Bachelor degree program Physics
Bachelor degree program Meteorology

Master degree program Physics
Master degree program Meteorology

Module catalog
Status 24.05.2017

Faculty of Mathematics and Physics
Leibniz University of Hanover
Modul catalog physic, meteorology

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Preliminary note

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

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

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

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

Meteorology:  
http://www.uni-hannover.de/de/studium/studiengaenge/meteorologie/ordnungen/index.php
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Master Thesis (Masterarbeit)

Advanced quantum theory (Fortgeschrittene Quantentheorie)
Introduction to electronic measurement data acquisition and processing with LabView (with practical parts)
Computer physics (Computerphysik)
Theoretical solid-state physics (Theoretische Festkörperphysik)
Statistical field theory (Statistische Feldtheorie)
Seminar to Theory of condensed matter
Seminar to Theory of the condensed matter (Seminar zu Theorie der kondensierten Materie)

Advanced computational physics (Fortgeschrittene Computerphysik)

Current problems of the theory of condensed matter theory
Theory of fundamental interactions (Theorie der fundamentalen Wechselwirkung)
Seminar to Theory of fundamental interactions
Addition to classical physics (Ergänzungen zur klassischen Physik)
Introduction to Particle Physics (Einführung in die Teilchenphysik)
Solid state physics in lower dimensions
Surface physics (Oberflächenphysik)
From the atom to the solid (Vom Atom zum Festkörper)
Seminar From the atom to the solid (Seminar zu Vom Atom zu Festkörper)
Semiconductor Physics (Halbleiterphysik)
Semiconductor measurement technology in photovoltaics (Halbleitermesstechnik in der Photovoltaik)
Scanning Probe Technology (Rastersondentechnik)
Molecular electronics (Molekulare Elektronik)
Methods of surface analysis (Methoden der Oberflächenanalytik)
Laboratory internship Methods of surface analysis
Physics in nanostructures (Physik der Nanostrukturen)
Optical spectroscopy of solids (Optische Spektroskopie von Festkörpern)
Quantum structure devices (Quantumstrukturbaulemente)
Physics of solar cells (Physik der Solarzellen)
Introduction to electronic measurement data acquisition and processing with LabView (with practical parts)
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<th>1. semester</th>
<th>2. semester</th>
<th>3. semester</th>
<th>4. semester</th>
<th>5. semester</th>
<th>6. semester</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Better grade determines final grade</td>
<td>Analysis A 5 CP, SL, PL</td>
<td>Analysis B 5 CP, SL, PL</td>
<td>Stochastics A 4 CP, SL, PL</td>
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</tr>
<tr>
<td>Experimental physics</td>
<td>Mechanics and relativity 6 CP, SL</td>
<td>Electricity 12 CP, SL</td>
<td>Optics, nuclear physics, quantum phenomena 10 CP, SL</td>
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<td>28</td>
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<tr>
<td></td>
<td>PL</td>
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<tr>
<td>Theoretical physics</td>
<td>Mathematical methods of physics 7 CP, SL</td>
<td>Theoretical electrodynamics 7 CP, SL</td>
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<td>14</td>
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<td></td>
<td>PL: one of the exams have to be passed</td>
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<tr>
<td>General and applied meteorology</td>
<td>Introduction to meteorology I 4 CP, SL, PL</td>
<td>Introduction to meteorology II 4 CP, SL, PL</td>
<td>Radiation I 4 CP SL, PL</td>
<td>Radiation II 4 CP</td>
<td>Instrument intern-ship 6 CP, SL</td>
<td>38</td>
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<td>Cloud physics 4 CP, SL, PL</td>
<td>Climatology 4 CP, SL, PL</td>
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<td>Synoptic meteorology I 4 CP, SL</td>
<td>Synoptic meteorology II 4 CP, SL</td>
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<tr>
<td>Theoretical meteorology</td>
<td>Thermodynamics and statics 4 CP, SL, PL</td>
<td>Turbulence and diffusion 4 CP, SL, PL</td>
<td>Kinematics and dynamics 4 CP, SL, PL</td>
<td></td>
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<td>12</td>
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<tr>
<td>Study and job</td>
<td>Introduction to the study of meteorology</td>
<td>Professional internship SL</td>
<td>5</td>
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<tr>
<td>Advanced studies</td>
<td></td>
<td>Meteorological excursion I</td>
<td>34</td>
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<td></td>
<td></td>
<td>2 CP, SL</td>
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<td>Elective module meteorology</td>
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<td></td>
<td></td>
<td>Selection from corresponding assigned courses of at least 20 CP</td>
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<td></td>
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<td>20 CP, (SL), PL</td>
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<tr>
<td></td>
<td></td>
<td>Natural scientific technical electoral area at least 12 CP from courses of the faculties named in the examination regulation</td>
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<td></td>
<td></td>
<td>12 CP, (SL)</td>
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<tr>
<td>Key competencies</td>
<td>A course from the offer of the language center (Fachsprachenzentrums) or center for key competencies (Zentrum für Schlüsselkompetenzen) or the corresponding offers of the faculty</td>
<td>writing 2 CP</td>
<td>4</td>
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<tr>
<td>Presentation and project work</td>
<td></td>
<td>Bachelor project</td>
<td>15</td>
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</tr>
<tr>
<td>Credit points/Examinations</td>
<td>28/4</td>
<td>32/4</td>
<td>30/5</td>
<td>Depending on individual planning.</td>
<td>180</td>
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</table>
# Curriculum BA Physics

<table>
<thead>
<tr>
<th>1. semester</th>
<th>2. semester</th>
<th>3. semester</th>
<th>4. semester</th>
<th>5. semester</th>
<th>6. semester</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics</td>
<td>Analysis I 10 CP, SL, PL</td>
<td>Analysis II 10 CP, SL, PL</td>
<td>Mathematics for physicists I 4 CP, SL</td>
<td>Mathematics for physicists II 4 CP, SL</td>
<td></td>
<td>38</td>
</tr>
<tr>
<td>PL</td>
<td>Only one exam has to be passed</td>
<td></td>
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<tr>
<td>Linear Algebra I 10 CP, SL, PL</td>
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</tr>
<tr>
<td>Experimental physics</td>
<td>Mechanics and relativity 6 CP, SL, PL</td>
<td>Electricity 12 CP, SL</td>
<td>Optics, nuclear physics, quantum phenomena 10 CP, SL</td>
<td>Molecules, cores, particles, solids 10 CP, SL</td>
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<td>38</td>
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<td>PL</td>
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</tr>
<tr>
<td>Theoretical physics</td>
<td>Mathematical methods of 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 the quantum theory 8 CP, SL</td>
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<td>38</td>
</tr>
<tr>
<td>PL</td>
<td>PL</td>
<td>PL</td>
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<tr>
<td>Advanced studies</td>
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<td></td>
<td>2 of 3 specialization modules each V3+U1+P3 each 8 CP - solid state physics - nuclear and molecular physics - coherent optics</td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>Physical electoral area</td>
<td></td>
<td></td>
<td></td>
<td>At least 12 CP from the courses of physics</td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>Key competencies</td>
<td>Seminar or lecture 4 CP</td>
<td></td>
<td></td>
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<td>4</td>
</tr>
<tr>
<td>Choosing compulsory subjects</td>
<td>Business administration, chemistry, electrical engineering, geodesy and geoinformatics, informatics, mechanical engineering, mathematics, meteorology, philosophy and political economy.</td>
<td></td>
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<td></td>
<td>16</td>
</tr>
<tr>
<td>Presentation and project work</td>
<td>Physics presentation seminar 3 CP, SL</td>
<td>Bachelor thesis 12 CP</td>
<td>Lecture 3 CP</td>
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</tbody>
</table>

| Credits | 33/2 | 29/1 | Depending on individual planning. | 180 |
Bachelor Physics – Basic modules

<table>
<thead>
<tr>
<th>Analysis I + II</th>
<th>0211</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Semester</strong></td>
<td>Winter and summer semester</td>
</tr>
<tr>
<td><strong>Responsibility</strong></td>
<td>Institut for Analysis and Institut for Differential geometry</td>
</tr>
<tr>
<td><strong>Courses</strong></td>
<td>Lecture &quot;Analysis I&quot;</td>
</tr>
<tr>
<td></td>
<td>Exercises to &quot;Analysis I&quot;</td>
</tr>
<tr>
<td></td>
<td>Lecture &quot;Analysis II&quot;</td>
</tr>
<tr>
<td></td>
<td>Exercises to &quot;Analysis II&quot;</td>
</tr>
<tr>
<td><strong>Assessment of credit points</strong></td>
<td>Study achievement:</td>
</tr>
<tr>
<td></td>
<td>In each case the practice for Analysis I and Analysis II</td>
</tr>
<tr>
<td></td>
<td>Exam achievement:</td>
</tr>
<tr>
<td></td>
<td>One exam to Analysis I or to Analysis II</td>
</tr>
<tr>
<td><strong>Note compound</strong></td>
<td>doesn’t enter the bachelor note</td>
</tr>
<tr>
<td><strong>Credit points (ECTS):</strong></td>
<td>20</td>
</tr>
<tr>
<td><strong>Attendance study (h):</strong></td>
<td>180</td>
</tr>
<tr>
<td><strong>Self study (h):</strong></td>
<td>420</td>
</tr>
<tr>
<td><strong>Competence:</strong></td>
<td>Competence in dealing with mathematical language. Basic understanding of the correct solution of mathematical problems by means of one-dimensional convergence considerations, differential and integral calculus. As a result of the exercise sessions, the students are familiar with mathematically exact formulations and conclusions in simple contexts and are able to present them.</td>
</tr>
<tr>
<td><strong>Contents:</strong></td>
<td><strong>Analysis I:</strong></td>
</tr>
<tr>
<td></td>
<td>• Number systems; systematic introduction of real numbers</td>
</tr>
<tr>
<td></td>
<td>• Sequences and series</td>
</tr>
<tr>
<td></td>
<td>• Convergence and continuity</td>
</tr>
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<td></td>
<td>• Differential calculus for functions of one variable</td>
</tr>
<tr>
<td></td>
<td>• Integral calculus for functions of one variable.</td>
</tr>
<tr>
<td></td>
<td><strong>Analysis II:</strong></td>
</tr>
<tr>
<td></td>
<td>• Topological concepts such as metric and normed spaces, convergence, continuity, completeness, compactness;</td>
</tr>
<tr>
<td></td>
<td>• 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;</td>
</tr>
<tr>
<td></td>
<td>• Ordinary differential equations, existence, uniqueness, elementary methods of solution.</td>
</tr>
</tbody>
</table>

**Fundamental literature:**

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

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

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

**Module affiliation:**
Bachelor Physics (Basic modules)
# Linear algebra I (Lineare Algebra I)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut for Algebra, Number theory and Discrete mathematics and Institut for Algebraic geometry</td>
</tr>
</tbody>
</table>
| Courses        | Lecture "Lineare algebra I"  
Exercises to "Linear algebra I" |
| Assessment of credit points | Study achievement: Exercises  
Exam achievement: Exam |
| Note compound  | doesn’t enter the bachelor note |
| Credit points (ECTS): | 10  
Attendance study (h): 90  
Self study (h): 210 |

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

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

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

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

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

**Module affiliation:**
- Bachelor Physics (Basic modules)
# Mathematics for Physicists (Mathematik für Physiker)

**Semester**: Winter and summer semester

**Responsibility**: Institut für Analysis and Institut für Differential geometry

### Courses
- Lecture "Mathematics for Physicists I"
- Exercises for "Mathematics for Physicists I"
- Lecture "Mathematics for Physicists II"
- Exercises for "Mathematics for Physicists II"

### Assessment of Credit Points
- **Study achievement:**
  - Exercises
- **Exam achievement:** Oral examination for mathematics education for the 4 semesters (Analysis I+II, Linear Algebra and Mathematics for Physicists)

### Note Compound
- Note of the oral exam

### Credit Points (ECTS)

<table>
<thead>
<tr>
<th>Weight</th>
<th>Attendance Study (h)</th>
<th>Self Study (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>90</td>
<td>150</td>
</tr>
</tbody>
</table>

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

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

### Fundamental Literature:
will be given in the lecture

### Recommended Knowledge:
Modules Analysis I + II

### If Applicable, Admission Prerequisites and Limited Number of Participants:
No

### Module Affiliation:
- Bachelor Physics (Basic module)
- Bachelor Meteorology (Natural scientific technical electoral area)
Mechanics and relativity (Mechanik und Relativität)  1011

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

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

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

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

Recommended knowledge:
High school knowledge of mathematics and physics

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

Module affiliation:
• Bachelor Physics (Basic module)
• Bachelor Meteorology (Basic module)
# Electricity (Elektrizität)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Summer semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Experimental Physics Institutes</td>
</tr>
</tbody>
</table>
| Courses           | Lecture „Electricity“  
|                   | Exercises to „Electricity“  
|                   | Beginners' Lab I: “Mechanics and electricity” |
| Assessment of Credit Points | Study achievement: Problem sets and labs |
| Note compound     | - |
| Credit points (ECTS): | 12 |
| Attendance study (h): | 150 |
| Self study (h): | 210 |

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

**Content:**
- Electrostatics, electric current
- Static magnetic fields
- Time-varying fields
- Maxwell’s equations
- Electromagnetic waves

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

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

**Recommended knowledge:**
Lectures „Mechanics and relativity“, and „ Mathematical methods of physics“

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

**Module affiliation:**
- Bachelor Physics (Basic module)
- Bachelor Meteorology (Basic module)
<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institute of Experimental physics</td>
</tr>
<tr>
<td>Courses</td>
<td>Lecture &quot;Optics, atom physics, quantum phenomena&quot; Exercises to &quot;Optics, atom physics, quantum phenomena&quot; Laboratory II: Optics and atom physics</td>
</tr>
<tr>
<td>Assessment of credit points</td>
<td>Study achievement: Exercises and laboratory</td>
</tr>
<tr>
<td>Note compound</td>
<td>-</td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>10</td>
</tr>
<tr>
<td>Attendance study (h):</td>
<td>120</td>
</tr>
<tr>
<td>Self study (h):</td>
<td>180</td>
</tr>
</tbody>
</table>

