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

Fachgruppe
Physik und Astronomie
Universität Bonn

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: universität**bonn** 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: universität**bonn**   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 pi-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: universitätbonn   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: universität**bonn**   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.

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Modules:

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

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Course: universität**bonn**   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: universität**bonn** **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**
physics720 **Applied Physics**

Course: universität**bonn** **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, Oldenbourg1998
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: universität**bonn**   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: universität**bonn**   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: universität**bonn** 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. Horrowitz, 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: universität**bonn** **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 (fisson 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: universität**bonn** **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: Scriptum 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 neutal particles: neutrons and neutrinos
- Measurement of 4-momentum in particle physics
- Ionisation detectors: Bragg chamber, avalanche detectors
- Position sensitive detectors: drift chambers, time-procjection 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 analoge 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 emphazised. 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-VCCH, Weinheim, 2010
J. Lequeux "The interstellar Medium" Spinger, 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 alignement
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).