

Module No.: physics720
Credit Points (CP):
Category: Elective
Semester: 8.

Module: Applied Physics

Module Elements:

| Nr. | Course Title | Number | CP | Type | Workload | Sem. |
|-----|--|---------------|-----|---------------|------------|-------|
| 1. | Selected 700-courses from catalogue type "A" (Applied) or "E/A" (Experimental/A) | see catalogue | 3-6 | see catalogue | 90-180 hrs | ST/WT |
| 2. | Courses from Cologne marked "A" | see catalogue | 3-8 | see catalogue | 90-240 hrs | WT/ST |
| 3. | Also possible classes from M.Sc. in Astrophysics | | | | | |

Requirements:

Preparation:

Content:

Advanced lectures in applied physics from the catalogue of selected courses

Aims/Skills:

Preparation for Master's Thesis work; broadening of scientific knowledge

Form of Testing and Examination:

If the lecture is offered with exercises: requirements for the submodule examination (written or oral examination): successful work with exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:

s. <https://basis.uni-bonn.de> u. <http://bamawww.physik.uni-bonn.de>

Note: The students must obtain 18 CP in all out of the modules physics700, -710, -720, -730.

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:

Advanced Electronics and Signal Processing (E/A)

Course No.: physics712

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English | 3+1 | 6 | ST |

Requirements:**Preparation:**

Electronics laboratory of the B.Sc. in physics programme

Recommended: module nuclear and particle physics of the B.Sc. programme

Form of Testing and Examination:

Requirements for the examination (written): successful work with the exercises

Length of Course:

1 semester

Aims of the Course:

Comprehension of the basics of electronics circuits for the processing of (detector) signals, mediation of the basics of experimental techniques regarding electronics and micro electronics as well as signal processing

Contents of the Course:

The physics of electronic devices, junctions, transistors (BJT and FET), standard analog and digital circuits, amplifiers, elements of CMOS technologies, signal processing, ADC, DAC, noise sources and noise filtering, coupling of electronics to sensors/detectors, elements of chip design, VLSI electronics, readout techniques for detectors

Recommended Literature:

P. Horowitz, W. Hill; The Art of Electronics (Cambridge University Press 2. Aufl. 1989)

S. Sze; The Physics of Semiconductor Devices (Wiley & Sons 1981)

H. Spieler, Semiconductor detector system (Oxford University Press 2005))

J. Krenz; Electronics Concepts (Cambridge University Press 2000)

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:

Particle Detectors and Instrumentation (E/A)

Course No.: physics713

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|-------------------------|----------|----------------|----|----------|
| Elective | Lecture with laboratory | English | 3+1 | 6 | ST |

Requirements:**Preparation:**

Completed B.Sc. in Physics, with experience in quantum mechanics, atomic- and nuclear physics

Form of Testing and Examination:

Requirements for the examination (written or oral): successful work with the exercises

Length of Course:

1 semester

Aims of the Course:

Designing an experiment in photoproduction on π^0 , selection and building of appropriate detectors, set-up and implementation of an experiment at ELSA

Contents of the Course:

Quark structure of mesons and baryons, nucleon excitation; electromagnetic probes, electron accelerators, photon beams, relativistic kinematics interaction of radiation with matter, detectors for photons, leptons and hadrons; laboratory course: setup of detectors and experiment at ELSA

Recommended Literature:

B. Povh, K. Rith, C. Scholz, F. Zetsche; Teilchen und Kerne (Springer, Heidelberg 6. Aufl. 2004)
 Perkins; Introduction to High Energy Physics (Cambridge University Press 4. Aufl. 2000)
 W. R. Leo; Techniques for Nuclear and Particle Detection (Springer, Heidelberg 2. Ed. 1994)
 K. Kleinknecht; Detektoren für Teilchenstrahlung (Teubner, Wiesbaden 4. überarb. Aufl. 2005)

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:

Advanced Accelerator Physics (E/A)

Course No.: physics714

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English | 3+1 | 6 | ST/WT |

Requirements:**Preparation:**

Accelerator Physics (physics612)

Form of Testing and Examination:

Requirements for the examination (written or oral): successful work with the exercises

Length of Course:

1 semester

Aims of the Course:

Understanding of the physics of synchrotron radiation and its influence on beam parameters
 Basic knowledge of collective phenomena in particle accelerators
 General knowledge of applications of particle accelerators (research, medicine, energy management)

Contents of the Course:

Synchrotron radiation:
 radiation power, spatial distribution, spectrum, damping, equilibrium beam emittance, beam lifetime
 Space-charge effects:
 self-field and wall effects, beam-beam effects, space charge dominated beam transport, neutralization of beams by ionization of the residual gas
 Collective phenomena:
 wake fields, wake functions and coupling impedances, spectra of a stationary and oscillating bunches, bunch interaction with an impedance, Robinson instability
 Applications of particle accelerators:
 medical accelerators, neutrino facilities, free electron lasers, nuclear waste transmutation, etc.