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

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

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

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

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

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

**Module affiliation:**
- Bachelor Physics (Basic module)
- Bachelor Meteorology (Basic module)
Molecules, nuclei, particles and solids
(Moleküle, Kerne, Teilchen, Festkörper)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Summer semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institute for Experimental physics</td>
</tr>
<tr>
<td>Courses</td>
<td></td>
</tr>
<tr>
<td>Lecture Molecules, nuclei, particles and solids</td>
<td></td>
</tr>
<tr>
<td>Exercises for Molecules, nuclei, particles and solids</td>
<td></td>
</tr>
<tr>
<td>Grundpraktikum III: Thermodynamics</td>
<td></td>
</tr>
<tr>
<td>Assessment of credit points</td>
<td>Study achievement: Exercises and laboratory</td>
</tr>
<tr>
<td>Note compound</td>
<td>-</td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>10</td>
</tr>
<tr>
<td>Attendance study (h):</td>
<td>120</td>
</tr>
<tr>
<td>Self study (h):</td>
<td>180</td>
</tr>
</tbody>
</table>

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

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

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

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

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

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

Module affiliation:
- Bachelor in physics (Basic module)
- Bachelor in meteorologie (Natural scientific technical electoral area)
<table>
<thead>
<tr>
<th>Module-Spanning Examine in Experimental Physics (Modulübergreifende Prüfung Experimentalphysik)</th>
<th>1001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semester</td>
<td>Winter and summer semester</td>
</tr>
<tr>
<td>Responsibility</td>
<td>Institute for Experimental physics</td>
</tr>
<tr>
<td>Courses</td>
<td>Oral exam</td>
</tr>
<tr>
<td>Assessment of credit points</td>
<td>Study achievement: oral exam</td>
</tr>
<tr>
<td>Note compound</td>
<td>Note of the oral exam</td>
</tr>
<tr>
<td>Weight:</td>
<td>2 (Physics) 28 (Meteorology)</td>
</tr>
</tbody>
</table>

**Competence:**
The students acquired a thorough overview over the fundamental aspects of Experimental Physics. They recognized the parallels and connections of the individual aspects of Physics and are able to present them in a scientific context. The students have an understanding of Physics as a whole and its different characteristics at the individual length- and energy-scales. They are proficient in the knowledge acquisition through study of scientific literature.

**Content:**

**Physics:**
- Mechanics and Relativity
- Electricity
- Optics, Atomic Physics and Quantum Phenomena
- Molecules, Nuclei, Particles and Solid State Physics

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

**If applicable, admission prerequisites and limited number of participants:**

**Physics:**
Three modules out of Mechanics and Relativity; Electricity; Optics, Atomic Physics and Quantum Phenomena; Molecules, Nuclei, Particles and Solid State Physics

**Meteorology:**
Two modules out of Mechanics and Relativity, Electricity, Optics, Atomic Physics and Quantum Phenomena.

**Module affiliation:**
- Bachelor in Physik (Basic module)
- Bachelor in Meteorology (Basic module)
# Mathematical Methods of Physics / Theoretical Electrodynamics

(Mathematische Methoden der Physik / Theoretische Elektrodynamik)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter and summer semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut for Theoretical physics</td>
</tr>
</tbody>
</table>
| Courses            | Lecture: Mathematical methods of physics  
|                    | Exercises for Mathematical methods of physics  
|                    | Lecture: Theoretical elektrodynamics  
|                    | Exercises for Theoretical elektrodynamics |
| Assessment of credit points | Study achievement: each exercise on Mathematical Methods of Physics and Theoretical Electrodynamics  
|                     | Exam achievement: one of the exams to Mathematical Methods of Physics and to Theoretical Electrodynamics |
| Credit points (ECTS): | 14 |
| Attendance study (h): | 150 |
| Self study (h): | 270 |
| Note compound       | does not enter the bachelor note |

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

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

**Content:**

**Mathematical Methods of Physics:**
- vector algebra: scalar and cross product, index notation, determinants
- space curves: differentiation, chain rule, gradient, Frenet formula
- ordinary differential equations: solution techniques
- Newtonian mechanics of a point mass, systems of mass 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

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

**Fundamental literature:**

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

**Recommended knowledge:**
- High school knowledge of mathematics and physics

If applicable, admission prerequisites and limited number of participants: none
### Module affiliation:
- Bachelor in Physics (Basic module)
- Bachelor in Meteorology (Basic module)

### Analytical mechanics and special relativity
(Analytische Mechanik und spezielle Relativitätstheorie)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut for Theoretical physics</td>
</tr>
</tbody>
</table>
| Courses         | Lecture: Analytical mechanics and special relativity  
|                 | Exercises for Analytical mechanics and special relativity |
| Assessment of credit points | Study achievement: Exercises |
| Note compound   | - |
| Credit points (ECTS): | 8 |
| Attendance study (h): | 90 |
| Self study (h): | 150 |

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

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

### Fundamental literature:
- Honerkamp & Römer, *Klassische Theoretische Physik*, Springer  
- Landau-Lifschitz, *Lehrbuch der Theoretischen Physik, Band 1*, Harri  
- H. Goldstein, Poole & Safko, *Classical Mechanics*, Wiley-VCH Verlag GmbH & Co  
- Arnold, *Classical Mechanics*, Springer

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

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

### Module affiliation:
- Bachelor in Physics (Basic module)  
- Bachelor in Meteorology (Natural scientific technical electoral area)
# Modulübergreifende Prüfung Theoretische Physik I
(Cross-module examination theoretical physics I)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter and summer semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut for Theoretical physics</td>
</tr>
<tr>
<td>Courses</td>
<td>oral exam</td>
</tr>
<tr>
<td>Assessment of credit points</td>
<td>Exam achievement: oral exam</td>
</tr>
<tr>
<td>Note compound</td>
<td>mark of the oral exam</td>
</tr>
<tr>
<td>Weight:</td>
<td>1</td>
</tr>
<tr>
<td>Attendance study</td>
<td>-</td>
</tr>
<tr>
<td>Self study (h):</td>
<td>-</td>
</tr>
</tbody>
</table>

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

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

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

## Module affiliation:
- Bachelor in Physics (Basic module)
**Introduction to quantum theory**  
*(Einführung in die Quantentheorie)*

<table>
<thead>
<tr>
<th>Semester</th>
<th>Summer semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut für Theoretical physics</td>
</tr>
<tr>
<td>Courses</td>
<td>Lecture &quot;Introduction to quantum theory&quot;</td>
</tr>
<tr>
<td></td>
<td>Exercises for &quot;Introduction to quantum theory&quot;</td>
</tr>
<tr>
<td>Assessment of credit points</td>
<td><strong>Study achievement:</strong> Exercises</td>
</tr>
<tr>
<td>Note compound</td>
<td>-</td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>8</td>
</tr>
<tr>
<td>Attendance study (h):</td>
<td>90</td>
</tr>
<tr>
<td>Self study (h):</td>
<td>150</td>
</tr>
</tbody>
</table>

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

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

**Fundamental literature:**
1. F. Schwabl, *Quantenmechanik*, Springer

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

**If applicable, admission prerequisites and limited number of participants:** None

**Module affiliation:**
- Bachelor in Physics (Basic module)
- Bachelor in Meteorology (Natural scientific technical electoral area)
## Statistical physics (Statistische Physik)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut for Theoretical physics</td>
</tr>
</tbody>
</table>
| Courses | Lecture: Statistical physics  
Exercises for Statistical physics |
| Assessment of credit points | Study achievement: Exercises |
| Note compound | - |
| Credit points (ECTS): | 8 |
| Attendance study (h): | 90 |
| Self study (h): | 150 |

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

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

### Fundamental literature:
- C. Kittel, H. Krömer, *Thermodynamik*, Oldenbourg
- F. Schwabl, *Statistische Physik*, Springer

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

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

### Module affiliation:
- Bachelor in Physics (Basic module)
- Bachelor in Meteorology (Natural scientific technical electoral area)
Modulübergreifende Prüfung Theoretische Physik II  
(Cross-module examination theoretical physics II)  

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter and summer semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut for Theoretical physics</td>
</tr>
<tr>
<td>Courses</td>
<td>Oral examination</td>
</tr>
</tbody>
</table>

**Assessment of credit points**: Exam achievement: oral examination

**Note compound**: The mark of the oral exam

**Weight**: 1

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

**Content:**
- Introduction to quantum theory
- Statistical physics

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

**Module affiliation:**
- Bachelor Physics (Basic module)
<table>
<thead>
<tr>
<th>Presenting Physics (Physik präsentieren)</th>
<th>1611</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semester</td>
<td>Winter and summer semester</td>
</tr>
<tr>
<td>Responsibility</td>
<td>Institute for physics</td>
</tr>
<tr>
<td>Courses</td>
<td>Proseminar</td>
</tr>
<tr>
<td>Assessment of credit points</td>
<td>Study achievement: Seminar achievement</td>
</tr>
<tr>
<td>Note compound</td>
<td>-</td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>3</td>
</tr>
<tr>
<td>Attendance study (h):</td>
<td>30</td>
</tr>
<tr>
<td>Self study (h):</td>
<td>60</td>
</tr>
<tr>
<td>Competence:</td>
<td>The students are able to familiarize themselves with a given topic under guidance. They can independently research literature and structure and hold a lecture. They know common presentation and visualization techniques. The students speak the German language in free speech.</td>
</tr>
<tr>
<td>Content:</td>
<td>• Physical topics (selection from a topic field specified by the lecturer) • Preparation of a presentation • Success factors of a comprehensible presentation • Use visualization media effectively • Handling stage fright • Scientific discussion</td>
</tr>
<tr>
<td>Fundamental literature:</td>
<td>Will be given to the topic</td>
</tr>
<tr>
<td>Recommended knowledge:</td>
<td>• In consultation with the lecturer</td>
</tr>
<tr>
<td>If applicable, admission prerequisites and limited number of participants: none</td>
<td></td>
</tr>
<tr>
<td>Module affiliation:</td>
<td>• Bachelor in Physics (Basic module)</td>
</tr>
</tbody>
</table>
Bachelor Physics – Deepence modules

<table>
<thead>
<tr>
<th>Introduction to the solid state physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Einführung in die Festkörperphysik)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Semester</td>
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<tr>
<td>Responsibility</td>
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<tr>
<td>Courses</td>
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<tr>
<td>Assessment of credit points</td>
</tr>
<tr>
<td>Note compound</td>
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<tr>
<td>Credit points (ECTS):</td>
</tr>
<tr>
<td>Attendance study (h):</td>
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<tr>
<td>Self study (h):</td>
</tr>
<tr>
<td>Competence:</td>
</tr>
<tr>
<td>Content:</td>
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<tr>
<td>Recommended knowledge:</td>
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<tr>
<td>If applicable, admission prerequisites and limited number of participants:</td>
</tr>
<tr>
<td>Module affiliation:</td>
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<td></td>
</tr>
</tbody>
</table>
## Atomic and molecular physics (Atom- und Molekülphysik)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut for Quantum optics</td>
</tr>
</tbody>
</table>
| Courses           | Lecture „Atomic and molecular physics“  
|                   | Exercises for „Atomic and molecular physics“  
|                   | Internship to „Atomic and molecular physics“ |
| Assessment of credit points | Study achievement: Exercises and laboratory |
| Note compound     | - |
| Credit points (ECTS): | 8  
| Attendance study (h): | 105  
| Self study (h): | 135 |

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

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

### Fundamental literature:


### Recommended knowledge:
- Lectures „Mechanics and relativity“, „Electricity“, „Optics, atomic physics, quantum phenomena“ and „Molecules, nuclei, particles and solids“

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

### Module affiliation:
- Bachelor in Physics (Deepence module)
- Bachelor in Meteorology (Natural scientific technical electoral area)
Coherent Optics (Kohärente Optik)

Semester: Summer semester
Responsibility: Institut für Quantenoptik
Courses:
- Lecture „Coherent optics“
- Exercises for “Coherent optics“
- Laboratory „Coherent optics“
Assessment of credit points: Study achievement: Exercises and laboratory
Note compound: -
Credit points (ECTS): 8
Attendance study (h): 105
Self study (h): 135

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

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

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

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

Recommended knowledge:
- Bachelor in Physics (Deepence module)

If applicable, admission prerequisites and limited number of participants: none
### Cross-module exam deepence area
(Modulübergreifende Prüfung Vertiefungsbereich)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter and summer semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institute for Experimental physics</td>
</tr>
<tr>
<td>Courses</td>
<td>oral exam</td>
</tr>
<tr>
<td>Assessment of credit points</td>
<td>Exam achievement: oral exam</td>
</tr>
<tr>
<td>Note compound</td>
<td>oral examination mark</td>
</tr>
<tr>
<td>Weight:</td>
<td>1</td>
</tr>
</tbody>
</table>

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

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

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

**Module affiliation:**
- Bachelor in Physics (Deepence area)
<table>
<thead>
<tr>
<th><strong>Modern aspects of physics (Moderne Aspekte der Physik)</strong></th>
<th><strong>1601</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Semester</strong></td>
<td>Winter and summer semester</td>
</tr>
<tr>
<td><strong>Responsibility</strong></td>
<td>Institute for Physics</td>
</tr>
<tr>
<td><strong>Courses</strong></td>
<td>Selection of courses with a minimum of 12 credits according to the course catalog.</td>
</tr>
<tr>
<td><strong>Assessment of credit points</strong></td>
<td>Study achievement: gemäß §6 der Prüfungsordnung</td>
</tr>
<tr>
<td><strong>Note compound</strong></td>
<td>oral examination mark</td>
</tr>
<tr>
<td><strong>Credit Points (ECTS):</strong></td>
<td>12</td>
</tr>
<tr>
<td><strong>Weight:</strong></td>
<td>1</td>
</tr>
<tr>
<td><strong>Attendance study (h):</strong></td>
<td>240</td>
</tr>
<tr>
<td><strong>Self study (h):</strong></td>
<td>240</td>
</tr>
</tbody>
</table>

**Competence:**
The students have in-depth knowledge in selected areas of physics. They are able to classify newly acquired knowledge in the logical thought building of physics. Students are able to understand English language literature.

**Content:**
Further physics courses of your choice.
The examination comprises courses of at least 4 credits at the choice of the students.

