: Review of the classification of multiscale and multiphysics problems and state-of-the-art
2. Multiscale modelling theory and analytical approaches
3. Concept of representative volume element
4. Computationl hierachical multiscale method
5. Computationl concurrent/semi-concurrent multiscale methods
6. Multiphysics model and some types of governing equations
7. Multiphysics modelling commercial software with testing examples e.g. COMSOL
8. Solvers for multifields problems
9. Particial issues in multiscale and multiphysics modelling

Students are also guided by practical exercises in the computer lab, assigning also specific projects to be solved through the implementation of numerical codes. The codes will be written in both LAMMPS for atomistic model, Mathematical/Matlab language at the continuum level or abaqus software when FE

Reading List:

Subject specific recommendation of textbooks and journal articles

Recommended Prior Knowledge:

- Numerical analysis for the solution of PDEs and basic mechanics or physics courses

Applicability:

- Selected Topics in Modern Physics (Bachelor/Master)

Institute of Gravitational Physics

Data Analysis		
SH 2	**Credit points:** 2	**Responsible for Module** Institute of Gravitational Physics
Frequency: Summer Semester		
Topics: • Detectors (interferometer and „resonant mass" detectors) • Data analysis • Templates • Vetoes		
Reading List: To be announced in the lecture.		
Recommended Prior Knowledge: • „Basics of Special Relativity Theory" • „Coherent Optics"		
Applicability: • Selected Topics in Modern Physics		

Lab Course: Data Analysis

(Laborpraktikum Data Analysis)

SH	Credit points:	**Responsible for Module**
4	4	Institute of Gravitational Physics

Frequency: Summer Semester and Winter Semester

Topics:

- 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

Reading List:

🕮 To be announced during the Lab Course

Recommended Prior Knowledge:

- Experience with Linux

Applicability:

- Modern Aspects of Physics
- Selected Topics in Modern Physics

Neutron Stars and Black Holes		
SH 2	**Credit points:** 2	**Responsible for Module** Institute of Gravitational Physics
Frequency: Summer Semester		
Topics: • Sources and expansion of gravitational waves • Neutron stars and Black Holes		
Reading List: To be announced in class.		
Recommended Prior Knowledge: • „Basics of Special Relativity Theory " • „Coherent Optics"		
Applicability: • Selected Topics in Modern Physics		

Seminar: Gravitational Waves

(Seminar Gravitationswellen)

SH	Credit points:	Responsible for Module
2	3	Institute of Gravitational Physics

Frequency: Summer Semester

Topics:

In consultation with the lecturer.

Reading List:

To be announced in lecture and seminar.

Recommended Prior Knowledge:

- Basics of Special Relativity Theory
- Coherent Optics

Applicability:

- Selected Topics in Modern Physics

Seminar: Gravitational Physics

(Seminar Gravitationsphysik)

SH	Credit points:	Responsible for Module
3	3	Institute of Gravitational Physics

Frequency: Summer Semester und Winter Semester

Topics:

- General Theory of Relativity
- Sources of gravitational waves
- Gravitational wave detectors
- Astrophysics and cosmology

Reading List:

to be announced in class

Recommended Prior Knowledge:

- Gravitational Physics

Applicability:

- Selected Topics in Modern Physics
- Seminar

Laser Interferometry

(Laserinterferometrie)

SH	Credit points:	Responsible for Module
3	3	Institute of Gravitational Physics

Frequency: Summer Semester or Winter Semester (irregular)

Topics:

- 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

Reading List:

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

Recommended Prior Knowledge:

Optics, Complexe Lineare Algebra

Applicability:

- Selected Topics in Modern Physics
- Selected Topics in Photonics

Lab Course Laser interferometry

(Laborpraktikum Laserinterferometrie)

SH	Credit points:	Responsible for Module
4	4	Institute of Gravitational Physics

Frequency: Summer Semester oder Winter Semester (irregular)

Topics:

- 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

Reading List:

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

Recommended Prior Knowledge:

- „Coherent Optics"
- „Nonlinear Optics"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics in Photonics