Recommended Literature:

F. Hinterberger; Physik der Teilchenbeschleuniger und Ionenoptik (Springer, Heidelberg 1997)
 H. Wiedemann; Particle Accelerator Physics (Springer, Heidelberg 2 Aufl. 1999)
 K. Wille; Physik der Teilchenbeschleuniger und Synchrotronstrahlungsquellen (Teubner, Wiesbaden 2. Aufl. 1996)
 D. A. Edwards, M.J. Syphers; An Introduction to the Physics of High Energy Accelerators (Wiley & Sons 1993)
 A. Chao; Physics of Collective Beam Instabilities in High Energy Accelerators (Wiley & Sons 1993)
 Script of the Lecture Particle Accelerators (physics612)
<http://www-elsa.physik.uni-bonn.de/~hillert/Beschleunigerphysik/>

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:

Programming in Physics and Astronomy with C++ or Python (E/A)

Course No.: physics718

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English | 2+1 | 4 | ST |

Requirements:**Preparation:**

Basic knowledge of programming and knowledge of simple C/C++ or Python constructs.

Form of Testing and Examination:

C/C++ part: Requirements for the examination (written or oral): successful work with the exercises.

Python part: Requirements for examination: successful implementation of the scientific projects in Python during the semester.

Length of Course:

1 semester

Aims of the Course:

C++ part: In-depth understanding of C++ and its applications in particle physics. Discussion of advanced features of C++ using examples from High Energy Physics. The course is intended for students with some background in C++ or for advanced students who wish to apply C++ in their graduate research.

Python part: Effective and flexible program solving with the easy-to-learn, high level programming language Python. The course addresses master and PhD students with prior Python-programming knowledge as taught in the bachelor course physics131.

Contents of the Course:

C++ part: - Basic ingredients of C++, - Object orientation: classes, inheritance, polymorphism, - How to solve physics problems with C++, - Standard Template Library, - C++ in data analysis, example: the ROOT library, - C++ and large scale calculations, - How to write and maintain complex programs, - Parallel computing and the Grid, - Debugging and profiling

Python part: - In-depth introduction to Python based on prior programming experience, - Introduction to numpy arrays (primary Python data structure for scientific computing), - Introduction to scientific-Python modules (scipy, astropy), - Interactive work / development with Python (ipython), - Web interaction with Python (jupyter notebooks, web and database queries), - Plotting with Python (the matplotlib module)

Recommended Literature:

Eckel: Thinking in C++, Prentice Hall 2000.

Lippman, Lajoie, Moo: C++ Primer, Addison-Wesley 2000.

Deitel and Deitel, C++ how to program, Prentice Hall 2007.

Stroustrup, The C++ Programming Language, Addison-Wesley 2000.

- The course is given in the summer term and alternates between C++ and Python
- The course can only be taken once for credit points.

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:**Low Temperature Physics (E/A)****Course No.:** physics731

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English | 3+1 | 6 | WT/ST |

Requirements:**Preparation:**

Elementary thermodynamics; principles of quantum mechanics; introductory lecture on solid state physics

Form of Testing and Examination:

Requirements for the examination (written or oral): successful work with the exercises

Length of Course:

1 semester

Aims of the Course:

Experimental methods at low (down to micro Kelvin) temperatures; methods of refrigeration; thermometry; solid state physics at low temperatures

Contents of the Course:

Thermodynamics of different refrigeration processes, liquefaction of gases; methods to reach low (< 1 Kelvin) temperatures: evaporation cooling, He-3-He-4 dilution cooling, Pomeranchuk effect, adiabatic demagnetisation of atoms and nuclei; thermometry at low temperatures (e.g. helium, magnetic thermometry, noise thermometry, thermometry using radioactive nuclei); principles for the construction of cryostats for low temperatures

Recommended Literature:

O.V. Lounasmaa; Experimental Principles and Methods Below 1K (Academic Press, London 1974)

R.C. Richardson, E.N. Smith; Experimental Techniques in Condensed Matter Physics at Low Temperatures (Addison-Wesley 1988)

F. Pobell, Matter and Methods at Low Temperatures (Springer-Verlag, Heidelberg 2. Aufl. 1996)

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:**Optics Lab (E/A)**

Course No.: physics732

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|------------|----------|----------------|----|----------|
| Elective | Laboratory | English | | 4 | WT/ST |

Requirements:**Preparation:****Form of Testing and Examination:**

Credit points can be obtained after completion of a written report.

Length of Course:

4-6 weeks

Aims of the Course:

The student learns to handle his/her own research project within one of the optics groups

Available projects and contact information can be found at: <http://www.iap.uni-bonn.de/opticslab/>

Contents of the Course:

Practical training/internship in a research group, which can have several aspects:

- setting up a small experiment
- testing and understanding the limits of experimental components
- simulating experimental situations

Recommended Literature:

Will be given by the supervisor

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:**Holography (E/A)**

Course No.: physics734

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|---------|----------|----------------|----|----------|
| Elective | Lecture | English | 2 | 3 | ST |

Requirements:**Preparation:****Form of Testing and Examination:**

Written or oral examination

Length of Course:

1 semester

Aims of the Course:

The goal of the course is to provide in-depth knowledge and to provide practical abilities in the field of holography as an actual topic of applied optics

Contents of the Course:

The course will cover the basic principle of holography, holographic recording materials, and applications of holography. In the first part the idea behind holography will be explained and different hologram types will be discussed (transmission and reflection holograms; thin and thick holograms; amplitude and phase holograms; white-light holograms; computer-generated holograms; printed holograms). A key issue is the holographic recording material, and several material classes will be introduced in the course (photographic emulsions; photochromic materials; photo-polymerization; photo-addressable polymers; photorefractive crystals; photosensitive inorganic glasses). In the third section several fascinating applications of holography will be discussed (art; security-features on credit cards, banknotes, and passports; laser technology; data storage; image processing; filters and switches for optical telecommunication networks; novelty filters; phase conjugation ["time machine"]; femtosecond holography; space-time conversion). Interested students can also participate in practical training. An experimental setup to fabricate own holograms is available

Recommended Literature:

Lecture notes;

P. Hariharan; Optical Holography - Principles, Techniques, and Applications (Cambridge University Press, 2nd Edition, 1996)

P. Hariharan; Basics of Holography (Cambridge University Press 2002)

J. W. Goodman; Introduction to Fourier Optics (McGraw-Hill Education - Europe 2nd Ed. 2000)

A. Yariv; Photonics (Oxford University Press 6th Ed. 2006)

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:**Crystal Optics (E/A)**

Course No.: physics736

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English | 3+1 | 6 | WT |

Requirements:**Preparation:****Form of Testing and Examination:**

Requirements for the examination (written or oral): successful work with the exercises

Length of Course:

1 semester

Aims of the Course:

Because of their aesthetic nature crystals are termed "flowers of mineral kingdom". The aesthetic aspect is closely related to the symmetry of the crystals which in turn determines their optical properties. It is the purpose of this course to stimulate the understanding of these relations. The mathematical and tools for describing symmetry and an introduction to polarization optics will be given before the optical properties following from crystal symmetry are discussed. Particular emphasis will be put on the magneto-optical properties of crystals in magnetic internal or external fields. Advanced topics such as the determination of magnetic structures and interactions by nonlinear magneto-optics will conclude the course

Contents of the Course:

Crystal classes and their symmetry; basic group theory; polarized light; optical properties in the absence of fields; electro-optical properties; magneto-optical properties: Faraday effect, Kerr effect, magneto-optical materials and devices, semiconductor magneto-optics, time-resolved magneto-optics, nonlinear magneto-optics

Recommended Literature:

R. R. Birss, Symmetry and Magnetism, North-Holland (1966)
 R. E. Newnham: Properties of Materials: Anisotropy, Symmetry, Structure, Oxford University (2005)
 A. K. Zvezdin, V. A. Kotov: Modern Magneto-optics & Magneto-optical Materials, Taylor/Francis (1997)
 Y. R. Shen: The Principles of Nonlinear Optics, Wiley (2002)
 K. H. Bennemann: Nonlinear Optics in Metals, Oxford University (1999)

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:

Lecture on Advanced Topics in Photonics (E/A)

Course No.: physics739

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English | 2+1 | 4 | WT/ST |

Requirements:**Preparation:**

Optics

Form of Testing and Examination:

Requirements for the examination (written or oral): successful work within the exercises

Length of Course:

1 semester

Aims of the Course:

The goal of the course is to introduce the students to a special field of research in photonics. New research results will be presented and their relevance is discussed.

Contents of the Course:

Will be given in the bulletin of lectures. The main theme will vary from term to term

Recommended Literature:

Will be given in the lecture

This course may be offered as "Teaching hours (3+1)" with 6 cp, as well

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:

Hands-on Seminar: Experimental Optics and Atomic Physics (E/A)

Course No.: physics740

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|------------|----------|----------------|----|----------|
| Elective | Laboratory | English | 2 | 3 | WT/ST |

Requirements:**Preparation:**

Fundamentals of optics and quantum mechanics

Form of Testing and Examination:

Credit points can be obtained after successful carrying out the experiments and preparing a written report on selected experiments

Length of Course:

1 semester

Aims of the Course:

The students learn to handle optical setups and carry out optical experiments. This will prepare participants both for the successful completion of research projects in experimental quantum optics/photonics and tasks in the optics industry.

Contents of the Course:

Practical training in the field of optics, where the students start their experiment basically from scratch (i.e. an empty optical table). The training involves the following topics:

- diode lasers
- optical resonators
- acousto-optic modulators
- spectroscopy
- radiofrequency techniques

Recommended Literature:

Will be given by the supervisor

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:**Modern Spectroscopy (E/A)**

Course No.: physics741

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English | 2+1 | 4 | WT/ST |

Requirements:**Preparation:**

Fundamentals of Optics, Fundamentals of Quantum Mechanics

Form of Testing and Examination:

Requirements for the examination (oral or written): successful work with the exercises

Length of Course:

1 semester

Aims of the Course:

The aim of the course is to introduce the students to both fundamental and advanced concepts of spectroscopy and enable them to practically apply their knowledge.