**Fundamental literature:**
It will be announced in the lecture.

**Recommended knowledge:**
Basic lectures of Physics

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

**Module affiliation:**
- Bachelor in Physics (physical elective module)
# Foundations of laser medicine and biomedical optics

**(Grundlagen der Lasermedizin und Biomedizinischen Optik)**

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Alexander Heisterkamp, Holger Lubatschowski</td>
</tr>
<tr>
<td>Courses</td>
<td>Foundations of laser medicine and biophotonics</td>
</tr>
</tbody>
</table>

## Assessment of credit points

- **Study achievement:** regular participation, participation at the block seminar and excursion
- **Exam achievement:** oral or written exam at professors choice

<table>
<thead>
<tr>
<th>Credit points (ECTS):</th>
<th>4</th>
<th>Weight:</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attendance study (h):</td>
<td>45</td>
<td>Self study (h):</td>
<td>30</td>
</tr>
</tbody>
</table>

### Competence:

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

### Content:

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

### Fundamental literature:

- Eichler, Seiler: "Lasertechnik in der Medizin." Springer-Verlag
- Berlien: "Applied Laser Medicine"
- Bille, Schlegel: Medizinische Physik. Bd. 2: Medizinische Strahlphysik, Springer
- Originalliteratur

### Recommended knowledge:

- Lecture „Coherent Optics“

### If applicable, admission prerequisites and a limited number of participants:

Limited number of presentations at the block seminar (20 available places, 5 ECTS), Participation in lecture class and block seminar unlimited (4 ECTS)

### Module affiliation:

- Bachelor in Physics (Deepence phase/ modern aspects of physics)
- Master in Physics (Advanced deepence phase/ modern aspects to physics)
### Key competencies (Schlüsselkompetenzen)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter and summer semester</th>
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</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Student deanery</td>
</tr>
<tr>
<td>Courses</td>
<td>Courses from the offer of the specialized language center or the center for key competences and correspondingly advertised offers of the faculties as well as computer courses from the data center offer.</td>
</tr>
<tr>
<td>Assessment of credit points</td>
<td>Study achievement: according to §6 of the examination regulation</td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>2−4</td>
</tr>
<tr>
<td>Attendance and self study (h):</td>
<td>60−120</td>
</tr>
</tbody>
</table>

**Competence:**
You learn and master exemplary key competences in the field of the chosen course

**Content:**
- Content depending on the chosen course

**Fundamental literature:** It will be announced in the course.

**Recommended knowledge:** none

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

**Module affiliation:**
- Bachelor in Physics
Bachelor Meteorology – Basic modules

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

<table>
<thead>
<tr>
<th>Linear algebra (Lineare Algebra)</th>
<th>2550</th>
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</thead>
<tbody>
<tr>
<td><strong>Semester</strong></td>
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<tr>
<td>Winter and summer semester</td>
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<tr>
<td><strong>Responsibility</strong></td>
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<tr>
<td>Institut for Algebra, Number theory and Discrete mathematics and Institut for Algebraic geometry</td>
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<tr>
<td><strong>Courses</strong></td>
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<tr>
<td>Lecture Linear Algebra A</td>
<td></td>
</tr>
<tr>
<td>Exercises for Linear Algebra A</td>
<td></td>
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<tr>
<td>Lecture Linear Algebra B</td>
<td></td>
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<tr>
<td>Exercises for Linear Algebra B</td>
<td></td>
</tr>
<tr>
<td><strong>Assessment of credit points</strong></td>
<td></td>
</tr>
<tr>
<td>Study achievement: Exercises for Linear Algebra A und B</td>
<td></td>
</tr>
<tr>
<td>Exam achievement: One exam each to Linear Algebra A and B</td>
<td></td>
</tr>
<tr>
<td><strong>Note compound</strong></td>
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<tr>
<td>The bettermark of the two exams determines the overall mark of the module.</td>
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<tr>
<td><strong>Credit points (ECTS):</strong></td>
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<tr>
<td>8</td>
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<td>Weight:</td>
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<td>4</td>
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<tr>
<td><strong>Attendance study (h):</strong></td>
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<tr>
<td>90</td>
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<tr>
<td><strong>Self study (h):</strong></td>
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<tr>
<td>150</td>
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<tr>
<td><strong>Competence:</strong></td>
<td></td>
</tr>
<tr>
<td>Basic understanding of the mathematical way of thinking and its application towards a variety of problems. Solid competence in handling systems of linear equations and the corresponding methods for solving them; sound knowledge of the underlying algebraic structures. Capability of expressing and presenting mathematical reasoning, and knowledge of adequate methods for this.</td>
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<tr>
<td><strong>Content:</strong></td>
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<tr>
<td>• Basic properties of vector spaces (basis and dimension);</td>
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<tr>
<td>• linear maps and matrices;</td>
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<td>• determinants;</td>
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<tr>
<td>• systems of linear equations and methods for solving them (Gauss algorithm);</td>
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<tr>
<td>• eigenvalues and eigenvectors;</td>
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<tr>
<td>• diagonalisation;</td>
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<tr>
<td>• Euclidean vector spaces</td>
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<td>• quadrics</td>
<td></td>
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<tr>
<td><strong>Fundamental literature:</strong></td>
<td></td>
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<tr>
<td>📖 G. Fischer: <em>Lineare Algebra</em></td>
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<tr>
<td><strong>Recommended knowledge:</strong></td>
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<tr>
<td><strong>If applicable, admission prerequisites and limited number of participants:</strong> none</td>
<td></td>
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<tr>
<td><strong>Module affiliation:</strong></td>
<td></td>
</tr>
<tr>
<td>• Bachelor Meteorology (Basic module)</td>
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</tr>
<tr>
<td>Analysis</td>
<td>2551</td>
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<tr>
<td>-------------------------------------------------------------------------</td>
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<tr>
<td>Semester</td>
<td>Winter and summer semester</td>
</tr>
<tr>
<td>Responsibility</td>
<td>Institut for analysis</td>
</tr>
</tbody>
</table>
| Courses                                                                 | Lecture „Analysis A“  
Exercises for „Analysis A“  
Lecture „Analysis B“  
Exercises for „Analysis B“ |
| Assessment of credit points                                            | Study achievement: Exercises for Analysis A und B  
Exam achievement: One exam each for Analysis A and B |
| Note compound                                                          | The better note of the two exams determines the overall grade |
| Credit points (ECTS):                                                  | 10   |
| Weight:                                                                 | 5    |
| Attendance study (h):                                                  | 120  |
| Self study (h):                                                        | 180  |
| Competence goals:                                                      | Competence in dealing with mathematical language. Basic understanding of the correct solution of mathematical problems by means of one-dimensional convergence considerations, differential and integral calculus. As a result of the exercise sessions, the students are familiar with mathematically exact formulations and conclusions in simple contexts and are able to present them. |
| Content:                                                               | Analysis A:  
Analysis B:  
Differentiation of functions of several variables, extrema; ordinary differential equations. |
📖 O. Forster: Analysis 1 und 2, Vieweg+Teubner  
📖 K. Meyberg & P. Vachenauer: Höhere Mathematik 1, Springer-Verlag 2001 |
| Recommended knowledge:                                                 | |
| If applicable, admission prerequisite and limited number of participants: none |
| Module affiliation:                                                    | • Bachelor Meteorology (Basic module) |
## Applied mathematics (Angewandte Mathematik)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter and summer semester</th>
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</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut for Mathematical stochastics, Institut for Applied mathematics</td>
</tr>
</tbody>
</table>
| Courses             | Lecture „Numerical mathematics A“  
                     | Exercises for „Numerical mathematics A“  
                     | Lecture „Stochastics A“  
                     | Exercises for „Stochastics A“  
| Assessment of credit points | Study achievement: Exercises for “Numerical mathematics A” and “Stochastics A“  
                            | Exam achievement: One exam each for “Numerical mathematics A” and “Stochastics A“  
| Note compound       | Grade of the two exam (to the same weight) |
| Credit points (ECTS): | 8  
Weight: | 8 |
| Attendance study (h): | 90  
Self study (h): | 150 |

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

### Content:

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

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

### Fundamental literature:
- Georgii, H.: *Stochastik*, de Gruyter

### Recommended knowledge:

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

### Module affiliation:
- Bachelor Meteorology (Basic module)
### Applied programming
(Angewandtes Programmieren)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Summer semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut for Meteorology and Climatology</td>
</tr>
</tbody>
</table>
| Courses        | Lecture Applied programming  
                 | Exercises Applied programming |
| Assessment of credit points | Study achievement: Exercises |
| Note compound  | -                         |
| Credit points (ECTS): | 4 |
| Attendance study (h): | 45 |
| Self study (h):   |                           |

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

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

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

**Recommended knowledge:** None

**If applicable, admission prerequisites and limited number of participants:** None

**Module affiliation:**
- Bachelor Meteorology (Basic module)
### Introduction to meteorology (Einführung in die Meteorologie)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Summer and winter semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut for Meteorology and limatology</td>
</tr>
</tbody>
</table>
| Courses | Lecture „Introduction to meteorology I“  
Exercises for „Introduction to meteorology I“  
Lecture „Introduction to meteorology II“  
Exercises for „Introduction to meteorology II“ |
| Assessment of credit points | Study achievement: Exercises to „Introduction to meteorology I and II“  
Exam achievement: One exam each for „Introduction to meteorology I and II“ |
| Note compound | Grade of the two exams (to the same weight) |
| Credit points (ECTS): | 8  
Weight: | 8  
Attendance study (h): | 90  
Self study (h): | 150 |

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

### Content:
**Introduction to Meteorology I:**
The atmosphere and the earth system. Weather and climate. Atmospheric scales. The most important physical quantities for describing the atmosphere; Their typical spatial and temporal variability and their measurement methods. The basics of solar and terrestrial radiation. The chemical composition of the air, water vapor, ozone including the ozone hole formation mechanisms, the greenhouse gases and climate change, the water cycle and the mass circulation of various trace gases.

**Introduction to Meteorology II:**

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

### Recommended knowledge:

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

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

<table>
<thead>
<tr>
<th>Semester</th>
<th>Summer and winter semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut for Meteorology and climatology</td>
</tr>
</tbody>
</table>
| Courses          | Lecture “Radiation I”  
Lecture “Radiation II”  
Exercises to „Radiation I“  
Exercises to „Radiation II“ |
| Assessment of credit points | Study achievement: Exercises to “Radiation I” and “Radiation II”  
Exam achievement: Oral exam |
| Note compound    | Mark of the oral exam |
| Credit points (ECTS): | 8  
Weight: | 8 |
| Attendance study (h): | 90  
Self study (h): | 150 |

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

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

#### Fundamental literature:
- Seckmeyer, *Skript zur Vorlesung Strahlung*
- Bergmann-Schäfer, Band 3 *Optik*, Gruyter

#### Englisch:
- Petty, *A first course in atmospheric radiation*

#### Recommended knowledge:
- Module “Introduction to meteorology (Einführung in die Meteorologie)”

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

#### Module affiliation:
- Bachelor Meteorology (Basic module)
- Master Optical technologies
- Bachelor and Master Physics
# Cloud physics (Wolkenphysik)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Summer semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut für Meteorologie und Climatology</td>
</tr>
</tbody>
</table>
| Courses | Lecture „Cloud physics“  
Exercises to „Cloud physics“ |
| Assessment of credit points | Study achievement: Exercises  
Exam achievement: Oral exam |
| Note compound | Note of the oral exam |
| Credit points (ECTS): | 4  
Weight: | 4  
Attendance study (h): | 45  
Self study (h): | 75 |

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

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

## Fundamental literature:
- Pruppacher und Klett, Microphysics of Clouds and Precipitation, Springer
- Rogers, Cloud Physics A Butterworth-Heinemann Title; 3 edition,

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

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

## Module affiliation:
- Bachelor Meteorology (Basic module)
- Bachelor and Master Physics
<table>
<thead>
<tr>
<th>Instrument internship (Instrumentenpraktikum)</th>
<th>2102</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semester</td>
<td>Winter semester</td>
</tr>
<tr>
<td>Responsibility</td>
<td>Institut for Meteorology and Climatology</td>
</tr>
<tr>
<td>Courses</td>
<td>Internship Instrument internship</td>
</tr>
<tr>
<td>Assessment of credit points</td>
<td>Study achievement: Laboratory</td>
</tr>
<tr>
<td>Note composition</td>
<td>-</td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>6</td>
</tr>
<tr>
<td>Attendance study (h):</td>
<td>90</td>
</tr>
<tr>
<td>Self study (h):</td>
<td>90</td>
</tr>
</tbody>
</table>

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

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

**Fundamental literature:**
Script to Instrument internship

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

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

**Module affiliation:**
- Bachelor Meteorology (Basic module)
- Master Landscape sciences
- Bachelor Physics
| **Semester** | Winter semester |
| **Responsibility** | Institut for Meteorology and Climatology |
| **Courses** | Lecture Climatology  
Exercises to Climatology |
| **Assessment of credit points** | Study achievement: Exercises  
Exam achievement: Exam |
| **Note compound** | Note of the exam |
| **Credit points (ECTS):** | 4  
Weight: 4 |
| **Attendance study (h):** | 45 |
| **Self study (h):** | 75 |

