Degree: **M.Sc. in Physics (PO von 2006)**

Module No.: physics700
Credit Points (CP):
Category: Elective
Semester: 7.

Fachgruppe Physik und Astronomie Universität Bonn

Module: Elective Advanced Lectures

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
Particle Physics						
1.	Selected 700-courses from catalogue	physics711-729	4-6	see catalogue	120-180 hrs	WT/ST
Condensed Matter and Photonics						
1.	Selected 700-courses from catalogue	physics731-749	3-6	see catalogue	90-180 hrs	WT/ST
Theoretical Physics						
1.	Selected 700-courses from catalogue	physics751-769	5-7	see catalogue	150-210 hrs	WT/ST
Special Topics						
1.	Selected 700-courses from catalogue	physics771-779	3-6	see catalogue	90-180 hrs	WT/ST
Research Internship						
1.	Internships in the Research Groups	physics799	4	internship		WT/ST
Cologne Courses						
1.	Courses from Cologne marked "E", "A", or "T"	see catalogue	3-8	see catalogue	90-240 hrs	WT/ST
1.	Also possible classes from M.Sc. in Astrophysics					

Requirements:

Preparation:

Content:
Special lectures on research topics of the physics section of the Bonn University

Aims/Skills:
The students are offered the opportunity to get insight into today's research problems

Form of Testing and Examination:
If the lecture is offered with exercises: requirements for the module 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**

Course: universitätbonn Particle Astrophysics and Cosmology (E)

Course No.: physics711

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

Requirements:

Preparation:
physics611 (Particle Physics), useful: Lectures Observational Astronomy

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Basics of particle astrophysics and cosmology

Contents of the Course:
Observational Overview (distribution of galaxies, redshift, Hubble expansion, CMB, cosmic distance latter, comoving distance, cosmic time, comoving distance and redshift, angular size and luminosity distance); Standard Cosmology (cosmological principle, expansion scale factor, curved space-time, horizons, Friedmann-Equations, cosmological constant, cosmic sum rule, present problems); Particle Physics relevant to cosmology (Fundamental Particles and their Interactions, quantum field theory and Lagrange formalism, Gauge Symmetry, spontaneous symmetry breaking and Higgs mechanism, parameters of the Standard Model, Running Coupling Constants, CP Violation and Baryon Asymmetry, Neutrinos); Thermodynamics in the Universe (Equilibrium Thermodynamics and freeze out, First Law and Entropy, Quantum Statistics, neutrino decoupling, reheating, photon decoupling); Nucleosynthesis (Helium abundance, Fusion processes, photon/baryon ratio)
Dark Matter (Galaxy Rotation Curves, Clusters of Galaxies, Hot gas, Gravitational lensing, problems with Cold Dark Matter Models, Dark Matter Candidates); Inflation and Quintessence; Cosmic Microwave Background (origin, intensity spectrum, CMB anisotropies, Temperature correlations, power spectrum, cosmic variance, density and temperature fluctuations, causality and changing horizons, long and short wavelength modes, interpretation of the power spectrum)

Recommended Literature:
A. Liddle; An Introduction to Modern Cosmology (Wiley & Sons 2. Ed. 2003)
E. Kolb, M. Turner; The Early Universe (Addison Wesley 1990)
J. Peacock; Cosmological Physics (Cambridge University Press 1999)

Modules:

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

Course: universitätbonn 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 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: 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**

Course: Experiments on the Structure of Hadrons (E)

Course No.: physics715

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

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:
Understanding the structure of the nucleon, understanding experiments on baryon-spectroscopy, methods of identifying resonance contributions, introduction into current issues in meson-photoproduction

Contents of the Course:
Discoveries in hadron physics, quarks, asymptotic freedom and confinement; multiplets, symmetries, mass generation; quark models, baryon spectroscopy, formation and decay of resonances, meson photoproduction; hadronic molecules and exotic states

Recommended Literature:
Perkins, Introduction to High Energy Physics (Cambridge University Press 4. Aufl. 2000)
K. Gottfried, F. Weisskopf; Concepts of Particle Physics (Oxford University Press 1986)
A. Thomas, W. Weise, The Structure of the Nucleon (Wiley-VCH, Weinheim, 2001)

Modules:	physics700 **Elective Advanced Lectures** physics710 **Experimental Physics**

Course: universitätbonn Statistical Methods of Data Analysis (E)

Course No.: physics716

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

Requirements:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Provide a foundation in statistical methods and give some concrete examples of how the methods are applied to data analysis in particle physics experiments

Contents of the Course:
Fundamental concepts of statistics, probability distributions, Monte Carlo methods, fitting of data, statistical and systematic errors, error propagation, upper limits, hypothesis testing, unfolding

Recommended Literature:
R. Barlow: A Guide to the Use of Statistical Methods in the Physical Sciences; J. Wiley Ltd. Wichester 1993
S. Brandt: Datenanalyse (Spektrum Akademischer Verlag, Heidelberg 4. Aufl. 1999)

Modules:

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

Course: universitätbonn High Energy Physics Lab (E)

Course No.: physics717

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

Requirements:

Preparation:
Recommended: B.Sc. in physics, physics611 (Particle Physics) or physics618 (Physics of Particle Detectors)

Form of Testing and Examination:
Credit points can be obtained after completion of a written report or, alternatively, a presentation in a meeting of the research group.