Contents of the Course:

Spectroscopy phenomena - time and frequency domain;
 high resolution spectroscopy;
 pulsed spectroscopy; frequency combs;
 coherent spectroscopy;
 nonlinear spectroscopy: Saturation, Raman spectroscopy, Ramsey spectroscopy.
 Applications of spectroscopic methods (e.g. Single molecule spectroscopy; spectroscopy at interfaces & surfaces, spectroscopy of cold atoms; atomic clocks; atom interferometry)

Recommended Literature:

W. Demtröder; Laser spectroscopy (Springer 2002)
 S. Svanberg; Atomic and molecular spectroscopy basic aspects and practical applications (Springer 2001)
 A. Corney; Atomic and laser spectroscopy (Clarendon Press 1988)
 N. B. Colthup, L. H. Daly, S. E. Wiberley; Introduction to infrared and Raman spectroscopy (Academic Press 1990)
 P. Hannafor; Femtosecond laser spectroscopy (Springer New York 2005)
 C. Rulliere; Femtosecond laser pulses: principles and experiments (Springer Berlin 1998)

Modules:

physics700 **Elective Advanced Lectures**
 physics720 **Applied Physics**

Course:

Environmental Physics & Energy Physics (A)

Course No.: physics771

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|---------|----------|----------------|----|----------|
| Elective | Lecture | English | 2 | 3 | WT |

Requirements:**Preparation:**

Physik I-V (physik110-physik510)

Form of Testing and Examination:

Active contributions during term and written examination

Length of Course:

1 semester

Aims of the Course:

A deeper understanding of energy & environmental facts and problems from physics (and, if needed, nature or agricultural science) point of view

Contents of the Course:

After introduction into related laws of nature and after a review of supply and use of various resources like energy a detailed description on each field of use, use-improvement strategies and constraints and consequences for environment and/or human health & welfare are given.

Recommended Literature:

Diekmann, B., Heinloth, K.: Physikalische Grundlagen der Energieerzeugung, Teubner 1997
 Hensing, I., Pfaffenberger, W., Ströbele, W.: Energiewirtschaft, Oldenbourg 1998
 Fricke, J., Borst, W., Energie, Oldenbourg 1986
 Bobin, J. L., Huffer, E., Nifenecker, H., L'Energie de Demain, EDP Sciences 2005
 Thorndyke, W., Energy and Environment, Addison Wesley 1976
 Schönwiese, C. D., Diekmann, B., Der Treibhauseffekt, DVA 1986
 Boeker, E., von Grondelle, R., Physik und Umwelt, Vieweg, 1997

Modules:

physics700 **Elective Advanced Lectures**
 physics720 **Applied Physics**

Course:

Physics in Medicine: Fundamentals of Analyzing Biomedical Signals (A)

Course No.: physics772

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English | 3+1 | 6 | WT |

Requirements:**Preparation:**

Elementary thermodynamics; principles of quantum mechanics, principles of condensed matter

Form of Testing and Examination:

Requirements for the examination (written or oral): successful work with the exercises

Length of Course:

1 semester

Aims of the Course:

Understanding of the principles of physics and the analysis of complex systems

Contents of the Course:

Introduction to the theory of nonlinear dynamical systems; selected phenomena (e.g. noise-induced transition, stochastic resonance, self-organized criticality); Nonlinear time series analysis: state-space reconstruction, dimensions, Lyapunov exponents, entropies, determinism, synchronization, interdependencies, surrogate concepts, measuring non-stationarity.

Applications: nonlinear analysis of biomedical time series (EEG, MEG, EKG)

Recommended Literature:

Lehnertz: Skriptum zur Vorlesung

E. Ott; Chaos in dynamical systems (Cambridge University Press 2. Aufl. 2002)

H. Kantz, T. Schreiber ; Nonlinear time series analysis. (Cambridge University Press 2:Aufl. 2004).

A. Pikovsky, M. Rosenblum, J. Kurths; Synchronization: a universal concept in nonlinear sciences (Cambridge University Press 2003)

Modules:

physics700 **Elective Advanced Lectures**
 physics720 **Applied Physics**

Course:**Physics in Medicine:**
**Fundamentals of Medical Imaging
 (A)**

Course No.: physics773

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English | 3+1 | 6 | ST |

Requirements:**Preparation:**

Lectures Experimental Physics I-III (physik111-physik311) respectively

Form of Testing and Examination:

Requirements for the examination (written or oral): successful work with the exercises

Length of Course:

1 semester

Aims of the Course:

Understanding of the principles of physics of modern imaging techniques in medicine

Contents of the Course:

Introduction to physical imaging methods and medical imaging; Physical fundamentals of transmission computer tomography (Röntgen-CT), positron emission computer tomography (PET), magnetic resonance imaging (MRI) and functional MRI

detectors, instrumentation, data acquisition, tracer, image reconstruction, BOLD effect; applications: analysis of structure and function.