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

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

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

**Recommended knowledge:**
- Module Introduction in meteorology

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

**Module affiliation:**
- Bachelor Meteorology (Basic module)  
- Bachelor Geography  
- Bachelor und Master Physics
# Theoretical meteorology (Theoretische Meteorologie)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter and summer semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut for Meteorology and climatology</td>
</tr>
</tbody>
</table>
| Courses | Lecture „Thermodynamics and statistics“  
Exercise to “Thermodynamics and statistics”  
Lecture “Kinematics and dynamics”  
Exercises to “Kinematics and dynamics”  
Lecture “Turbulences and diffusion”  
Exercises to “Turbulences and diffusion” |
| Assessment of credit points | Study achievement: Exercises to „Thermodynamics and statics“, “Kinematics and dynamics” and “Turbulence and diffusion”  
Exam achievement: One exam each for „Thermodynamics and statics“, “Kinematics and dynamics” and “Turbulence and diffusion” |
| Credit points (ECTS): | 12  
Weight: | 12 |
| Attendance study (h): | 135  
Self study (h): | 225 |
| Competence: | Students are learning the basics of theoretical meteorology and are able to apply them in exercises (Methodenkompetenz). |
| Content: | Thermodynamics and Statics  
- first and second principle of thermodynamics, entropy, Carnot circle, thermodynamic efficiency  
- potential temperature, thermal stratification, vertical structure of the atmosphere at rest  
- water and its phase changes  
- thermodynamic diagrams  
Kinematic and Dynamic  
- physical-mathematical basics of atmospheric flows: Euler equation of motion, vorticity-equation (2D/3D), quasi-geostrophic equations  
- meteorological phenomena: geostrophic and thermal wind, sound waves, gravity waves, Rossby waves  
- linearisation, stability analysis  
- barotropic and baroclinic instability  
Turbulence and Diffusion  
- meteorological phenomena which are dominated by friction  
- Navier-Stokes-equation  
- Reynolds-averaging, equation for the turbulent kinetic energy, Richardson-flux-number  
- vertical wind profiles and processes in the atmospheric boundary layer: constant-flux layer, Ekman layer |
| Fundamental literature: |  
- Etling, Theoretische Meteorologie, Springer Verlag  
- Bohren und Albrecht, Atmospheric Thermodynamics, Oxford University Press  
- Dutton, J.A.: The Ceaseless Wind, Dover Pubns  
- Stull, R.B.: An Introduction to Boundary Layer Meteorology, Springer |
| Recommended knowledge: |  
- Module „Introduction to meteorology (Einführung in die Meteorologie)”  
- Module „Mechanics and relativity (Mechanik und Relativität)”  
- Lecture and exercises to “Mathematical methods of physics (Mathematische Methoden der Physik)” |
| If applicable, admission prerequisites and limited number of participants: | none |
| Module affiliation: |  
- Bachelor Meteorology (Basic module)  
- Bachelor und Master Physics |
## Synoptic meteorology (Synoptische Meteorologie)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter and summer semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut for meteorology and climatology</td>
</tr>
</tbody>
</table>
| Courses | Lecture „Synoptic meteorology I”  
Exercises for „Exercises to operational synoptic”  
Lecture „Synoptic meteorology II”  
Seminar „Weather discussion”  
Exercises for "Introduction to the working with NINJO" |
| Assessment of credit points | Study achievement: Exercises to the lectures and seminar achievement to “Weather discussion” |
| Credit points (ECTS) | 8 |
| Attendance study (h): | 164 |
| Self study (h): | 76 |

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

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

### Fundamental literature:

### Recommended knowledge:
- Module „Introduction to meteorology”
- Lecture and exercises to Thermodynamics and statics and "Kinematics and dynamics"

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

### Module affiliation:
- Bachelor meteorology (Basic module)
- Master Landscape Architecture
## Study and job (Studium und Arbeit)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter semester, no lecture time (internship), following winter semester (presentation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut für Meteorology and Climatology</td>
</tr>
<tr>
<td>Courses</td>
<td>Seminar „Introduction in the study of meteorology“ Internship „Professional internship“</td>
</tr>
<tr>
<td>Assessment of credit points</td>
<td>Study achievement: Internship with report</td>
</tr>
<tr>
<td>Note compound</td>
<td>-</td>
</tr>
<tr>
<td>Credit Points (ECTS):</td>
<td>5</td>
</tr>
<tr>
<td>Attendance and self study (h):</td>
<td>150</td>
</tr>
</tbody>
</table>

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

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

### Fundamental literature:

### Recommended knowledge:

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

### Module affiliation:
- Bachelor Meteorology (Basic module)
| Meteorological excursion I  
(Meteorologische Exkursion I) | 2106 |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Semester</strong></td>
<td>Summer semester, no lecture time (internship)</td>
</tr>
<tr>
<td><strong>Responsibility</strong></td>
<td>Institut for Meteorology and climatology</td>
</tr>
<tr>
<td><strong>Courses</strong></td>
<td>Excursion „Meteorological excursion I“</td>
</tr>
<tr>
<td><strong>Assessment of credit points</strong></td>
<td>Study achievement: Excursion report</td>
</tr>
<tr>
<td><strong>Note compound</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>Credit points (ECTS):</strong></td>
<td>2</td>
</tr>
<tr>
<td><strong>Attendance and self study (h):</strong></td>
<td>60</td>
</tr>
</tbody>
</table>

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

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

**Fundamental literature:**

**Recommended knowledge:**
- Module „Study and job“
- Lecture “Introduction to meteorology I”

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

**Module affiliation:**
- Bachelor meteorology (Basic module)
Bachelor meteorology – Elective subject

<table>
<thead>
<tr>
<th>Elective module meteorology (Wahlmodul Meteorologie)</th>
<th>2107</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semester</td>
<td>Winter semester or summer semester</td>
</tr>
<tr>
<td>Responsibility</td>
<td>Institut for meteorology and climatology</td>
</tr>
<tr>
<td>Courses</td>
<td>See in the lecture-catalog (Lehrveranstaltungskatalog)</td>
</tr>
<tr>
<td>Assessment of Credit Points</td>
<td>Study achievement: according to §6 of the examination regulation</td>
</tr>
<tr>
<td></td>
<td>Exam achievement : oral exam</td>
</tr>
<tr>
<td></td>
<td>(exam equivalent to at least 8LP )</td>
</tr>
<tr>
<td>Note compound</td>
<td>the note of the oral exam</td>
</tr>
<tr>
<td>Credit Points (ECTS):</td>
<td>20</td>
</tr>
<tr>
<td>Weight:</td>
<td>8</td>
</tr>
<tr>
<td>Attendance and self study (h):</td>
<td>600</td>
</tr>
<tr>
<td>competence goals:</td>
<td>Expansion of expertise.</td>
</tr>
</tbody>
</table>

Content:
- See in the lecture-catalog (Lehrveranstaltungskatalog)
- A programming internship must be chosen

Fundamental literature:
See in the lecture-catalog (Lehrveranstaltungskatalog)

Recommended knowledge:
- See in the lecture-catalog (Lehrveranstaltungskatalog)

If applicable, admission prerequisite and limited number of participants:
See in the lecture-catalog (Lehrveranstaltungskatalog)

Module affiliation:
- Bachelor meteorology (Elective subject meteorology)
# Bachelor Meteorology – Scientific-technical elective area

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

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

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

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

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

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

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

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

### Module affiliation:
- Master physics (Advanced expansion phase)
### Advanced gravitational physics
(Fortgeschrittene Gravitationphysik)  1421

<table>
<thead>
<tr>
<th>Semester</th>
<th>Summer semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institute for gravitational physics</td>
</tr>
</tbody>
</table>
| Courses        | Lecture "Advanced gravitational physics"  
Exercises to „Advanced gravitational physics" |
| Assessment of credit points | Study achievement: Exercises  
Exam achievement: oral exam or written exam after the choice of the lecture |
| Note compound  | note of the exam |
| Credit Points (ECTS): | 5  |
| Weight:          | 1  |
| Attendance study (h): | 60  |
| Self study (h):  | 90  |

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

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

**Fundamental literature:**
will be given in the lecture

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

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

**Module affiliation:**
- Master physics (Advanced expansion phase)
## Quantum optics (Quantenegroptik)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut for quantum optics</td>
</tr>
<tr>
<td>Courses</td>
<td>Lecture “Quantum optics”</td>
</tr>
<tr>
<td></td>
<td>Exercises to “Quantum optics”</td>
</tr>
<tr>
<td>Assessment of credit points</td>
<td>Study achievement: Exercises</td>
</tr>
<tr>
<td></td>
<td>Exam achievement: oral or written exam after the choice of the lecture</td>
</tr>
<tr>
<td>Note compound</td>
<td>Note of the exam</td>
</tr>
<tr>
<td>Credit Points (ECTS):</td>
<td>5</td>
</tr>
<tr>
<td>Weight</td>
<td>1</td>
</tr>
<tr>
<td>Attendance study (h):</td>
<td>60</td>
</tr>
<tr>
<td>Self study (h):</td>
<td>90</td>
</tr>
</tbody>
</table>

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

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

### Fundamental literature:
- Walls/Milburn, *Quantum Optics*, Springer
- Schleich, *Quantum Optics in Phase space*, Wiley-VCH

### Recommended knowledge:
- Module “Coherent optics”

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

### Module affiliation:
- Master physics (Advanced expansion phase)
## Quantum field theory (Quantenfeldtheorie) 1121

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter semester of summer semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut for Theoretical physics</td>
</tr>
</tbody>
</table>
| Courses | Lecture „Quantum field theory“  
Exercises to „Quantum field theory“ |
| Assessment of credit points | Study achievement: Exercises  
Exam achievement: oral or written exam (lecturer's choice) |
| Note compound | Examination mark |
| Credit Points (ECTS): | 5 |
| Weight: | 1 |
| Attendance study (h): | 60 |
| Self study (h): | 90 |

### Competence goals:

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

### Content:

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

### Fundamental literature:


### Recommended knowledge:

- Module „Advanced quantum theory (Fortgeschrittene Quantentheorie)“

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

### Module affiliation:

- Master Physics (Advanced expansion phase)
### Electronics and measuring technology

**Semester**: Winter semester or summer semester

**Responsibility**: Institut für Solid state physics

**Courses**
- Lecture “Electronics”
- Lecture “Measuring technology”
- Electronics internship

**Assessment of credit points**
- Study achievement: Laboratory exercises
- Exam achievement: Oral or written exam at the choice of the lecturer

**Note compound**
- Examination mark

**Credit Points (ECTS):** 8
**Weight:** 1

<table>
<thead>
<tr>
<th>Attendance study (h):</th>
<th>Self study (h):</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>120</td>
</tr>
</tbody>
</table>

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

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

**Fundamental literature:**
- Hering, Bressler, Gutekunst, *Elektronik für Ingenieure*, Springer Verlag

**Recommended knowledge:**
- Modules:
  - Mechanics and relativity
  - Electricity
  - Optics, atomic physics, quantum phenomena
  - Molecules, cores, particles, solid

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

**Module affiliation:**
Master Physics – Priority phase

<table>
<thead>
<tr>
<th>Selected topics of modern physics A</th>
<th>1621</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semester</td>
<td>Winter or summer semester</td>
</tr>
<tr>
<td>Responsibility</td>
<td>All institutes of Physics</td>
</tr>
<tr>
<td>Courses</td>
<td>Courses amounting to min. 31 credit points according to the lecture timetable</td>
</tr>
<tr>
<td>Assessment of credit points</td>
<td>Required performance: according to §14 from the Examination Regulation Examination: oral exam</td>
</tr>
<tr>
<td>Note compound</td>
<td>Oral examination mark</td>
</tr>
<tr>
<td>ECTS:</td>
<td>31</td>
</tr>
<tr>
<td>Weight:</td>
<td>1</td>
</tr>
<tr>
<td>Attendance study (h):</td>
<td></td>
</tr>
<tr>
<td>Self-study (h):</td>
<td></td>
</tr>
</tbody>
</table>

**Competence:**
Student will acquire a broad overview of modern physics on an advanced level, and will be able to classify this knowledge within the general context of physics. Within this module they will also exemplarily go into greater depth in a special subject of physics, which will enable them to join a research group working in this field on their master thesis.

**Content:**
Advanced courses of physics according to the choice of the student.
The exam will cover the contents of thematically connected courses of at least 12 CP.

**Fundamental Literature:**
To be announced in class

**Recommended knowledge:**
Description of each course in the module catalogue

**If applicable, admission prerequisite and a limited number of participants:** none
| Selected topics of modern physics B  
(Ausgewählte Themen moderner Physik B) | 1622 |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Semester</td>
<td>Winter or summer semester</td>
</tr>
<tr>
<td>Responsibility</td>
<td>Institute of Physics</td>
</tr>
<tr>
<td>Courses</td>
<td>Courses of at least 17 credit points according to the course catalog.</td>
</tr>
</tbody>
</table>
| Assessment of credit points            | Study achievement: according to §6 of the examination regulation  
Exam achievement: oral exam |
| Note compound                          | Note of the oral exam |
| Credit points (ECTS): 17               | Attendance study (h):  
Self study (h): 1 |

**Competence:**
The students have a broad overview of the range of topics of modern physics and can classify this knowledge in the overall building of physics. By way of example, they have worked their way into a selected area of specialization in physics and are in a position to start in a research group in this field.

**Content:**
Advanced courses in physics according to the students' choice  
The exam covers subject-related courses of at least 12 credits.

**Fundamental literature:**
Will be said in the course

**Recommended knowledge:**
according to the course catalog

**If applicable, admission prerequisites and limited number of participants:** Should be selected together with the module "Industrial internship"

**Module affiliation:**
• Master Physics (Priority phase)
| Selected Topics in Photonics  
(Ausgewählte Themen der Photonik) | 1021 |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Semester</td>
<td>Winter or summer semester</td>
</tr>
<tr>
<td>Responsibility</td>
<td>Institut for Quantumoptics</td>
</tr>
<tr>
<td>Courses</td>
<td>Courses of at least 18 credits according to the course catalog</td>
</tr>
</tbody>
</table>
| Assessment of credit points   | Study achievement: according to §14 of the examination regulation  
Exam achievement: oral exam |
| Note compound                 | Note of the oral exam |
| Credit points (ECTS):         | 18   |
| Gewicht:                      | 1    |
| Präsenzstudium (h):           |      |
| Selbststudium (h):            |      |

### Competence:
The students have a comprehensive overview over the field of optics and photonic. They can embed this knowledge into the larger context of physics. The students have deeply studied one topical sub-area and are prepared to work in the corresponding research groups.