Laser Stabilization and Control of Optical Experiments

(Laserstabilisierung und Kontrolle optischer Experimente)

SH	Credit points:	Responsible for Module
2	2	Institute of Gravitational Physics

Frequency: Summer Semester /Winter Semester (irregular)

Topics:

- Description of light fields and interference
- Descriptions of fluctuations and noise
- Principles 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

Reading List:

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

Recommended Prior Knowledge:

- Coherent Optics

Applicability:

- Selected Topics in Modern Physics
- Selected Topics in Photonics

Non-classical Light

(Nichtklassisches Licht)

SH	Credit points:	Responsible for Module
2	2	Institute of Gravitational Physics

Frequency: Winter Semester (irregular)

Topics:

- 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

Reading List:

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

Recommended Prior Knowledge:

- „Coherent Optics"
- „Quantum Optics"
- „Nonlinear Optics"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics in Photonics

Non-classical Laser Interferometry

(Nichtklassische Laserinterferometrie)

SH	Credit points:	Responsible for Module
2	2	Institute of Gravitational Physics

Frequency: Summer Semester (irregular)

Topics:

- 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

Reading List:

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

Recommended Prior Knowledge:

- „Coherent Optics"
- „Nonlinear Optics"
- „Non-classical Light"
- „Quantum Optics"

Applicability:

- Selected Topics in Modern Physics
- Selected Topics in Photonics

Electronic Metrology in the Optics Lab

(Elektronische Metrologie im Optiklabor)

SH	Credit points:	Responsible for Module
2	2	Institute of Gravitational Physics

Frequency: Summer Semester or Winter Semester (irregular)

Topics:

- 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

Reading List:

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

Recommended Prior Knowledge:

- „Coherent Optics"

Applicability:

- Selected Topics in Modern Physics

Institute of Radioecology and Radiation Protection

Nuclear Energy and Fuel Cycle, Technical Aspects and Public Discourse

(Kernenergie und Brennstoffkreislauf, technische Aspekte und gesellschaftlicher Diskurs)

SH	Credit points:	Responsible for Module
2/Semester	2/Semester	Institute of Radioecology and Radiation Protection

Frequency: Winter Semester (Part 1) and Summer Semester (Part 2)

Topics:

In the winter semester, one focus is on the technical basics. The energy situation is considered globally and in the following the technical basics of nuclear energy use, from uranium extraction to the functioning of current and future reactors to the disposal of spent nuclear fuel, are dealt with. In addition to the technical aspects, the problem is also explained from a sociological / ethical and legal point of view.

In the following summer semester, the main focus is on the problem of finding a repository on a very broad, multidisciplinary basis and from different scientific perspectives. There is plenty of room for discussion (your own opinion is welcome!)

Reading List:

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

Recommended Prior Knowledge:

- Recommended: Lecture "Nuclei, Particles and Solids " and „Radiation Protection and Radioecology"

Applicability:

- Modern Aspects of Physics
- Selected Topics in Modern Physics

Radioactive Contaminations in the Environment and Risk to Human Health

(Radioaktivität in der Umwelt und Strahlengefährdung des Menschen)

SH	Credit points:	Responsible for Module
2	2	Institute of Radioecology and Radiation Protection

Frequency: Summer Semester

Topics:

The 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 at Windscale, Three Mile Island, Chernobyl, Fukushima, Kystym and criticality accidents. Lost highly radioactive sources (Goiania). Consequences of uranium mining for workers and the environment. Patient exposure due to radium and radon treatments.