Neuromagnetic (MEG) and Neuroelectrical (EEG) Imaging; Basics of neuroelectromagnetic activity, source models

instrumentation, detectors, SQUIDs; signal analysis, source imaging, inverse problems, applications

Recommended Literature:

K. Lehnertz: Scriptum zur Vorlesung

S. Webb; The Physics of Medical Imaging (Adam Hilger, Bristol 1988)

O. Dössel; Bildgebende Verfahren in der Medizin (Springer, Heidelberg 2000)

W. Buckel; Supraleitung (Wiley-VCH Weinheim 6. Aufl. 2004)

E. Niedermeyer/F. H. Lopes da Silva; Electroencephalography (Urban & Schwarzenberg, 1982)

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:**Electronics for Physicists (E/A)**

Course No.: physics774

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English | 3+1 | 6 | ST |

Requirements:**Preparation:**

Electronics laboratory of the B.Sc. in physics programme

Form of Testing and Examination:

Requirements for the examination (written): successful work with the exercises

Length of Course:

1 semester

Aims of the Course:

Comprehension of electronic components, methods to derive the dynamical performance of circuits and mediation that these methods are widely used in various fields of physics

Contents of the Course:

Basics of electrical engineering, RF-electronics I: Telegraph equation, impedance matching for lumped circuits and electromagnetic fields, diodes, transistors, analogue and digital integrated circuits, system analysis via laplace transformation, basic circuits, circuit synthesis, closed loop circuits, oscillators, filters, RF-electronics II: low-noise oscillators and amplifiers

Recommended Literature:

P. Horowitz, W. Hill; The Art of Electronics (Cambridge University Press)
 Murray R. Spiegel; Laplace Transformation (McGraw-Hill Book Company)
 A.J. Baden Fuller; Mikrowellen (Vieweg)
 Lutz v. Wangenheim; Aktive Filter (Hüthig)

Modules:

physics700 **Elective Advanced Lectures**
 physics720 **Applied Physics**

Course:**Nuclear Reactor Physics (A)**

Course No.: physics775

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|---------|----------|----------------|----|----------|
| Elective | Lecture | English | 2 | 3 | ST |

Requirements:**Preparation:**

Fundamental nuclear physics

Form of Testing and Examination:

Written or oral examination

Length of Course:

1 semester

Aims of the Course:

Deeper understanding of nuclear power generation (fission and fusion)

Contents of the Course:

Physics of nuclear fission and fusion, neutron flux in reactors, different reactor types, safety aspects, nuclear waste problem, future aspects
 and

Excursion to a nuclear power plant

Recommended Literature:

H. Hübel: Reaktorphysik (Vorlesungsskript, available during the lecture)

M. Borlein: Kerntechnik, Vogel (2009)

W. M. Stacey: Nuclear Reactor Physics, Wiley & Sons (2007)

Modules:

physics700 **Elective Advanced Lectures**
 physics720 **Applied Physics**

Course:

Physics in Medicine: Physics of Magnetic Resonance Imaging (A)

Course No.: physics776

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English | 3+1 | 6 | WT |

Requirements:**Preparation:**

Lectures Experimental Physics I-III (physik111-physik311) respectively

Form of Testing and Examination:

Requirements for the examination (written or oral): successful work with the exercises

Length of Course:

1 semester

Aims of the Course:

Understanding the principles of Magnetic Resonance Imaging Physics

Contents of the Course:

- Theory and origin of nuclear magnetic resonance (QM and semiclassical approach)
- Spin dynamics, T1 and T2 relaxation, Bloch Equations and the Signal Equation
- Gradient echoes and spin echoes and the difference between T2 and T2*
- On- and off-resonant excitation and the slice selection process
- Spatial encoding by means of gradient fields and the k-space formalism
- Basic imaging sequences and their basic contrasts, basic imaging artifacts
- Hardware components of an MRI scanner, accelerated imaging with multiple receiver
- Computation of signal amplitudes in steady state sequences
- The ultra-fast imaging sequence EPI and its application in functional MRI
- Basics theory of diffusion MRI and its application in neuroimaging
- Advanced topics: quantitative MRI, spectroscopic imaging, X-nuclei MRI

Recommended Literature:

- T. Stöcker: Skriptum zur Vorlesung
- E.M. Haacke et al, Magnetic Resonance Imaging: Physical Principles and Sequence Design, John Wiley 1999
- M.T. Vlaardingerbroek, J.A. den Boer, Magnetic Resonance Imaging: Theory and Practice, Springer, 20
- Z.P. Liang, P.C. Lauterbur, Principles of Magnetic Resonance Imaging: A Signal Processing Perspective, SPIE 1999

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:**Physics of Detectors (E/A)****Course No.:**

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|---------|----------|----------------|----|----------|
| Elective | Lecture | English | 3 | 4 | ST |

Requirements:**Preparation:**

Nuclear Physics I, Quantum Mechanics

Form of Testing and Examination:

Part of the obligatory courses for area of specialisation Nuclear and Particle Physics, separate oral examination is possible exceptionally.

Length of Course:

1 semester

Aims of the Course:

Study detection methods of experimental techniques in nuclear and particle physics.

Contents of the Course:

- Interaction of electrons and charged heavy particles in matter
- Coherent effects: Cherenkov and transition radiation
- Interaction of gamma-radiation in matter
- Detection of neutral particles: neutrons and neutrinos
- Measurement of 4-momentum in particle physics
- Ionisation detectors: Bragg chamber, avalanche detectors
- Position sensitive detectors: drift chambers, time-projection chamber
- Anorganic and organic scintillators
- Energy detection, calorimeter and shower detectors
- Semiconductor detectors
- Position sensitive Si detectors (strip-, pixel-detectors)
- Ge detectors
- Low background measurements
- Lifetime measurements
- Mössbauer Spectroscopy
- Basic principles of analogue and digital signal processing

Recommended Literature:

A script or slides of the course will be distributed during the course.