### Content:
Advanced physics courses of student’s choice.  
The examination covers topical courses of at least 4 LP

### Fundamental literature:
See the individual courses

### Recommended knowledge:

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

### Module affiliation:
- Master Physics
<table>
<thead>
<tr>
<th>Seminar</th>
<th>1622</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semester</td>
<td>Winter or summer semester</td>
</tr>
<tr>
<td>Responsibility</td>
<td>Institute of Physics</td>
</tr>
<tr>
<td>Courses</td>
<td>Seminar</td>
</tr>
<tr>
<td>Assessment of credit points</td>
<td>Exam achievement: Seminar performance</td>
</tr>
<tr>
<td>Note compound</td>
<td>Note of the seminar performance</td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>Attendance study (h): 30</td>
</tr>
<tr>
<td>Weight: 3</td>
<td>1</td>
</tr>
</tbody>
</table>

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

**Content:**
Advanced topics of physics

**Fundamental literature:**
Will be said in the course

**Recommended knowledge:**

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

**Module affiliation:**
- Master Physics (Priority phase)
<table>
<thead>
<tr>
<th>Key competencies (Schlüsselkompetenzen)</th>
<th>1970</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semester</td>
<td>Winter and Summer semester</td>
</tr>
<tr>
<td>Responsibility</td>
<td>Student Deanery</td>
</tr>
<tr>
<td>Courses</td>
<td>According to the obligatory counseling, the students have to pass language courses in German in an extent of up to 10 CP. Classes from the offer by the Applied Linguistics and Special Languages (FSZ) or the Key Skills Centre (ZfSK) and relevant classes from the Faculties and computer classes offered by the computing centre (LUIS) as well.</td>
</tr>
<tr>
<td>Assessment of credit points</td>
<td>Required performance: according to §6 from the examination regulation</td>
</tr>
<tr>
<td>Note compound</td>
<td></td>
</tr>
<tr>
<td>ECTS:</td>
<td>10</td>
</tr>
<tr>
<td>Weight:</td>
<td>10</td>
</tr>
<tr>
<td>Attendance and self study (h):</td>
<td>120 - 300</td>
</tr>
<tr>
<td>Competence:</td>
<td>You learn and handle exemplarily key skills in the field of the chosen class.</td>
</tr>
<tr>
<td>Content:</td>
<td>Topics according to the chosen class</td>
</tr>
<tr>
<td>Fundamental literature:</td>
<td>To be announced in class</td>
</tr>
<tr>
<td>Recommended knowledge:</td>
<td>none</td>
</tr>
<tr>
<td>If applicable, admission prerequisites and limited number of participants:</td>
<td>none</td>
</tr>
<tr>
<td>Module affiliation:</td>
<td>Master Physics</td>
</tr>
<tr>
<td></td>
<td>For all other students, this module includes 4 credit points</td>
</tr>
<tr>
<td><strong>Industrial Internship (Industriepraktikum)</strong></td>
<td>1831</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Semester</td>
<td>Winter or summer semester</td>
</tr>
<tr>
<td>Responsibility</td>
<td>Institutes of Experimental Physics</td>
</tr>
<tr>
<td>Courses</td>
<td>-</td>
</tr>
<tr>
<td>Assessment of credit points</td>
<td>Required performance: Internship report</td>
</tr>
<tr>
<td>Note compound</td>
<td>-</td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>10</td>
</tr>
<tr>
<td>Attendance study (h):</td>
<td>Self study (h):</td>
</tr>
</tbody>
</table>

**Competence:**
Students are aware of typical task fields and scope of activities of graduates in technical physics in the professional practice. They are able to integrate into a working environment with scientists and engineers and to work in teams. They know exemplarily the implementation of scientific knowledge into an industrial process and understand the occurred task.

**Content:**
Internship at an industrial enterprise

**Fundamental literature:**

**Recommended knowledge:**

If applicable, admission prerequisite and a limited number of participants : none
Master Meteorology – Advanced Meteorology

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

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

The students speak German or English jargon in free speech

Content:
- Advanced topics of meteorology

Fundamental literature:
Will be said in the course

Recommended knowledge:
Will be said in the course

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

Module affiliation:
- Master Meteorology (Advanced Meteorology)
### Advanced internship (Fortgeschrittenenpraktikum)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Lecture free time between winter and summer semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut for Meteorology and Climatology</td>
</tr>
<tr>
<td>Courses</td>
<td>Advanced internship</td>
</tr>
<tr>
<td>Assessment of credit points</td>
<td>Study achievement: Laboratory</td>
</tr>
<tr>
<td>Note composition</td>
<td>-</td>
</tr>
<tr>
<td>Credit points (ECTS):</td>
<td>6</td>
</tr>
<tr>
<td>Attendance and self study (h):</td>
<td>180</td>
</tr>
</tbody>
</table>

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

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

#### Fundamental literature:
- Script for instrument internship

#### Recommended knowledge:

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

#### Module affiliation:
- Master Meteorology (Advanced Meteorology)
### Key competencies (Schlüsselkompetenzen)

<table>
<thead>
<tr>
<th></th>
<th>2670</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Semester</strong></td>
<td>Winter and summer semester</td>
</tr>
<tr>
<td><strong>Responsibility</strong></td>
<td>Institut for Meteorology and Climatology</td>
</tr>
<tr>
<td><strong>Courses</strong></td>
<td>Courses from the offer of the language center or the center for key competencies and correspondingly advertised offers of the faculties, as well as computer courses from the data center offer.</td>
</tr>
<tr>
<td><strong>Assessment of credit points</strong></td>
<td>Study achievement: according to §6 of the examination regulation</td>
</tr>
<tr>
<td><strong>Note compound</strong></td>
<td>--</td>
</tr>
<tr>
<td><strong>Credit points (ECTS):</strong></td>
<td>4</td>
</tr>
<tr>
<td><strong>Attendance and self study (h):</strong></td>
<td>120</td>
</tr>
</tbody>
</table>

**Competence:**
The students learn and master exemplary key competencies in the field of selected courses.

**Content:**
Content depending on the chosen course

**Fundamental literature:**
- Content depending on the chosen course

**Recommended knowledge:**
- None

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

**Module affiliation:**
- Master Meteorology (Key competencies)
Master Meteorology – Elective area

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

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter and summer semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institut for Meteorology and Climatology</td>
</tr>
<tr>
<td>Courses</td>
<td>Courses of at least 8 credit points from the courses catalog of meteorology</td>
</tr>
</tbody>
</table>
| Assessment of credit points | Study achievement: Election of the lecturer  
Exam achievement: Oral exam |
| Note composition | Note of the oral exam |
| Credit points (ECTS): 8  
Weight: 1 | Attendance and self study (h): 240 |

**Competence:**
Expanding the expertise, as well as depending on the choice of events deepening or acquiring new methodological skills in the context of internships, for example in the programming of models, applying complex models or in experimentation.

**Content:**
Courses of 8 credit points according to the course catalog.  
The exam covers subject-related courses of at least 8 credits points.

**Fundamental literature:**
Siehe Lehrveranstaltungskatalog

**Recommended knowledge:**
See course catalog (Lehrveranstaltungskatalog)

**If applicable, admission prerequisites and limited number of participants:**
See course catalog (Lehrveranstaltungskatalog)

**Module affiliation:**
- Master Meteorology (Elective area Meteorology)
**Selected topics of modern meteorology C**  
*(Ausgewählte Themen moderner Meteorologie C)*

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Semester</strong></td>
<td>Winter and summer semester</td>
</tr>
<tr>
<td><strong>Responsibility</strong></td>
<td>Institut for Meteorology and Climatology</td>
</tr>
<tr>
<td><strong>Courses</strong></td>
<td>Courses of at least 8 credit points from the courses catalog of meteorology</td>
</tr>
</tbody>
</table>
| **Assessment of credit points** | Study achievement: Election of the lecturer  
Exam achievement: - |
| **Note compound** | Module is not graded |
| **Credit points (ECTS):** | 8 |
| **Attendance and self study (h):** | 240 |

**Competence:**  
Expanding the expertise, as well as depending on the choice of events deepening or acquiring new methodological skills in the context of internships, for example in the programming of models, applying complex models or in experimentation.

**Content:**  
Courses of 8 credit points according to the course catalog.  
It is also possible to introduce a maximum of another seminar on advanced meteorology (5CP) (see course catalog):  
In consultation with a lecturer in meteorology, a written paper of 3 CP may be added to the module instead of a course.

**Fundamental literature:**  
See course catalog (Lehrveranstaltungskatalog)

**Recommended knowledge:**  
See course catalog (Lehrveranstaltungskatalog)

**If applicable, admission prerequisites and limited number of participants:**  
See course catalog (Lehrveranstaltungskatalog)

**Module affiliation:**  
- Master Meteorology (Elective area Meteorology)
Theses and research phase

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

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

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

**Fundamental literature:**
- Aktuelle Literatur zum Thema der Bachelorarbeit
- Abacus communications, *The language of presentations*, CDROM Lehr- und Trainingsmaterial

**Recommended knowledge:**
Basic modules of the respective degree program

**If applicable, admission prerequisites and limited number of participants:**
- Physics: Completed module "Mathematics for physicists" and passed cross-module examinations "Experimental physics" and "Theoretical physics I"
- Meteorology: At least 100 CP from the basic modules of the Bachelor’s degree program

**Module affiliation:**
- Bachelor Physics (Module Bachelor thesis)
- Bachelor Meteorology (Module Bachelor thesis)

**Examination procedure:** The topic of the bachelor thesis is determined by the examiner after consultation with the examinee. The issue must be recorded and communicated in writing to the candidate and the Dean of Studies. The examiner is appointed with the issue of the topic. During the preparation of the work, the candidate is supervised by the examiner.
<table>
<thead>
<tr>
<th><strong>Research Internship (Forschungspraktikum)</strong></th>
<th>9031</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Semester</strong></td>
<td>Winter and summer semester</td>
</tr>
<tr>
<td><strong>Responsibility</strong></td>
<td>Institutes of Physics and Meteorology</td>
</tr>
<tr>
<td><strong>Courses</strong></td>
<td>Internship: Research internship Class: Working group class</td>
</tr>
<tr>
<td><strong>Assessment of credit points</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>Note compound</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>Credit points (ECTS):</strong></td>
<td>15</td>
</tr>
<tr>
<td><strong>Attendance study (h):</strong></td>
<td>450</td>
</tr>
</tbody>
</table>

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

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

### Fundamental literature:
- Relevant literature about current research area
- Abacus communications, *The language of presentations*, CDROM Lehr- und Trainingsmaterial

### Recommended knowledge:
- Advanced modules of the relevant Master course

### If applicable, admission prerequisite and a limited number of participants: none
## Project Planning (Projektplannung)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter and summer semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institutes of Physics</td>
</tr>
</tbody>
</table>
| Courses                   | Project: Project planning for Master thesis  
                          | Class: Working group class |
| Assessment of credit points | -                         |
| Note compound             | -                         |
| Credit points (ECTS)      | 15                        |
| Attendance and self study (h): | 450                      |

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

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

### Fundamental literature:
- Little, (Hrsg.), *Management der Hochleistungsorganisation*, Gabler Verlag, Wiesbaden, 1990

### Recommended knowledge:
- Advanced module of the relative Master course
- Module Research training

### If applicable, admission prerequisite and a limited number of participants : none
<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter and summer semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institutes of Physics</td>
</tr>
<tr>
<td>Courses</td>
<td>Required performance: Course participation</td>
</tr>
<tr>
<td>Assessment of credit points</td>
<td>Examination: Project work</td>
</tr>
<tr>
<td>Note compound</td>
<td>does not effect the Master mark</td>
</tr>
<tr>
<td>Weight:</td>
<td>0</td>
</tr>
</tbody>
</table>

**Competence:**
The student can acquire an overview of the scientific literature pertaining to a research project. He or she is able to conduct a scientific presentation and to describe his or her own research project in relation to the current state of the field.

**Content:**
Project planning, research training

If applicable, admission prerequisite and a limited number of participants: none
# Master Thesis (Masterarbeit)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Winter and summer semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>Institutes of Physics</td>
</tr>
<tr>
<td>Courses</td>
<td></td>
</tr>
<tr>
<td>Assessment of credit points</td>
<td>Examination: Master thesis</td>
</tr>
<tr>
<td>Note compound</td>
<td>Master thesis mark</td>
</tr>
<tr>
<td>Credit points (ECTS)</td>
<td>30</td>
</tr>
<tr>
<td>Weight:</td>
<td>5</td>
</tr>
<tr>
<td>Attendance and self study (h):</td>
<td>900</td>
</tr>
</tbody>
</table>

## Competence:

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

## Content:

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

## Fundamental literature:

- Relevant literature about current scientific problem definition

## Recommended knowledge:

- Project planning

## If applicable, admission Prerequisite and a limited number of participants:

- Project planning

## Examination procedure:

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

Courses of Physics

Institut for Theoretical physics

Advanced quantum theory
Seminar to Advanced quantum theory
Computer physics
Theoretical solid state physics
Statistical field theory
Seminar to Theory of condensed matter
Advanced computer physics
Current problems of the theory of condensed matter
Theory of fundamental interactions
Seminar to Theory of fundamental interactions
Additions to classical physics
Introduction to particle physics

Institut for Solid state physics

Solid state physics in low dimensions
Laboratory internship Solid state physics in low dimensions
Surface physics
From the atom to the solid
Seminar to From the atom to the solid
Semiconductor physics
Semiconductor measurement technology in photovoltaics
Scanning probe technology
Molecular electronics
Methods of surface analysis
Laboratory internship to Methods of surface analysis
Physics of nanostructures
Optical spectroscopy of solids
Quantum structure devices
Physics of the solar cell
Laboratory internship Solid state physics
Seminar Current research topics in solid state physics
Thermodynamics, kinetics and structure of defects in semiconductors
Physics in nanostructures

Institut for Quantum optics

Leibniz Universität Hannover
Nonlinear optics
Photonics
Seminar to Photonics
Atom optics
Laboratory internship optics
Solid state laser
Optical layers

Institut for Gravitational physics

Data Analysis
Neutron Stars and Black Holes
Seminar Gravitational waves
Seminar Gravitational physics
Laser interferometry
Laboratory internship Laser interferometry
Laser stabilization and control of optical experiments
Laboratory internship Cluster Computing
Nonclassic light
Nonclassic laser interferometry
Electronic metrology in the optics laboratory

Institut for Radioecology and radiation protection

Nuclear physics and nuclear chemistry of radiation protection and radioecology
Nuclear energy and fuel cycle, technical aspects and social discourse
Radioactivity in the environment and radiation hazard to humans
Radiation protection and radioecology
Nuclear radioanalytical techniques
Radiochemistry and radioanalysis
Introduction to radioecology and radiation protection
Seminar/internship Radiation protection and radioecology

Expertise in radiation protection

Courses of meteorology

Numerical weather forecast
Programming internship to Numerical weather forecast
Pollutant spread in the atmosphere
Turbulence II
Atmospheric convection
Programming internship to simulation of atmospheric border layers .......... Fehler! Textmarke nicht definiert.
Simulation of turbulent flows with LES-models .................. Fehler! Textmarke nicht definiert.
Numerical internship to Simulation of turbulent flows mit LES-models .... Fehler! Textmarke nicht definiert.