Length of Course:
4-6 weeks

Aims of the Course:
This is a research internship in one of the high energy physics research groups which prepare and carry out experiments at external accelerators. The students deepen their understanding of particle and/or detector physics by conducting their own small research project as a part-time member of one of the research groups. The students learn methods of scientific research in particle physics data analysis, in detector development for future colliders or in biomedical imaging (X-FEL) and present their work at the end of the project in a group meeting.

Contents of the Course:
Several different topics are offered among which the students can choose. Available projects can be found at http://heplab.physik.uni-bonn.de. For example:
- Analysis of data from one of the large high energy physics experiments (ATLAS, DØ, ZEUS)
- Investigation of low-noise semiconductor detectors using cosmic rays, laser beams or X-ray tubes
- Study of particle physics processes using simulated events
- Signal extraction and data mining with advanced statistical methods (likelihoods, neural nets or boosted decision trees)

Recommended Literature:
Will be provided by the supervisor

Modules:

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

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

universitätbonn

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**

Course: Physics with Antiprotons (E)

Course No.: physics720

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

Requirements:

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

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Insight in current research topics with antiprotons, understanding experimental methods in particle and nuclear physics, understanding interrelations between different fields of physics such as hadron physics, (astro-)particle physics, atomic physics

Contents of the Course:
Matter-antimatter asymmetry, test of the standard model, anti-hydrogen, anti-protonic atoms, antiproton beams, key issues in hadron physics with antiprotons, planned research facilities (FAIR) and experiments (PANDA)

Recommended Literature:
B. Povh, K. Rith, C. Scholz, F. Zetsche; Teilchen und Kerne (Springer, Heidelberg 8. Aufl. 2009)
D.H. Perkins; Introduction to High Energy Physics (Cambridge University Press 4. Aufl. 2000)
further literature will be given in the lecture

Modules:

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

Course: Intensive Week: Advanced Topics in Hadron Physics (E)

Course No.: physics721

Category	Type	Language	Teaching hours	CP	Semester
Elective	Combined lecture, seminar, lab course	English	3	4	WT/ST

Requirements:

Preparation:
Fundamentals of hadron physics

Form of Testing and Examination:
Presentation, working group participation

Length of Course:
1 - 2 weeks

Aims of the Course:
This course will convey recent topics in hadron physics. Guided by lectures, original publications and tutors, the students will prepare a proposal for a planned or recent experiment. The class will not only focus on the experimental aspects, but also on the theoretical motivation for the experiment.

Contents of the Course:
As announced in the course catalogue. The main topics will vary from semester to semester.

Recommended Literature:
Will be given in the lecture

Modules:

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

Course: Advanced Gaseous Detectors - Theory and Practice (E)

Course No.: physics722

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 electrodynamics, quantum mechanics, nuclear and particle physics, physics618 (Physics of Particle Detectors)

Form of Testing and Examination:
Form of examination: written or oral report

Length of Course:
1 semester

Aims of the Course:
- Design, construction, commissioning and characterization of a modern gaseous particle detector
- Simulations: GARFIELD, GEANT, FE-Methods, etc.
- Signals, Readout electronics and Data Acquisition
- Data analysis: pattern recognition methods, track fitting
- Scientific writing: report

Contents of the Course:
- Signal formation in detectors
- Microscopic processes in gaseous detectors
- Readout electronics
- Tools for detector design and simulation
- Performance criteria
- Laboratory course: commissioning of detector with sources, beam test at accelerator
- Track reconstruction

Recommended Literature:
http://root.cern.ch
http://garfieldpp.web.cern.ch/garfieldpp/
Blum, Rolandi, Riegler: Particle Detection with Drift Chambers
Spieler: Semiconductor Detector Systems

Modules:

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

Course: Intensive Week: Advanced Topics in Photonics and Quantum Optics (E)

Course No.: physics737

Category	Type	Language	Teaching hours	CP	Semester
Elective	Combined lecture, seminar, lab course	English	3	4	WT/ST

Requirements:

Preparation:
Fundamentals of optics, fundamentals of quantum mechanics

Form of Testing and Examination:
Seminar or oral examination

Length of Course:
1 - 2 weeks

Aims of the Course:
The intensive course will convey the basics of a recent topic in photonics or quantum optics in theory and experiments. Guided by a combination of lectures, seminar talks (based on original publications) and practical training, the participants will gain insight into recent developments in photonics/quantum optics.