Reading List:

- 🕮 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 as announced and provided in the lecture (original papers and web links)

Recommended Prior Knowledge:

- Lecture "Nuclei, Particles and Solids " and „Radiation Protection and Radioecology"

Applicability:

- Modern Aspects of Physics
- Selected Topics in Modern Physics

Radiation Protection and Radioecology

(Strahlenschutz und Radioökologie)

SH	Credit points:	Responsible for Module
2	2	Institute of Radioecology and Radiation Protection

Frequency: Winter Semester

Topics:

The lecture covers the following topics:
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 of acquiring "Fachkunde" (expertise for radiation protection officers, or "Strahlenschutzbeauftragte") for handling unsealed radioactive substances acc. to StrSchV S 4.1)

Reading List:

- 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 Prior Knowledge:

- Requirement: Lecture "Nuclei, Particles and Solids " and „Radiation Protection and Radioecology"

Applicability:

- Modern Aspects of Physics
- Selected Topics in Modern Physics

Nuclear Physics Applications in the Environmental Sciences

(Kernphysikalische Anwendungen in der Umweltphysik)

SH	**Credit points:**	**Responsible for Module**
2	2	Institute of Radioecology and Radiation Protection

Frequency: Summer Semester

Topics:

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 extra-terrestrial 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 earth's surface are explained. Stable and radioactive isotopes in various environmental compartments allow for the investigation of environmental evolution and changes due to anthropogenic influences.

Reading List:

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

Recommended Prior Knowledge:

- „Optics, Atomic Physics, Quantum Phenomena"
- „Nuclei, Particles and Solids"
- " Radiation Protection and Radioecology"

Applicability:

- Modern Aspects of Physics
- Selected Topics in Modern Physics

Chemistry and physical analysis of radionuclides

(Chemie und physikalische Analyse von Radionukliden)

SH	Credit points:	Responsible for Module
2	2	Institute of Radioecology and Radiation Protection

Frequency: Winter Semester

Topics:

This lecture deals with the chemical and physical properties of natural and artificial radionuclides, and in particular actinides. Based on element and group-specific properties, quantitative radioanalytical methods and separation techniques are examined in detail. The topics in this lecture are complementary to those in the lecture "Nuclear Radioanalytical Techniques". The application of separation techniques depending on different matrices is discussed. Common methods of collecting and preparing environmental samples are explained. An understanding of radionuclides of interest to speciation is essential for the application of certain separation techniques. Dominating factors that influence speciation are indicated. A central topic is the migration behaviour of radionuclides in the geo- and biosphere. Particular attention is paid to the chemical and physical properties of radioactive elements, aquatic chemistry of the radionuclides and especially of f-elements, quantitative radioanalytics, separation techniques, collection and preparation of environmental samples, radioactive nuclides and radiation in medicine, radionuclide production, behaviour of radionuclides in the environment

Reading List:

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

Recommended Prior Knowledge:

- Basic knowledge of Chemistry

Applicability:

- Modern Aspects of Physics
- Selected Topics in Modern Physics

Nuclear Forensics

(Nukleare Forensik)

SH	Credit points:	Responsible for Module
2	2	Institute of Radioecology and Radiation Protection

Frequency: Summer Semester

Topics:

The lecture provides an insight into and overview of the methods of nuclear forensics and deals with applications in criminal forensics and environmental forensics. These include age and origin determination of radioactive materials or contaminations with radionuclides as well as the application of the principle of isotopic and chemical fingerprints. Background information (relevant to forensics) on the functioning of nuclear weapons, on nuclear fuel reprocessing and on nuclear test ban verification will be discussed. The discussion of examples from the past deepens the understanding.

Reading List:

- M.F. L'Annunziata, *Handbook of Radioactivity Analysis*
- Kratz, Lieser: *Nuclear and Radiochemistry*
- G.F. Knoll, *Radiation detection and measurement*, J. Wiley & Sons, New York, 2000
- http://www.nucleonica.com/ : Karlsruhe Chart of Nuclides

Recommended Prior Knowledge:

- Physics IV „Nuclei, Particles and Solids"
- "Radiation Protection and Radioecology" or
- "Chemistry and Physical Analysis of Radionuclides"

Applicability:

- Modern Aspects of Physics
- Selected Topics in Modern Physics

Introduction to Mass Spectrometry

(Einführung in die Massenspektrometrie)

SH	Credit points:	Responsible for Module
2	2	Institute of Radioecology and Radiation Protection

Frequency: Winter Semester

Topics:

After an introduction to mass spectrometry, various ionisation, mass selection and detection procedures and vacuum technology aspects are explored. Common mass spectrometry methods are dealt with, focusing on elemental and isotope ratio analysis, determination of aqueous species and MS imaging methods. Finally, high precision mass measurements also of extremely short-lived radionuclides and antimatter are presented, as are also the employment of mass spectrometry methods in aerospace. Techniques: ICP-MS, AMS, IRMS, TIMS, RIMS, SIMS, ESI MS, Schottky MS, Isochrone MS, Penningfallen-MS

Reading List:

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

Recommended Prior Knowledge:

- Mechanics
- Elektrodynamics
- Optics, Atomic Physics, Quantum phenomena

Applicability:

- Selected Topics in Modern Physics

Seminar: Recent Advances in Protection and Radioecology

(Seminar/Praktikum Strahlenschutz und Radioökologie)

SH	Credit points:	Responsible for Module
2	3	Institute of Radioecology and Radiation Protection

Frequency: Winter and Summer Semester

Topics:

In consultation with the lecturer.

Reading List:

- DVD mit Unterlagen aller Lehrveranstaltungen, auch verfügbar unter www.zsr.uni-hannover.de
- H.-G. Vogt, H. Schultz: *Grundzüge des praktischen Strahlenschutzes*, 3. Aufl., Hanser Verlag München 2004,
- G. Choppin, J. Rydberg, J.O. Liljenzin, *Radiochemistry and Nuclear Chemistry*, Butterworth Heinemann, Oxford, 1995
- P. Marmier, E. Sheldon, *Physics of Nuclei and Particles*, 2 volumes, 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
- Karlsruher Nuklidkarte
- Strahlenschutzverordnung (StrlSchV)

Recommended Prior Knowledge:

- „Mechanics and Heat"
- „Electricity and Relativity"
- „Optics, Atomic Physics, Quantum Phenomena"
- „Nuclei, Particles and Solids"

Applicability:

- Modern Aspects of Physics
- Selected Topics in Modern Physics

Knowledge in Radiation Protection (acc. to StrlSchV)

(course held in German) (Fachkunde im Strahlenschutz)

SH	Credit points:	Responsible for Module
min. 2	2	Institute of Radioecology and Radiation Protection

Frequency: Winter and Summer Semester

Topics:

The IRS offers radiation protection courses to provide expertise in radiation protection ("Fachkunde") according to the German radiation protection ordinance, StrSchV, and the German X-ray ordinance, RöV. The course covers physical principles, dose concepts, biological radiation effects, and technical and organizational concepts of radiation protection.
Each student is free to choose one course from the programme offered by IRS (www.strahlenschutzkurse.de). The workload of one course varies between 2 and 6 hours per semester week. As an additional qualification the successful completion of the course entitles the student to apply for the "Fachkunde im Strahlenschutz" certificate (radiation protection skills) from 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 workload.

Reading List:

- 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 Prior Knowledge:

- „Mechanics and Heat"
- „Electricity and Relativity"
- „Optics, Atomic Physics, Quantum Phenomena"
- "Nuclei, Particles and Solids"

bility:

- Modern Aspects of Physics
- Selected Topics in Modern Physics

Courses in Meteorology

Numerical Weather Forecasting (Prediction)

SH	Credit points :	Responsible for Module
2+1	4	Institute of Meteorology and Climatology

Frequency: Summer Semester

Topics:

- Basic equations;
- Meteorological coordinate systems;
- Filtered and unfiltered forecast models;
- Initialisation;
- Numerical solution of the equation system
- The DWD (German weather service) forecasting model

Reading List:

- Roache, *Computational Fluid Dynamics*, Hermosa Publishers

Recommended Prior Knowledge:

- "Introduction to Meteorology"
- "Kinematics and Dynamics"

Applicability:

- Elective Module Meteorology
- Selected Topics of Modern Meteorology A
- Selected Topics of Modern Meteorology B
- Selected Topics of Modern Meteorology C
- Bachelor's and Master's in Physics

Lab Course: Numerical Weather Forecasting (Prediction)

SH	Credit points :	Responsible for Module
2	4	Institute of Meteorology and Climatology