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Local climates ............................................................................................................................................. 150
Remote sensing I ...................................................................................................................................... 151
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External internship abroad ...................................................................................................................... 156
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<table>
<thead>
<tr>
<th>Courses</th>
<th>Bachelor Physics</th>
<th>Bachelor Meteorology</th>
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## Courses

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Courses of Physics

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<td><strong>Content</strong>:</td>
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<tr>
<td>• Many-particle systems: identical particles, Fock space, field quantization</td>
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<td>• Open quantum systems: density operator, measurement process, Bell inequalities</td>
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<td>• Information and thermodynamics: partition functions, entropy, thermodynamic equilibrium</td>
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<td>• Semiclassical approximation: Bohr-Sommerfeld, tunneling, path integral</td>
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<td>• Relativistic quantum mechanics: space-time symmetries, Dirac equation</td>
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<td>• Scattering theory</td>
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<tr>
<td>• W. Greiner and J. Reinhardt, <em>Theoretische Physik 7 (Quantenelektrodynamik) und 7a (Feldquantisierung)</em>, Springer</td>
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<td>• A. Peres, <em>Quantum Theory: Concepts and Methods</em>, Springer</td>
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<tr>
<td>• M.E. Peskin &amp; D.V. Schroeder, <em>An Introduction to Quantum Field Theory</em>, Westview Press</td>
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<td>• J.J. Sakurai, <em>Modern Quantum Mechanics</em>, Addison Wesley</td>
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<td>• F. Schwabl, <em>Quantenmechanik für Fortgeschrittene</em>, Springer</td>
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<td><strong>Recommended knowledge</strong>:</td>
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<td>• Mathematics for physicists, Introduction to quantum theory</td>
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Seminar to Advanced quantum theory (Seminar zu Fortgeschrittene Quantentheorie)
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Regularity: Summer semester

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

Fundamental literature:
- W. Greiner and J. Reinhardt, *Theoretische Physik 7 (Quantenelektrodynamik) und 7a (Feldquantisierung)*, Springer
- J.J. Sakurai, *Modern Quantum Mechanics*, Addison Wesley
- F. Schwabl, *Quantenmechanik für Fortgeschrittene*, Springer

Recommended knowledge:
- Mathematics for physicists

Module affiliation:
- Modern aspects of physics
- Selected themes of modern physics
- Seminar

Introduction to electronic measurement data acquisition and processing with LabView (with practical parts)
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<th>Credit points:</th>
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Regularity: Summer semester

Competence:

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

Content:

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

Fundamental literature:

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

Recommended knowledge:

- Lecture Mechanics und Relativity and Electricity

If applicable, admission prerequisites and limited number of participants:

20 participants, registration via Stud.IP

Module affiliation:

- Modern aspects of physics
- Selected themes of modern physics
- Electronics and measurement technology
- Scientific-technical elective area of Meteorology
## Computer physics (Computerphysik)

<table>
<thead>
<tr>
<th>Courses (SWS)</th>
<th>Credit points:</th>
<th>Responsibility</th>
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<tbody>
<tr>
<td>2+2</td>
<td>6</td>
<td>Institut for Theoretical Physics</td>
</tr>
</tbody>
</table>

**Regularity:** Winter or summer semester

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

**Fundamental literature:**
- Wolfgang Kinzel und Georg Reents, „Physik per Computer“, Spektrum Akademischer Verlag
- S.E. Koonin and D.C. Meredith, „Computational Physics“, Addison-Wesley
- Tao Pang, „An Introduction to Computational Physics“, Cambridge University Press
- S. Brandt, „Datenaanalyse“, Spektrum Akademischer Verlag
- V. Blobel und E. Lohrmann, „Statistische und numerische Methoden der Datenanalyse“, Teubner Verlag

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

**Module affiliation:**
- Modern aspects of physics
- Scientific-technical elective area
- Selected themes of modern physics
### Theoretical solid-state physics (Theoretische Festkörperphysik)

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<tr>
<th>Courses (SWS)</th>
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<tr>
<td>3+1</td>
<td>5</td>
<td>Institut for Theoretical Physics</td>
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</tbody>
</table>

**Regularity:** Winter or summer semester

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

**Fundamental literature:**
- C. Kittel, *Quantum Theory of Solids*, Wiley
- W. Nolting, *Quantentheorie des Magnetismus, Band I + II*, Teubner Verlag

**Recommended knowledge:**
- Advanced Quantum Theory
- Quantum Field Theory

**Module affiliation:**
- Selected Topics of Modern Physics
## Statistical field theory (Statische Feldtheorie)

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<th>Courses (SWS)</th>
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<tbody>
<tr>
<td>3+1</td>
<td>5</td>
<td>Institut für Theoretische Physik</td>
</tr>
</tbody>
</table>

**Regularity:** Winter or summer semester

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

**Fundamental literature:**
- D. J. Amit & V. Martin-Mayor: *Field theory, the renormalization, group, and critical phenomena* (World Scientific 2005)

**Recommended knowledge:**
- Advanced Quantum Theory
- Advanced Quantum Theory
- Quantum Field Theory

**Module affiliation:**
- Selected Topics of Modern Physics
### Seminar to Theorie of condensed matter

**Seminar zu Theorie der kondensierten Materie**

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<th>Courses (SWS)</th>
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<td>2</td>
<td>3</td>
<td>Institut für Theoretische Physik</td>
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</table>

**Regularity:** Winter or summer semester

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

**Fundamental literature:**

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

**Recommended knowledge:**
- Advanced Quantum Theory
- Quantum Field Theory

**Module affiliation:**
- Selected Topics of Modern Physics
- Seminar
# Advanced computational physics (Fortgeschrittene Computerphysik)

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<th>Courses (SWS)</th>
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<td>4+2</td>
<td>8</td>
<td>Institut for Theoretical physics</td>
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</table>

**Regularity:** Winter or summer semester

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

**Fundamental literature:**
| Current problems of the theory of condensed matter theory  
(Aktuelle Probleme der Theorie der kondensierten Materie) |
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<tr>
<td><strong>Courses (SWS)</strong></td>
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<td><strong>Regularity:</strong> Winter or summer semester</td>
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<tr>
<td><strong>Content:</strong></td>
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<tr>
<td>Current topics at the teacher’s option:</td>
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<tr>
<td>• Theory of magnetism</td>
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<tr>
<td>• Theory of superconductivity</td>
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<tr>
<td>• Theory of the quantum Hall effect</td>
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<tr>
<td>• Theory of strongly correlated electrons</td>
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<tr>
<td>• Integrable quantum systems</td>
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<tr>
<td>• Systems out of equilibrium</td>
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<tr>
<td><strong>Fundamental literature:</strong></td>
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<tr>
<td><strong>Recommended knowledge:</strong></td>
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<tr>
<td>• Advanced Quantum Theory</td>
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<tr>
<td>• Advanced Solid State Physics</td>
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<tr>
<td><strong>Module affiliation:</strong></td>
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<tr>
<td>• Selected Topics of Modern Physics</td>
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</table>
### Theory of fundamental interactions (Theorie der fundamentalen Wechselwirkung)

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</table>

**Regularity:** Winter or summer semester

**Content:**

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

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

**Fundamental literature:**

- Peskin, Schröder, *Quantum Field Theory*, Westview Press
- Green, Schwarz, Witten, *Superstring Theory*, Cambridge University Press
- und aktuelle Forschungspublikationen

**Recommended knowledge:**

- Advanced quantum theory

**Module affiliation:**

- Selected Topics of Modern Physics
Seminar to Theory of fundamental interactions
(Seminar zu Theorie der fundamentalen Wechselwirkung)

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</table>

Regularity: Winter or summer semester

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

Fundamentale literature:
- Peskin, Schröder, *Quantum Field Theory*, Westview Press
- Green, Schwarz, Witten, *Superstring Theory*, Cambridge University Press
- und aktuelle Forschungspublikationen

Recommended knowledge:
- Advanced Quantum Theory

Module affiliation:
- Selected Topics of Modern Physics
- Seminar
### Addition to classical physics (Ergänzungen zur klassischen Physik)

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</table>

**Regularity:** Winter or summer semester

**Content:**

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

- **General Relativity:** Minkowski space, Lorentz group, its representations, relativistic particles, coupling to the electromagnetic field, Liénard-Wiechert potentials, Schwarzschild metric, tests of General Relativity in the solar system, Thirring-Lense effect, deflection of light, Einstein-Hilbert action, covariant energy-momentum conservation, gravitational waves: generation and detection, cosmology

- **Gauge Theories:** Parallel transport, covariant derivative, field strength, holonomy group, Bianchi identities, action principle, Noether identities, algebraic Poincaré lemma, the Standard Model of fundamental interactions, monopoles, spontaneous symmetry breaking, BRS(T) symmetry, anomalies

- **Integrable and Chaotic Motion:** Hamiltonian equations of motion, canonical transformations, Poincaré's integral invariants, action-angle variables, perturbation theory, Kolmogorov-Arnol'd-Moser theorem, Poincaré recurrence, Birkhoff's fixpoint theorem, self-similar Hamiltonian flow

**Fundamental literature:**

- J. Moser, *Stable and Random Motion in Dynamical Systems*, Princeton University Press

**Recommended knowledge:**

- Analytical Mechanics and Special Relativity

**Module affiliation:**

- Modern Aspects of Physics
- Selected Topics of Modern Physics
### Introduction to Particle Physics (Einführung in die Teilchenphysik)

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<td>Institut for Theoretical physics</td>
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</tbody>
</table>

**Regularity:** Summer semester

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

**Fundamental literature:**
- F. Halzen und A.D. Martin, *Quarks and Leptons*, Wiley
- B.R. Martin and G. Shaw, *Particle Physics*, Wiley
- E. Lohrmann, *Hochenergiephysik*, Teubner Verlag
- C. Berger, *Elementarteilchenphysik*, Springer

**Recommended knowledge:**

**Module affiliation:**
- Modern aspects of physics
- Selected topics of modern physics
## Solid state physics in lower dimensions

*(Festkörperphysik in niedrigen Dimensionen)*

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</table>

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

### Fundamental literature:
- Roth, Carroll, *One-dimensional metals*, VCH
- I. Markov, *Crystal growth for beginners*, World Scientific

### Recommended knowledge:
- Introduction to the solid state physics

### Module affiliation:
- Modern Aspects of Physics
- Selected Topics of Modern Physics
### Surface physics (Oberflächenphysik)

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<th>Courses (SWS)</th>
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<td>Institut for Solid state physics</td>
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</table>

**Regularity:** Summer semester

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

**Fundamental literature:**
- M. Henzler, M. Göpel, *Oberflächenphysik des Festkörpers*, Teubner
- Ph. Hoffmann, Wiley

**Recommended knowledge:**
- Introduction to Solid State Physics
- Advanced Solid State Physics

**Module affiliation:**
- Selected Topics of Modern Physics
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<td>5</td>
<td>Institut for Solid state physics</td>
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</tbody>
</table>

**Regularity:** Summer semester

**Content:**
- Generation of low-dimensional structures, epitaxy
- Electronic properties in 0 to 2 dimensions
- Consequences of electron correlation
- Resonant electronic devices
- Magnetic properties
- One-dimensional chains: dispersion, instabilities defects
- Solitons
- Superconductivity on strongly anisotropic systems
- Charge and spin density waves

**Fundamental literature:**
- Roth, Carroll, *One-dimensional metals*, VCH
- Bovensiepen, Wolf

**Recommended knowledge:**
- Introduction to Solid State Physics

**Module affiliation:**
- Selected Topics of Modern Physics
- Modern Aspects of Physics
### Seminar From the atom to the solid (Seminar zu Vom Atom zu Festkörper)

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<td>3</td>
<td>Institut für Festkörperphysik</td>
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</table>

**Regularity:** Summer semester

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

**Fundamental literature:**
- Roth, Carroll, *One-dimensional metals*, VCH
- I. Markov, *Crystal growth for beginners*, World Scientific

**Recommended knowledge:**
- Introduction to Solid State Physics

**Module affiliation:**
- Selected Topics of Modern Physics
- Seminar
## Semiconductor Physics (Halbleiterphysik)

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<td>2+1</td>
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<td>Institut for Solid state physics</td>
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</table>

**Regularity:** Winter semester

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

**Fundamental literature:**

**Recommended knowledge:**
- Introduction to Solid State Physics

**Module affiliation:**
- Selected Topics of Modern Physics
Semiconductor measurement technology in photovoltaics  
(Halbleitermesstechnik in der Photovoltaik)

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Regularity: Winter semester

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

- **Materials characterization**: conductivity, charge carrier density, charge carrier lifetime (photoluminescence, photoconductivity, thermography), defects (deep level transient spectroscopy, charge carrier lifetime spectroscopy, infrared spectroscopy), crystal orientation (electron back scattering diffraction)
- **Process characterization**: doping profile (electrochemical capacitance voltage profiling), texturing (scanning electron microscope, reflection), charge carrier lifetime (photoluminescence, photoconductivity, thermography), layer thickness and refractive index (ellipsometry, infrared spectroscopy)
- **Solar cell characterization**: current-voltage-curve, quantum efficiency, reflection, shunt analysis (thermography), series resistive (transmission line method, Photolumineszenz)

Fundamental literature:
- Bergmann, Schaefer, Lehrbuch der Experimentalphysik Bd. 6: Festkörper, de Gruyter (1992)

Recommended knowledge:
- Introduction to solid state physics
- Semiconductor physics
- Physics of solar cells

Module affiliation:
- Selected Topics of Modern Physics
- Modern Aspects of Physics
## Scanning Probe Technology (Rastersondentechnik)

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<td>2</td>
<td>Institut for Solid state physics</td>
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</table>