R. Leo, Techniques for Nuclear and Particle Physics Experiments

K Kleinknecht, Detektoren für Teilchenstrahlung

G.F. Knoll, Radiation Detection and Measurement

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:

Semiconductor Physics and Nanoscience (E/A)

Course No.:

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|---------|----------|----------------|----|----------|
| Elective | Lecture | English | 2 | 3 | ST |

Requirements:**Preparation:**

Basic knowledge in condensed matter physics

Form of Testing and Examination:

No examination

Length of Course:

1 semester

Aims of the Course:

Understanding of theoretical and experimental concepts of semiconductor physics, nanotechnology as well as aspects of future information technology.

Knowledge of basic fields and important applications of information technology.

Contents of the Course:

Semiconducting material and nanostructures represent the backbone of modern electronics and information technology. At the same time they are fundamental to the research of problems of modern solid state physics, information technology and biophysics. This lecture will provide an introduction to semiconductor physics and its applications.

Topics covered are

introduction to semiconductor physics, crystalline structure, band structure, electronic and optical properties,

heterostructures, junction and interfaces,

basic semiconductor device concepts,

up to date techniques and strategies of information technology ranging from nowadays preparation technologies and nanoscience to concepts of molecular electronic and bioelectronics.

Recommended Literature:

Skriptum (available during the course)

Bergmann/Schäfer, Experimentalphysik (Band 6: Festkörper)

Ibach/Lüth, Festkörperphysik

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:**Superconductivity (E/A)****Course No.:**

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|---------|----------|----------------|----|----------|
| Elective | Lecture | English | 2 | 3 | ST |

Requirements:**Preparation:**

Basic knowledge in condensed matter physics

Form of Testing and Examination:

Oral examination

Length of Course:

1 semester

Aims of the Course:

Understanding of the fundamental aspects of superconductivity.

Contents of the Course:

The lecture provides an overview of the fundamental aspects of superconductivity, theoretical description and technological applications, including the following topics:

Basic experimental facts and critical parameters
 Phenomenological description: London equations
 Ginzburg-Landau theory
 Magnetic flux quantization
 Type I and type II superconductors, characteristic length scales, vortices
 Microscopic description: BSC theory
 Electron-phonon interaction, Cooper pairs
 Josephson effects
 Applications of superconductivity in science, transport, and medicine
 Brief introduction to unconventional superconductivity with recent examples

Recommended Literature:

J. F. Annett: Superconductivity, Superfluids and Condensates (2004)
 M. Tinkham: Introduction to Superconductivity (1996)
 V. V. Schmidt: The Physics of Superconductors (1997)
 J. R. Waldram: Superconductivity of Metals and Cuprates (1996)
 D. R. Tilley and J. Tilley: Superfluidity and Superconductivity (1990)

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:**Magnetism (E/A)**

Course No.:

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|---------|----------|----------------|----|----------|
| Elective | Lecture | English | 2 | 3 | WT |

Requirements:**Preparation:**

Basic knowledge in condensed matter physics

Form of Testing and Examination:

Oral examination

Length of Course:

1 semester

Aims of the Course:

Understanding of magnetism in condensed matter systems

Contents of the Course:

The lecture introduces to the magnetism in condensed matter systems. Starting from basic concepts of the magnetic properties of free atoms it is aimed to illustrate the extremely rich field of collective magnetism that arises from the mutual interaction of an extremely large number of interacting particles.

Topics covered are

Magnetism of free atoms

Magnetism of ions in the crystal electric field

Magnetic interactions and ordering phenomena

Magnetic ground states and excitations

Itinerant magnetism

Magnetic frustration and low dimensionality

Magnetic order vs. competing ordering phenomena

Recommended Literature:

Skriptum (available during the course)

S. Blundell, Magnetism in Condensed Matter

Ashcroft/Mermin, Solid State Physics

Kittel, Festkörperphysik

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:

Experimental methods in condensed matter physics (E/A)

Course No.:

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|---------|----------|----------------|----|----------|
| Elective | Lecture | English | 2 | 3 | WT |

Requirements:**Preparation:**

Basic knowledge in condensed matter physics

Form of Testing and Examination:

Oral examination

Length of Course:

1 semester

Aims of the Course:

Understanding of experimental concepts in condensed matter science
 Knowledge of basic fields and important applications

Contents of the Course:

The lecture introduces to modern experimental approaches in solid state physics. Basic concepts are illustrated with examples of physical problems investigated employing different methods.