Frequency: Winter Semester

Topics:

velopment 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

developed code will be used to simulate Rossby-waves, and to carry out a simple, idealized forecast for the North atlantic

Reading List:

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

Recommended Prior Knowledge:

- „Applied Programming"
- „Numerical Weather Prediction"
- „Kinematics and Dynamics"

Applicability:

- Selected Topics of Modern Meteorology A
- Selected Topics of Modern Meteorology B
- Selected Topics of Modern Meteorology C
- Bachelor and Master Physics

Pollutant Dispersal in the Atmosphere

(Schadstoffausbreitung in der Atmosphäre)

SH	Credit points :	Responsible for Module
2+1	4	Gross, Institute of Meteorology and Climatology

Frequency: Summer Semester

Topics:

- Effects of atmospheric pollutants;
- Pollutant dispersal in the atmosphere (emission –transmission – immission).
- Mathematical dispersal models (Gauß model, Euler model, Lagrangsch Particle model).
- Clean air: laws and guidelines;
- Selected problems: smog, acid rain, urban pollution.

Reading List:

- 🕮 Helbig et al., *Stadtklima und LuftreTopicsung*. Springer Verlag, Berlin.
- 🕮 Zenger, *Atmosphärische Ausbreitungsmodellierung*. Springer Verlag, Berlin
- 🕮 Van Dop, *air pollution modelling and its application*, Plenum press

Recommended Prior Knowledge:

- „Introduction to Meteorology"
- "Theoretical Meteorology"

Applicability:

- Elective Module Meteorology
- Selected Topics of Modern Meteorology A
- Selected Topics of Modern Meteorology B
- Selected Topics of Modern Meteorology C
- Bachelor's and Master's Physik

Turbulence II

(Turbulenz II)

SH	Credit points :	Responsible for Module
2+1	4	Raasch, Institute of Meteorology and Climatology

Frequency: Winter Semester

Topics:

- Features of turbulence, ensemble averaged equations,
- Spatially averaged equations
- Turbulent fluxes
- Energy cascade, Kolmogorov spectrum

Reading List:

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

Recommended Prior Knowledge:

- „Kinematics and Dynamics"
- „Turbulence and Diffusion"

Applicability:

- Selected Topics of Modern Meteorology A
- Selected Topics of Modern Meteorology B
- Selected Topics of Modern Meteorology C
- Bachelor's and Master's Physics

Atmospheric Convection

(Atmosphärische Konvektion)

SH	Credit points:	Responsible for Module
2+1	4	Raasch, Institute of Meteorology and Climatology

Frequency: Winter Semester

Topics:

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

Reading List:

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

Recommended Prior Knowledge:

- „Thermodynamics"
- „Kinematics and Dynamics"
- „Turbulence and Diffusion"

Applicability:

- Selected Topics of Modern Meteorology A
- Selected Topics of Modern Meteorology B
- Selected Topics of Modern Meteorology C
- Bachelor's and Master's Physics

Lab Course: Simulation of the Atmospheric Boundary Layer

(Programmierpraktikum zur Simulation der atmosphärischen Grenzschicht)

SH	Credit points:	Responsible for Module
2	4	Raasch, Institute of Meteorology and Climatology

Frequency: Summer or Winter Semester

Topics:

- 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)

Reading List:

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

Recommended Prior Knowledge:

- „Applied Programming"
- „Kinematics and Dynamics"
- „Turbulence and Diffusion"
- „Numerical Weather Prediction"
- „Atmospheric Convection"

Applicability:

- Selected Topics of Modern Meteorology A
- Selected Topics of Modern Meteorology B
- Selected Topics of Modern Meteorology C
- Bachelor's and Master's in Physics

Simulation of Turbulent Flows with LES Models

(Simulation turbulenter Strömungen mit LES-Modellen)

SH	Credit points:	Responsible for Module
2+1	4	Raasch, Institute of Meteorology and Climatology

Frequency: Summer Semester

Topics:

- Principles 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

Reading List:

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

Recommended Prior Knowledge:

- „Turbulence and Diffusion"
- „Numerical Weather Prediction"
- „Atmospheric Convection"
- „Lab Course: Numerical Weather Prediction"

Applicability:

- Selected Topics of Modern Meteorology A
- Selected Topics of Modern Meteorology B
- Selected Topics of Modern Meteorology C
- Bachelor's and Master's Physics

Lab Course: Simulation of Turbulent Flows with LES Models

(Numerisches Praktikum zur Simulation turbulenter Strömungen mit LES-Modellen)

SH	Credit points:	Responsible for Module
2	4	Raasch, Institute for Meteorology and Climatology

Frequency: Block course at the end of summer Semester

Topics:

- Installation of LES Model PALM
- Simulations of different phenomena (convective boundary layer, neutrally stratified flow, flow around buildings, etc.), including data analysis
- Simulation of turbulent flow around buildings including dispusion modeling

Reading List:

- 🕮 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 Prior Knowledge:

- „Turbulence and Diffusion"
- „Atmospheric Convection"
- „Simulation of Turbulent Flows wiht LES Models"
- „Lab Course: Numerical Weather Prediction"

Applicability:

- Selected Topics of Modern Meteorology A
- Selected Topics of Modern Meteorology B
- Selected Topics of Modern Meteorology C
- Bachelor's and Master's Physics

Agrometeorology
(Agrarmeteorologie)

SH	Credit points:	Responsible for Module
2+1	4	Gross, Institute of Meteorology and Climatology

Frequency: Summer Semester

Topics:

- Energy and water balance of plants;
- Characteristic measures of plants (LAI);
- Measurements and calculating evapotranspiration;
- Specific plant climates;
- Phenology
- Atmospheric Dangers and countermeasures.
- Agrometeorology and changing climate

Reading List:

- 🕮 Van Eimern, *Wetter und Klimakunde für Landwirte*, Ulmer Verlag
- 🕮 Seeman et al., *Agrometeorology*, Springer Verlag

Recommended Prior Knowledge:

- „Introduction to Meteorology"

Applicability:

- Elective Module Meteorology
- Selected Topics of Modern Meteorology A
- Selected Topics of Modern Meteorology B
- Selected Topics of Modern Meteorology C
- Bachelor's Geographie
- Bachelor's and Master's in Physics

Local Climates

(Lokalklimate)

SH	Credit points:	Responsible for Module
2+1	4	Institute of Meteorology and Climatology

Frequency: Winter Semester

Topics:

- Climate of the air layer near the ground;
- Urban climate;
- Local Climate: forest;
- Local Climate: water and coast;
- Phenology;
- Climate and orography;

Reading List:

- 🕮 Geiger, *climate near the ground*, Vieweg Verlag
- 🕮 Hupfer et al., *Witterung und Klima*, Teubner Verlag

Recommended Prior Knowledge:

- "Introduction to Meteorology"

Applicability:

- Elective Module Meteorology
- Selected Topics of Modern Meteorology A
- Selected Topics of Modern Meteorology B
- Selected Topics of Modern Meteorology C
- Bachelor's Geographie
- Bachelor's and Master's in Physics

Remote Sensing I

(Fernerkundung I)

SH	Credit points:	Responsible for Module
2+1	4	Gross, Institute of Meteorology and Climatology

Frequency: Winter Semester

Topics:

- Satellite measurements and their applications for recording atmospheric processes
- Remote sensing with satellite instruments. Derivation of temperature, cloud and trace gas measurements using remote-sensing instruments from satellites and the ground.
- Derivation of radiation measurements from satellite data

Reading List:

- 🕮 Kidder and Vonder Haar: *Satellite Meteorology: An Introduction, Academic Press*

Recommended Prior Knowledge:

- „Introduction to Meteorology"
- „Radiation"

Applicability:

- Elective Module Meteorology
- Selected Topics of Modern Meteorology A
- Selected Topics of Modern Meteorology B
- Selected Topics of Modern Meteorology C
- Master's Subject optische Technologie
- Bachelor's and Master's in Physics