**Regularity:** Winter semester

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

**Fundamental literature:**
- E. Meyer; H. J. Hug, R. Bennewitz, *Scanning probe microscopy: the lab on a Tipp*, Springer

**Recommended knowledge:**
- Introduction to solid state physics

**Module affiliation:**
- Selected Topics of Modern Physics
- Modern Aspects of Physics
**Molecular electronics (Molekulare Elektronik)**

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<td>Institut for Solid state physics</td>
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</table>

**Regularity:** Summer semester

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

**Fundamental literature:**
- J. Tour, *Molecular electronics*, World scientific 2002

**Recommended knowledge:**
- Introduction to solid state physics

**Module affiliation:**
- Selected Topics of Modern Physics
- Modern Aspects of Physics
### Methods of surface analysis (Methoden der Oberflächenanalytik)

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<td>Institut for Solid state physics</td>
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</table>

**Regularity:** Summer semester

**Content:**
- Vacuum techniques and sample preparation
- Methods for chemical analysis: XPS, UPS, AES, EELS, ISS, TDS, ESD
- Determination of the geometric structure: STM, AFM, FIM, LEED, SEM
- Analysis of the electron structure: UPS, XPS, IPESD, NEXAFS

**Fundamental literature:**
- Springer Series in Surface Science

**Recommended knowledge:**
- Introduction to solid state physics

**Module affiliation:**
- Selected Topics of Modern Physics
- Modern Aspects of Physics
| Laboratory internship Methods of surface analysis  
| (Laborpraktikum Methoden der Oberflächenanalytik) |
|---|---|---|
| Courses (SWS) | Credit points: | Responsibility |
| 3 | 3 | Institut for Solid state physics |
| Regularity: Summer semester |
| Content: |
| Appropriate experiments, e.g. XPS, UPS, LEED, EELS, STM, AFM. The lab course should be attended together with the Surface Science lecture. |
| Fundamental literature: |
| 📖 H. Bubert, H. Jenett, *Surface and Thin Film Analysis*, Wiley-VCH |
| 📖 Springer Series in Surface Science |
| Recommended knowledge: |
| • Introduction to Solid State Physics |
| Module affiliation: |
| • Selected Topics of Modern Physics |
| • Modern Aspects of Physics |
# Physics in nanostructures (Physik der Nanostrukturen)

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<th>Courses (SWS)</th>
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<td>5</td>
<td>Institute for Solid State Physics</td>
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</table>

**Semester:** not regular

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

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

**Recommended knowledge:**
- Introduction to solid state physics
- Surface physics

**Module affiliation:**
- Modern Aspects of Physics
- Selected Topics of Modern Physics
## Optical spectroscopy of solids (Optische Spektroskopie von Festkörpern)

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<td>Institute for Solid state physics</td>
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</table>

**Semester:** Winter semester

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

**Fundamental literature:**

**Recommended knowledge:**
- Introduction to Solid State Physics

**Module affiliation:**
- Selected Topics of Modern Physics
Quantum structure devices (Quantumstrukturbauelemente)

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<td>Institute for Solid State Physics</td>
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</table>

Semester: Summer semester

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

Fundamental literature:
- C. Weisbuch, B. Vinter, *Quantum Semiconductor Structures*, Academic Pr Inc

Recommended knowledge:
- Introduction to solid state physics
- Advanced solid state physics

Module affiliation:
- Selected Topics of Modern Physics
**Physics of solar cells (Physik der Solarzellen)**

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<td>Institute for Solid State Physics</td>
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</table>

**Semester:** Summer semester

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

**Fundamental literature:**
- P. Würfel, „Physik der Solarzellen“ (Spektrum Akademischer Verlag, 2000).

**Recommended knowledge:**
- Introduction to Solid State Physics

**Module affiliation:**
- Modern Aspects of Physics
- Selected Topics of Modern Physics
Introduction to electronic measurement data acquisition and processing with LabView
(with practical parts)

(Einführung in die elektronische Messdatenerfassung und –verarbeitung mit LabView
(mit praktischen Teilen)

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

Semester: Summer semester

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

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

Recommended knowledge:
- Module „Mechanics and relativity” and “Electricity”

Module affiliation:
- Modern aspects of physics
- Selected topics of modern physics
- Elektronics and Measuring technology
- Scientific-technical elective area Meteorology
- Selected topics of nanoelectronics
- Elective course in the master Nanotechnology
### Laboratory internship Solid state physics  
**(Laborpraktikum Festkörperphysik)**

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<td>Institute for Solid State Physics</td>
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</table>

**Semester:** Winter and summer semester

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

**Fundamental literature:**
will be given during the course

**Recommended knowledge:**
- Introduction to Solid State Physics

**Module affiliation:**
- Selected Topics of Modern Physics
# Seminar Current research topics of the solid state physics

(Seminar Aktuelle Forschungsthemen der Festkörperphysik)

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<tr>
<th>Courses (SWS)</th>
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<th>Responsibility</th>
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<tbody>
<tr>
<td>2</td>
<td>3</td>
<td>Institute for Solid State Physics</td>
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</tbody>
</table>

Semster: Summer semester

**Content:**

Problems of the current Research, e.g. from the topics:
- Ultrathin metallic layers
- Phase transitions in two dimensions
- Molecular electronics
- Defect analysis in silicon wafers
- Isolator epitaxie
- Nanostructured metal/isolator system
- Electron-beam lithography
- Structuring of semiconductor components with atomic force microscope
- Resonant tunnel through InAs quantum dots
- High frequency experiments in quantum hall effect
- Electron-phonon-correlation in quantum hall systems
- Transport experiments in Si/SiGe heterostructure
- Noises in low dimensional electronic system
- Spintronics in semiconductors
- Optics in quantum hall regime

**Fundamental literature:**

Will be announced to every topic

**Recommended knowledge:**

- Advanced solid state physics

**Module affiliation:**

- Seminar
## Thermodynamics, kinetics and structure of defect semiconductors

*(Thermodynamik, Kinetik und Struktur von Defekten in Halbleitern)*

<table>
<thead>
<tr>
<th>Courses (SWS):</th>
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<td>2</td>
<td>Institut for Solid State Physics</td>
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</table>

### Content:

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

### Fundamental literature:

- to be announced in class

### Recommended knowledge:

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

### Module affiliation:

- Selected topics of modern physics
# Physics in nanostructure (Physik in Nanostrukturen)

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<tr>
<th>Courses (SWS)</th>
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<td>2+1</td>
<td>4</td>
<td>Institut for Solid state physics</td>
</tr>
</tbody>
</table>

Regularity: Summer semester

Content:
- Fabrication of nanostructures by lithography and self-assembly
- Electronic structure, interface states
- Quantum size effects
- Transport signatures in mesoscopic systems
- Magnetoresistance effects
- Quantum effect, i.a. in graphs
- Instabilities of 1-dimensional structures
- Single-electron transistors
- Molecular electronics
- Experimental methods

Fundamental literature:
- *Crystal Growth for Beginners*, Ivan V Markov (World Scientific)
- *Surface Science: An Introduction*, Philip Hofmann (kindle.edition)
- *Nanoelectronics and Information Technology*, Rainer Waser (Wiley)

Recommended knowledge:
- Introduction to Solid state physics
- Surface physics

Module affiliation:
- Modern aspects of physics
- Selected topics of modern physics
## Nonlinear Optics (Nicht lineare Optik)

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<th>Courses (SWS)</th>
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<tr>
<td>3+1</td>
<td>5</td>
<td>Institute of Quantum Optics</td>
</tr>
</tbody>
</table>

**Semester:** Summer semester

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

**Fundamental literature:**
- Dmitriev, *Handbook of nonlinear crystals*, Springer
- Originalliteratur

**Recommended knowledge:**
- Atom and molecular physics

**Module affiliation:**
- Modern Aspects of Physics
- Selected Topics of Modern Physics
## Photonics (Photonik)

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<td>2+1</td>
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<td>Institute of Quantum Optics</td>
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</table>

**Semester:** Winter semester

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

**Fundamental literature:**
- [Saleh, Teich: Photonics, Wiley](#)
- [Boyd: Nonlinear Optics, Academic Press](#)
- [Original literature](#)

**Recommended knowledge:**
- Coherent Optics
- Nonlinear Optics

**Module affiliation:**
- Selected topics of modern physics
- Selected topics of photonics

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## Seminar Photonics (Seminar Photonik)
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<td>3</td>
<td>Institute of Quantum Optics</td>
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</table>

**Semester:** Winter semester

**Content:**
According to discussion with lecturers. The seminar has to be chosen in combination with the lecture Photonics.

**Fundamental literature:**
- Saleh, Teich: Photonics, Wiley;
- Original literature

**Recommended knowledge:**
- Coherent Optics
- Nonlinear Optics
## Atom optics (Atomoptik)

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<td>2+1</td>
<td>4</td>
<td>Institute of Quantum Optics</td>
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</table>

**Semester:** Summer semester

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

**Fundamental literature:**
- Original research publications Aktuelle Publikationen

**Recommended knowledge:**
- Atomic and molecular physics Atom- und Molekülphysik
- Quantum optics Quantenoptik

**Module Affiliation:**
- Selected Topics of Modern Physics
- Selected topics of photonics
# Laboratory internship optics (Laborpraktikum Optik)

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<th>Courses (SWS)</th>
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<td>6</td>
<td>Institute of Quantum Optics</td>
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</table>

**Semester:** Winter and summer semester

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

**Fundamental literature:**
Will be specified in the lab course

**Recommended knowledge:**
- Coherent optics

**Module affiliation:**
- Modern aspects of physics
- Selected topics of modern physics
## Solid state lasers (Festkörperlaser)

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<td>Institute for Quantum Optics</td>
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</table>

**Semester:** Summer semester

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

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

**Recommended knowledge:**
- Coherent Optics or Nonlinear optics

**Module affiliation:**
- Selected Topics of Modern Physics
### Optical layers (Optische Schichten)

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<td>Institute of Quantum Optics</td>
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</table>

**Semester:** Winter semester

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

**Fundamental literature:**
- Will be announced during the lecture

**Recommended knowledge:**
- Lectures „Coherent optics“ or „Nonlinear optics“

**Module affiliation:**
- Selected Topics of Modern Physics
## Data Analysis

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<td>2</td>
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<td>Institute for Gravitational Physics</td>
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</tbody>
</table>

**Semester:** Summer semester

**Content:**
- Detectors (interferometer and „resonant mass“ detectors)
- Data analysis
- Templates
- vetoes

**Fundamental literature:**
to be announced in class

**Recommended knowledge:**
- Basics of special relativity theory
- Coherent optics

**Module affiliation:**
- Selected Topics of Modern Physics
## Neutron Stars und Black Holes

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<td>Institute for Gravitational Physics</td>
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</tbody>
</table>

**Semester:** Summer semester

**Content:**
- Sources and expansion of gravitational waves
- Neutron stars and Black Holes

**Fundamental literature:**
to be announced in class

**Recommended knowledge:**
- Basics of special relativity theory
- Coherent optics

**Module affiliation:**
- Selected Topics of Modern Physics
### Seminar Gravitational waves (Seminar Gravitationswellen)

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<tr>
<th>Courses (SWS)</th>
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<td>2</td>
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<td>Institute for Gravitational Physics</td>
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</table>

**Semester:** Summer semester

**Content:**
In agreement with the professor

**Fundamental literature:**
to be announced in lecture class and course

**Recommended knowledge:**
- Basics of special relativity theory
- Coherent optics

**Module affiliation:**
- Selected Topics of Modern Physics
<table>
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<tr>
<th>Course Area</th>
<th>Description</th>
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<td>Courses (SWS)</td>
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<td>Credit points (ECTS)</td>
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<tr>
<td>Responsibility</td>
<td>Institute for Gravitational Physics (Institut für Gravitationsphysik)</td>
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<tr>
<td>Regularity</td>
<td>Summer semester and Winter semester</td>
</tr>
<tr>
<td>Content</td>
<td>• General Theory of relativity</td>
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<td></td>
<td>• Sources of Gravitational waves</td>
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<td></td>
<td>• Gravitational waves detectors</td>
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<td></td>
<td>• Astrophysics and cosmology</td>
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<tr>
<td>Fundamental Literature</td>
<td>to be announced in class</td>
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<tr>
<td>Recommended knowledge</td>
<td>• Gravitational Physics</td>
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<tr>
<td>Module Affiliation</td>
<td>• Selected Topics of Modern Physics</td>
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<td>• Seminar</td>
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Laser Interferometry (Laserinterferometrie)

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<td>3</td>
<td>Institute for Gravitational Physics</td>
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</table>

Semester: Summer or winter semester (irregular)

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

Fundamental literature:
- Siegman: *Lasers*
- Yariv: *Quantum Electronics*

Recommended knowledge:
Optics, complex linear algebra

Module affiliation:
- Selected Topics of Modern Physics
### Laboratory internship Laser interferometry (Laborpraktikum Laserinterferometrie)

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<td>4</td>
<td>Institute for Gravitational Physics</td>
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</table>

**Regularity:** Summer or winter semester (irregular)

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

**Fundamental literature:**

2. Originalliteratur

**Recommended knowledge:**
- Coherent optics
- Nonlinear optics

**Module affiliation:**
- Selected Topics of Modern Physics
# Laser stabilization and control of optical experiments

(Laserstabilisierung und Kontrolle optischer Experimente)

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<tr>
<th>Courses (SWS)</th>
<th>Credits:</th>
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<td>Institute for Gravitational Physics</td>
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</table>

Semester: winter or summer semester (irregular)

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

Fundamental literature:
- Optical electronics in modern communications; Yariv, Amnon; New York, Oxford Univ. Press; (1997); ISBN 0195106261 (cl)
- Feedback control systems: a fast-track guide for scientists and engineers; Abramovici, Alex (Chapsky, Jake); Boston, Kluwer Acad. Publ; (2000); ISBN 0792379357

Recommended knowledge:
- coherent optics

Module affiliation:
- special topics of modern physics
### Laboratory internship Cluster Computing (Laborpraktikum Cluster Computing)

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<th>Courses (SWS)</th>
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<td>4</td>
<td>Institut for Gravitational physics</td>
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</tbody>
</table>