Topics covered are

Introduction on sample preparation

X-ray powder diffraction

Specific heat, Thermal expansion

Magnetization and magnetic susceptibility

DC-Transport

Dielectric spectroscopy

Photo-emission spectroscopy

Inelastic scattering (neutrons, light)

THz spectroscopy / Optical spectroscopy

Scanning probe microscopy/spectroscopy (AFM, STM)

Recommended Literature:

Skriptum (available during the course)

Bergmann/Schäfer, Experimentalphysik (Band 6: Festkörper)

Ibach/Lüth, Festkörperphysik

Ashcroft/Mermin, solid state physics

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:

Physics of Surfaces and Nanostructures (E/A)

Course No.:

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|---------|----------|----------------|----|----------|
| Elective | Lecture | English | 2 | 3 | WT |

Requirements:**Preparation:**

Basic knowledge of solid state physics

Form of Testing and Examination:

Oral examination

Length of Course:

1 semester

Aims of the Course:

Understanding of fundamental concepts in surface and nanostructure science
 Knowledge of basic fields and important applications

Contents of the Course:

The lecture introduces to modern topics of surface and nanostructure physics. Basic concepts are illustrated with examples and the link to technical applications is emphasised. Topics covered are

- surface structure and defects,
- adsorption and heterogeneous catalysis,
- surface thermodynamics and energetics
- surface electronic structure and quantum dots,
- magnetism at surfaces
- epitaxy and thin film processes,
- oxide films
- ion beam processes at surfaces,
- clusters,
- graphene

Recommended Literature:

Michely: Skriptum (available during the course)

H. Ibach: Physics of Surfaces and Interfaces (Springer, Berlin 2006)

K. Oura et al: Surface Science - an introduction (Springer, Berlin 2003)

M. Prutton: Introduction to Surface Physics (Oxford University Press, 1994)

H. Lüth: Solid Surfaces, Interfaces and Thin Films, (Springer, Berlin 2001)

M. Henzler/ W. Göpel: Oberflächenphysik des Festkörpers (Teubner, Stuttgart 1994)

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:

Introduction to neutron scattering (E/A)

Course No.:

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|---------|----------|----------------|----|----------|
| Elective | Lecture | English | 2 | 3 | ST |

Requirements:**Preparation:**

Basic knowledge in condensed matter physics

Form of Testing and Examination:

Oral examination

Length of Course:

1 semester

Aims of the Course:

Understanding of the basic concepts and techniques of elastic and inelastic neutron scattering experiments.

Contents of the Course:

The lecture introduces to the techniques of elastic and inelastic neutron scattering that can be used to determine the crystal or magnetic structure as well as the dispersion of nuclear or magnetic excitations.

Topics covered are

Crystal structures and reciprocal space

Neutron powder diffraction

Single-crystal diffraction

Structure refinements

Inelastic neutron scattering

Phonon dispersion

Magnetic excitations

Examples of current research (high-temperature superconductors, manganates with colossal magnetoresistivity, multiferroics)

Polarized neutron scattering

Recommended Literature:

Skriptum (available during the course)

S. W. Lovesey, Theory of Neutron Scattering from Condensed Matter, Oxford (1981)

G. E. Bacon, Neutron Diffraction, Oxford (1979)

Shirane, Shapiro and, Tranquada, Neutr. Scattering with a triple-axis spectrometer, Cambridge (2002)

Izyumov, Ozerov, Magnetic Neutron Diffraction Plenum (1970)

Marshall and Lovesey, Theory of thermal neutron scattering, Oxford (1971)

Squires, Introduction to the theory of Thermal Neutron scattering, Cambridge (1978)

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:**Optical Spectroscopy (E/A)****Course No.:**

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|---------|----------|----------------|----|----------|
| Elective | Lecture | English | 2 | 3 | WT/ST |

Requirements:**Preparation:**

Basic knowledge in condensed matter physics

Form of Testing and Examination:

Oral examination

Length of Course:

1 semester

Aims of the Course:

Understanding of the basic concepts and techniques of optical spectroscopy on solid-state samples.

Contents of the Course:

Topics covered are:

Electromagnetic waves in matter, dielectric function

Electromagnetic response of metals and insulators, Drude-Lorentz model

Kramers-Kronig relations

THz spectroscopy (time domain and cw)

Fourier-transform spectroscopy

Ellipsometry

Examples of current research (phonons, magnons, orbital excitations, superconductors, ...)

Recommended Literature:

Skriptum (available during the course)

Dressel/Grüner: Electrodynamics of Solids: Optical Properties of Electrons in Matter (Cambridge, 2002)

Klingshirn: Semiconductor Optics (Springer, 1997)

Kuzmany: Solid-State Spectroscopy: An Introduction (Springer, 2009)

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**

Course:**Astrochemistry (E/A)**

Course No.:

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|---------|----------|----------------|----|----------|
| Elective | Lecture | English | 2 | 4 | ST |

Requirements:**Preparation:**

Atomic Physics, Molecular Physics and Quantum Mechanics at the level of the bachelor courses in physics, Molecular Physics I

Form of Testing and Examination:

Oral Examination

Length of Course:

1 semester

Aims of the Course:

The lecture introduces to astrochemistry of various astrophysical environments. Fundamental processes, such as molecular collisions, fragmentations, and chemical reactions, are explained, and implications for astrophysical observations by means of high resolution spectroscopy are treated.