Remote Sensing II

(Fernerkundung II)

SH	Credit points:	Responsible for Module
2+1	4	Gross, Institute of Meteorology and Climatology

Frequency: Summer Semester

Topics:

- The contribution of ground and satellite-assisted remote sensing procedures to current research topics on climate, weather and global change.
- Presenting methods and their results

Reading List:

- 🕮 Kidder and Von der Haar: *Satellite Meteorology: An Introduction, Academic Press*

Recommended Prior Knowledge:

- „Introduction to Meteorology"
- „Radiation"
- „Remote Sensing I"

Applicability:

- Elective Module Meteorology
- Selected Topics of Modern Meteorology A
- Selected Topics of Modern Meteorology B
- Selected Topics of Modern Meteorology C
- Bachelor's and Master's in Physics

Seminar: Advanced Meteorology

(Seminar zur fortgeschrittenen Meteorologie)

SH	Credit points:	Responsible for Module
2	5	Institute of Meteorology and Climatology

Frequency: Winter and Summer Semester

Topics:
Advanced Topics in Meteorology

Reading List:
To be announced in the seminar.

Recommended Prior Knowledge:
To be announced in the seminar.

Applicability:
- Selected Topics of Modern Meteorology C

Meteorological Field Trip II

(Meteorologische Exkursion II)

SH	Credit points:	Responsible for Module
1	2	Institute of Meteorology and Climatology

Frequency: Summer or Winter Semester

Topics:

Students in the master's programme in Meteorology may take part in the regular annual meteorological field trip. They prepare a partial aspect of one of the field trip topics, present this during the field trip and are available for discussion and information. They make a written contribution to the field trip report and give a talk on it in the final seminar. The contents and formal requirements of these contributions are determined by the qualification of a completed bachelor's degree.

Reading List:

Recommended Prior Knowledge:

Applicability:

- Selected Topics of Modern Meteorology C

Seminar: Radiation and Remote Sensing

(Seminar Strahlung und Fernerkundung)

SH	Credit points:	Responsible for Module
2	0	Institute of Meteorology and Climatology

Frequency: Summer Semester and Winter Semester

Topics:

Actual research topics in meteorology concerning radiation and remote sensing

Reading List:

To be announced in the seminar

Recommended Prior Knowledge:

Applicability:

- Master's Programme in Meteorology

What do you need mathematics and physics for or in meteorology studies? WOMA

(Wofür braucht man Mathematik und Physik (im Meteorologie Studium)? WOMA)

SH	Credit points:	Responsible for Module
1	0	Institute of Meteorology and Climatology

Frequency: Summer Semester and Winter Semester (Duration of 2 semester)

Topics:

On the basis of concrete examples from the courses listed under the Recommended Prior Knowledge, students will learn during their studies for which meteorological questions and applications the mathematical and physical knowledge gained during the first two semesters is needed in meteorology

Reading List:

nounced in the seminar

Recommended Prior Knowledge:

Applicability:

- Bachelor's Programme in Physics
- Bachelor's Programme in Meteorology

External internship (domestic)

(Externes Praktikum Inland)

SH	Credit points:	Responsible for Module
2	4	Günther Gross, Institute of Meteorology and Climatology

Frequency: Summer or Winter Semester

Topics:

Students apply independently to an institution in Germany (research facility, authority, engineering office etc) for a four-week meteorologically relevant internship. On successful completion of the internship, they write a report.

Reading List:

Recommended Prior Knowledge:

Applicability:

- Selected Topics of Modern Meteorology C

External internship (international)

(Externes Praktikum Ausland)

SH	Credit points:	Responsible for Module
3	6	Günther Gross, Institute of Meteorology and Climatology

Frequency: Summer or Winter Semester

Topics:

Students apply independently to an institution abroad (research facility, authority, engineering office etc) for a four-week meteorologically relevant internship. On successful completion of the internship, they write a report.

Reading List:

Recommended Prior Knowledge:

Applicability:

- Selected Topics of Modern Meteorology C
- The External Internship Abroad may, on application, be submitted in the area Key Skills.