**Semester:** Summer and winter semester

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

**Fundamental literature:**

- 📖 To be announce in the class

**Recommended knowledge:**
- Experience with Linux

**Module affiliation:**
- Modern aspects of physics
- Selected topics of modern physics
### Nonclassic light (Nichtklassisches Licht)

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<td>2</td>
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<td>Institute for Gravitational Physics</td>
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</table>

**Semester:** Winter semester (irregular)

**Content:**
- classical and non-classical states of light
- criteria for "non-classicity"
- detection and generation of Fock states
- detection and generation of squeezed light
- quantum state tomography
- EPR entangled (two-mode squeezed) light
- optical test of non-locality

**Fundamental literature:**

**Recommended knowledge:**
- coherent optics
- non-linear optics
- non-classical light
- quantum optics

**Module affiliation:**
- Selected Topics of Modern Physics
# Nonclassic laser interferometry (Nichtklassische Laserinterferometrie)

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<th>Courses (SWS)</th>
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<td>5</td>
<td>Institute for Gravitational Physics</td>
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</tbody>
</table>

Semester: Summer semester (irregular)

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

**Fundamental literature:**
- Original literature

**Recommended knowledge:**
- coherent optics
- non-linear optics
- non-classical light
- quantum optics

**Module affiliation:**
- Selected Topics of Modern Physics
# Electronic metrology in the optics laboratory

*(Elektronische Metrologie im Optiklabor)*

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<td>Institute for Gravitational Physics</td>
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</tbody>
</table>

**Semester:** summer or winter semester (irregularly)

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

**Fundamental literature:**
- Yariv, *Quantum Electronics*, Wiley
- Primary literature (given in lecture)

**Recommended knowledge:**
- Coherent optics

**Module affiliation:**
- Selected Topics of Modern Physics
# Nuclear physics and nuclear chemistry of radiation protection and radioecology

(Kernphysikalische und kernchemische Grundlagen des Strahlenschutzes und der Radioökologie)

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<td>Institute for Radioecology and Radiation Protection</td>
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</table>

**Semester:** Winter semester

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

**Fundamental literature:**
- http://www.nucleonica.com/: Karlsruhe Chart of Nuclides

**Recommended knowledge:**
- Mechanics / Quantum Mechanics
- Electrodynamics
- Molecules, Nuclei, Particles, Statistics

**Module Affiliation:**
- Modern Aspects of Physics
- Selected Topics of Modern Physics
## Nuclear energy and fuel cycle, technical aspects and public discourse
*(Kernenergie und Brennstoffkreislauf, technische Aspekte und gesellschaftlicher Diskurs)*

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<td>Institute for Radioecology and Radiation Protection</td>
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</table>

**Semester:** Winter semester

**Content:**

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

**Fundamental literature:**

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

**Recommended knowledge:**

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

**Module affiliation:**

- Modern Aspects of Physics
- Selected Topics of Modern Physics
## Radioactivity in the environment and radiation hazard to humans
(Radioaktivität in der Umwelt und Strahlengefährdung des Menschen)

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<td>Institute for Radioecology and Radiation Protection</td>
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</table>

**Regularity:** Summer semester

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

**Fundamental literature:**
- Richard Rhodes, *The making of the Atomic Bomb*
- Warner, Kirchmann *Nuclear Test Explosions*
- Eisenbud, *Environmental Radioactivity*
- Further literature announced and provided in the lecture (original papers and web links)

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

**Module affiliation:**
- Modern Aspects of Physics
- Selected Topics of Modern Physics
Radiation Protection and Radioecology (Strahlenschutz und Radioökologie)

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

Regularity: Summer semester

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

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

Fundamental literature:
- Allgemeine Verwaltungsvorschrift zu § 47 Strahlenschutzverordnung: *Ermittlung der Strahlenexposition durch die Ableitung radioaktiver Stoffe aus Anlagen oder Einrichtungen*, Drucksache 88/12 15.02.12
- Additional literature to be announced in the lecture

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

Module affiliation:
- Modern Aspects of Physics
- Selected Topics of Modern Physics
### Nuclear radioanalytical techniques (Nukleare Radioanalytische Techniken)

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</table>

**Regularity:** Winter semester

**Content:**

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

**Fundamental literature:**

- Knoll, Radiation detection and measurement, J. Wiley & Sons, New York, 2000
- Http://www.nucleonica.com/: Karlsruhe Chart of Nuclides

**Recommended knowledge:**

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

**Module Affiliation:**

- Modern Aspects of Physics
- Selected Topics of Modern Physics
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<th>Courses (SWS)</th>
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<td>2</td>
<td>2</td>
<td>Institute for Radioecology and Radiation Protection</td>
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</table>

**Regularity:** Summer semester

**Content:**

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

**Fundamental literature:**

- Davis, *Meteorites, Comets and Planets*
- [Http://www.nucleonica.com/](http://www.nucleonica.com/) : Karlsruhe Chart of Nuclides

**Recommended knowledge:**

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

**Module affiliation:**

- Modern Aspects of Physics
- Selected Topics of Modern Physics
Radiochemistry and radioanalysis (Radiochemie und Radioanalytik)

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<td>Institut for Radioecology and Radiation protection</td>
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</table>

Regularity: Winter semester

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

Fundamental literature:

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

Module affiliation:
- Selected topics of modern physics
### Introduction to radioecology and radiation protection

(Einführung in die Massenspektrometrie)

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<td>Institut für Radioökologie und Strahlenschutz</td>
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**Regularity:** Winter semester

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

**Fundamental literature:**

**Recommended knowledge:**
- Mechanics
- Elektrodynamics
- Optics, nuclear physics, quantum phenomena

**Module affiliation:**
- Selected topics of modern physics
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<td>Institute for Radioecology and Radiation Protection</td>
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Semester: Winter and summer semester

Content:
To be arranged with the lecturer

Fundamental literature:
- Will be provided according to topic

Recommended knowledge:
- Lecture “Basics of radioecology and radiation protection: Nuclear Physics and Nuclear Chemistry Aspects”

Module affiliation:
- Modern Aspects of Physics
- Selected Topics of Modern Physics
**Expertise in radiation protection (acc. to StrSchV)**

*(only in German language)*

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<td>Institute for Radioecology and Radiation Protection</td>
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**Semester:** Winter and summer semester

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

**Fundamental literature:**
- [Röntgenverordnung](http://www.gesetze-im-internet.de/rsv/)

**Recommended knowledge:**
- Mechanic and Relativity
- Electricity
- Optics, Atom physics, Quantum phenomenas
- Molecules, cors, Particals, Solid State

**Module affiliation:**
- Modern Aspects of Physics
- Selected Topics of Modern Physics
### Courses in Meteorology

#### Numerical weather forecast (Numerische Wettervorhersage)

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<td>Institut for Meteorology and Climatology</td>
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**Regularity:** Summer semester

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

**Fundamental literature:**
- Roache, *Computational Fluid Dynamics*, Hermosa Publishers

**Recommended knowledge:**
- Introduction to meteorology
- Kinematics and dynamics

**Module affiliation:**
- Elective area Meteorology
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology C
- Bachelor and Master Physics
### Programming internship to Numerical weather forecast

(Pro grammierpraktikum zur Numerischen Wettervorhersage)

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**Regularity:** Winter semester

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

**Fundamental literature:**
- Etling, D.: *Theoretische Meteorologie*, Springer
- Roache, *Computational Fluid Dynamics*, Hermosa Publishers

**Recommended knowledge:**
- Applied programming
- Numerical weather forecast
- Kinematics and dynamics

**Module affiliation:**
- Wahlmodul Meteorologie
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology C
- Bachelor and Master Physics
### Pollutant spread in the atmosphere (Schadstoffausbreitung in der Atmosphäre)

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**Regularity:** Winter semester

**Content:**
- Effects of air pollution on living and inanimate nature.
- Mathematical Propagation Models (Gaussian Model, Euler Model, Lagrangian Particle Model).
- Air monitoring (limit and assessment values, TA-Luft).
- Selected problems of air pollution control (ozone, smog, acid rain, spreading in street canyons).

**Fundamental literature:**

**Recommended knowledge:**
- Introduction to the meteorology
- Kinematics and dynamics
- Turbulence and diffusion

**Module affiliation:**
- Elective module Meteorology
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology C
- Bachelor and Master Physics
# Turbulence II (Turbulenz II)

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**Regularity:** Winter semester

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

**Fundamental literature:**

* Wyngaard, Turbulence in the Atmosphere, Cambridge University Press

**Recommended knowledge:**
- Kinematics and dynamics
- Turbulence and diffusion

**Module affiliation:**
- Elective area Meteorology
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology C
- Bachelor and Master Physics
**Atmospheric convection (Atmosphärische Konvektion)**

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<td>Institut for Meteorology and Climatology</td>
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**Regularity:** Winter semester

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

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

**Recommended knowledge:**
- Thermodynamics and Statics
- Kinematics and dynamics
- Turbulence and diffusion

**Module affiliation:**
- Elective area Meteorology
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology B
- Bachelor and Master Physics
# Programming internship to Simulation of atmospheric boundary layers  
*(Programmierpraktikum zur Simulation der atmosphärischen Grenzschicht)*

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**Regularity:** Summer or winter semester

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

**Fundamental literature:**
- Etling, D.: *Theoretische Meteorologie*, Springer
- Roache, *Computational Fluid Dynamics*, Hermosa Publishers

**Recommended knowledge:**
- Applied programming
- Kinematics and dynamics
- Turbulence and diffusion
- Numerical weather forecast
- Atmospheric boundary layers and convection

**Module affiliation:**
- Elective area Meteorology
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology C
- Bachelor and Master Physics
# Simulation of turbulent flows with LES Models

**Simulation turbulenter Strömungen mit LES-Modellen**

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<td>Institut for Meteorology and Climatology</td>
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**Regularity:** Summer semester

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

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

**Recommended knowledge:**
- Turbulence and diffusion
- Numerical weather forecast
- Atmospheric boundary layers and convection
- Programming practical to numerical weather forecast

**Module affiliation:**
- Elective area Meteorology
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology C
- Bachelor and Master Physics
Numerical internship to Simulation of turbulent flows with LES Models  
(Numerisches Praktikum zur Simulation turbulenter Strömungen mit LES-Modellen)

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Regularity: Block event at the end of the summer semester

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

Fundamental literature:
- Fröhlich, J.: *Large Eddy Simulation turbulenter Strömungen*, Springer
- Roache: *Computational Fluid Dynamics*, Hermosa Publishers
- Sagault, P: *Large Eddy Simulation for Incompressible Flows*, Springer

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

Module affiliation:
- Elective area Meteorology
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology C
- Bachelor and Master Physics
### Agriculture meteorology (Agrarmeteorologie)

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<td>Institut for Meteorology and Climatology</td>
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</table>

**Regularity:** Summer semester

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

**Fundamental literature:**
Lecture notes

**Recommended knowledge:**
- Introduction to meteorology

**Module affiliation:**
- Elective area Meteorology
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology C
- Bachelor Geography
- Bachelor and Master Physics
# Local climates (Lokalklimate)

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**Regularity:** Winter semester

**Content:**
- The climate of the ground-level air layer
- The climate of the city
- Local climate forest
- Local climate water and coast
- The climate in orographically structured terrain

**Fundamental literature:**
Lecture notes

**Recommended knowledge:**
- Introduction to meteorology

**Module affiliation:**
- Elective area Meteorology
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology C
- Bachelor Geography
- Bachelor and Master Physics
### Remote sensing I (Fernerkundung I)

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<td>Institut for Meteorology and Climatology</td>
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**Regularity:** Winter semester

**Content:**
- Basics for measurements of satellites and their application for the detection of atmospheric processes
- Remote sensing with satellite instruments. Derivation of temperature, clouds and trace gas measurements with remote sensing instruments from the satellite and the ground.
- Derivation of radiation measurements from satellite data.

**Fundamental literature:**

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

**Recommended knowledge:**
- Introduction to meteorology
- Radiation

**Module affiliation:**
- Elective area Meteorology
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology C
- Master Optical technology
- Bachelor and Master Physics
### Remote sensing II (Fernerkundung II)

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<td>Institut for Meteorology and Climatology</td>
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**Regularity:** Summer semester

**Content:**

The contribution of land-based and satellite-based remote sensing to current research topics on climate, weather and global change.

Presentation of the methods and the results.

**Fundamental literature:**

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

**Recommended knowledge:**

- Introduction to meteorology
- Radiation
- Remote sensing I

**Module affiliation:**

- Elective area Meteorology
- Selected topics of modern meteorology A
- Selected topics of modern meteorology B
- Selected topics of modern meteorology C
- Bachelor and Master Physics
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**Regularity:** Winter and summer semester

**Content:**
Advanced topics of meteorology

**Fundamental literature:**
Will be announced in the seminar.

**Recommended knowledge:**
Will be announced in the seminar.

**Module affiliation:**
- Selected topics of modern meteorology C
### Meteorological excursion II (Meteorologische Exkursion II)

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<td>Institut for Meteorology and Climatology</td>
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**Regularity:** Summer or winter semester

**Content:**
Students in the master's program meteorology can take part in the annual and regular meteorological excursion. They prepare for a thematic aspect of the excursion, explain it during the excursion and are available for discussion and contact, write a contribution to the excursion report and present it in the final seminar. The content and formal requirements of these contributions to the excursion are determined by the qualification of a completed Bachelor’s degree.

**Fundamental literature:**

**Recommended knowledge:**

**Module affiliation:**
- Selected topics of modern meteorology C
**External internship inland (Externes Praktikum Inland)**

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**Regularity:** Summer or winter semester

**Content:**
The students apply independently to an inland institution (research institution, authority, engineering office, etc.) for a meteorological four-week internship and prepare for this. After successful completion of the internship they will write a report.

**Fundamental literature:**

**Recommended knowledge:**

**Module affiliation:**
- Selected topics of modern meteorology C
## External internship abroad (Externes Praktikum Ausland)

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**Regularity:** Summer or winter semester

**Content:**
The students apply independently to a foreign institution (research institution, authority, engineering office, etc.) for a meteorological four-weeks internship and prepare for it. After successful completion of the internship they will write a report.

**Fundamental literature:**

**Recommended knowledge:**