Contents of the Course:

- Detection of Molecules in Space
- Elementary Chemical Processes
- Chemical Networks
- Grain Formation (Condensation)
- Properties of Grains and Ice
- Grain Chemistry
- Diffuse Clouds, Shocks, Dark Clouds, Star Forming Regions

Recommended Literature:

- A. Tielens "The Physics and Chemistry of the Interstellar Medium" Cambridge University Press, 2005
 S. Kwok "Physics and Chemistry of the Interstellar Medium" University Science Books, 2006
 D. Rehder "Chemistry in Space, From Interstellar Matter to the Origin of Life" Wiley-VCH, Weinheim, 2010
 J. Lequeux "The interstellar Medium" Springer, 2004
 A. Shaw "Astrochemistry" Wiley, 2006
 D. Whittet "Dust in the Galactic Environment", Taylor and Francis, 2nd edition, 2002

Modules:

physics700 **Elective Advanced Lectures**
 physics710 **Experimental Physics**
 physics720 **Applied Physics**
 physics730 **Theoretical Physics**

Course:

Fundamentals of Molecular Symmetry (E/A/T)

Course No.:

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|---------|----------|----------------|----|----------|
| Elective | Lecture | English | 2 | 4 | ST |

Requirements:**Preparation:**

Basic knowledge of quantum mechanics

Form of Testing and Examination:

Oral Examination

Length of Course:

1 semester

Aims of the Course:

Understanding the fundamental concepts of representation theory and its application to describe the symmetry of molecules

Contents of the Course:

The lecture introduces to group theory with special emphasis on representations and their use to describe the symmetry of molecules in high-resolution spectroscopy and in molecular physics generally. The theory is accompanied by a series of "prototypical" examples. Topics covered are

- symmetry in general and symmetry of a molecule.
- groups and point groups.
- irreducible representations, characters.
- vanishing integral rule
- the Complete Nuclear Permutation-Inversion (CNPI) group.
- the Molecular Symmetry (MS) group).
- the molecular point group.
- classification of molecular states: electronic, vibrational, rotational, and nuclear spin states
- nuclear spin statistical weights
- hyperfine structure
- non-rigid molecules (inversion, internal rotation)

Recommended Literature:

Jensen: Script (text of powerpoint presentation files; available during the course)
 P. Jensen and P. R. Bunker: The Symmetry of Molecules, in: "Encyclopedia of Chemical Physics and Physical Chemistry" (J. H. Moore and N. D. Spencer, Eds.), IOP Publishing, Bristol, 2001.
 P. R. Bunker and Per Jensen: "Molecular Symmetry and Spectroscopy, 2nd Edition," NRC Research Press, Ottawa, 1998 (ISBN 0-660-17519-3).
 P. R. Bunker and P. Jensen: "Fundamentals of Molecular Symmetry", IOP Publishing, Bristol, 2004 (ISBN 0-7503-0941-5).

Modules:

physics700 **Elective Advanced Lectures**
 physics720 **Applied Physics**
 physics730 **Theoretical Physics**

Course:**Physical biology (T/A)****Course No.:**

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English | 4+2 | 8 | ST |

Requirements:**Preparation:**

Advanced statistical mechanics

Form of Testing and Examination:

Oral examination

Length of Course:

1 semester

Aims of the Course:

Acquaintance with basic concepts of molecular and evolutionary biology; understanding of statistical issues arising in the analysis of sequence data and the application of methods from statistical physics addressing them.

Contents of the Course:

Statistics of the genome
 Sequence analysis and sequence alignment
 Evolutionary theory and population genetics
 Theory of bio-molecular networks

Recommended Literature:

J.H. Gillespie, Population Genetics: A concise guide (Johns Hopkins University Press, 2004)
 R. Durbin, S.R. Eddy, A. Krogh, G. Mitchison, Biological Sequence Analysis: Probabilistic Models of Proteins and Nucleic Acids (Cambridge University Press, 1998)
 F. Kepes, Biological Networks (World Scientific, Singapore 2007)
 D.J. Wilkinson, Stochastic Modelling for Systems Biology (Chapman&Hall, 2006)

Modules:

physics700 **Elective Advanced Lectures**
 physics720 **Applied Physics**
 physics730 **Theoretical Physics**

Course:

Statistical physics of soft matter and biomolecules (T/A)

Course No.:

| Category | Type | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English | 4+2 | 8 | ST |

Requirements:**Preparation:**

Advanced statistical mechanics

Form of Testing and Examination:

Oral examination

Length of Course:

1 semester

Aims of the Course:

Understanding the molecular structure and mesoscopic properties of various types of soft matter systems, in particular with regard to their role in living cells.

Contents of the Course:

Colloids, polymers and amphiphiles
 Biopolymers and proteins
 Membranes
 Physics of the cell

Recommended Literature:

J. K. G. Dhont, An Introduction to Dynamics of Colloids (Elsevier, Amsterdam, 1996).
 M. Doi and S. F. Edwards, The Theory of Polymer Dynamics (Clarendon Press, Oxford, 1986).
 S. A. Safran, Statistical Thermodynamics of Surfaces, Interfaces, and Membranes (Addison-Wesley, Reading, MA, 1994).
 G. Gompper, U. B. Kaupp, J. K. G. Dhont, D. Richter, and R. G. Winkler, eds., Physics meets Biology — From Soft Matter to Cell Biology, vol. 19 of Matter and Materials (FZ Jülich, Jülich, 2004).
 D. H. Boal, Mechanics of the Cell (Cambridge University Press, Cambridge, 2002).