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

Modules:

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

Course: Lecture on Advanced Topics in Quantum Optics (E)

Course No.: physics738

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

Requirements:

Preparation:
Fundamentals of Quantum Mechanics, Atomic Physics

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 quantum optics. 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

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**
physics730 **Theoretical Physics**

Course: universitätbonn Ultracold Atomic Gases (E/T)

Course No.: physics742

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

Requirements:

Preparation:
Quantum Mechanics

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:
This lecture discusses both the experimental and theoretical concepts of ultra-cold atomic gases.

Contents of the Course:
Almost hundred years ago, in 1924, A. Einstein and S.N. Bose predicted the existence of a new state of matter, the so-called Bose-Einstein condensate. It took 70 years to successfully realize this macroscopic quantum state in the lab using ultracold atomic gases (Nobel prize 2001). The main challenge was to achieve cooling to Nanokelvin temperatures, the coolest temperatures ever reached by mankind. Nowadays, ultracold gases are exciting systems to study a broad range of quantum phenomena. These phenomena range from the direct observation of quantum matter waves and superfluidity over the creation of artificial crystal structures as analogous to solids, to the realization of complex quantum phase transitions of interacting atoms, e.g. the formation of a bosonic Mott-insulator or the BCS superconducting state for Fermions. In this lecture we will discuss both the experimental and theoretical concepts of ultra-cold atomic gases.

Outline: Introduction and revision of basic concepts, Fundamentals of atom-laser interaction
Laser cooling & trapping, Bose-Einstein condensation of atomic gases. Dynamics of Bose-Einstein condensates
Optical lattices: strongly interacting atomic gases and quantum phase transitions
The crossover of Fermi-gases between a BCS superconducting state and a Bose-Einstein condensate of molecules.

Recommended Literature:
C. J. Pethick and H. Smith, Bose-Einstein Condensation in Dilute Gases (Cambridge University Press)

Modules:

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

Course: Group Theory (T)

Course No.: physics751

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:
physik421 (Quantum Mechanics)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the

Length of Course:
1 semester

Aims of the Course:
Acquisition of mathematical foundations of group theory with regard to applications in theoretical physics

Contents of the Course:
Mathematical foundations:
Finite groups, Lie groups and Lie algebras, highest weight representations, classification of simple Lie algebras, Dynkin diagrams, tensor products and Young tableaux, spinors, Clifford algebras, Lie super algebras

Recommended Literature:
B. G. Wybourne; Classical Groups for Physicists (J. Wiley & Sons 1974)
H. Georgi; Lie Algebras in Particle Physics (Perseus Books 2. Aufl. 1999)
W. Fulton, J. Harris; Representation Theory (Springer, New York 1991)

Modules:

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

Course: universitätbonn Superstring Theory (T)

Course No.: physics752

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:
Quantum Field Theory (physics755)
Group Theory (physics751)
Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)
Theoretical Particle Physics (physics615)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Survey of modern string theory as a candidate of a unified theory in regard to current research

Contents of the Course:
Bosonic String Theory, Elementary Conformal Field Theory
Kaluza-Klein Theory
Crash Course in Supersymmetry
Superstring Theory
Heterotic String Theory
Compactification, Duality, D-Branes
M-Theory

Recommended Literature:
D. Lüst, S. Theisen; Lectures on String Theory (Springer, New York 1989)
S. Förste; Strings, Branes and Extra Dimensions, Fortsch. Phys. 50 (2002) 221, hep-th/0110055
C. Johnson, D-Brane Primer (Cambridge University Press 2003)
M. Green, J. Schwarz, E. Witten; Superstring Theory I & II (Cambridge University Press 1988)
H.P. Nilles, Supersymmetry and phenomenology (Phys. Reps. 110 C (1984) 1)
J. Polchinski; String Theory I & II (Cambridge University Press 2005)

Modules:

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

Course: Theoretical Particle Astrophysics (T)

Course No.: physics753

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:

Preparation:
General Relativity and Cosmology (physics754)
Quantum Field Theory (physics755)
Theoretical Particle Physics (physics615)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Introduction to the current status at the interface of particle physics and cosmology

Contents of the Course:
Topics on the interface of cosmology and particle physics:
Inflation and the cosmic microwave background;
baryogenisis,
Dark Matter,
nucleosynthesis
the cosmology and astrophysics of neutrinos

Recommended Literature:
J. Peacock, Cosmological Physics (Cambridge University Press 1998)
E. Kolb, M. Turner; The Early Universe (Addison Wesley 1990)

Modules:

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

Course: universitätbonn General Relativity and Cosmology (T)

Course No.: physics754

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:

Preparation:
physik221 and physik321 (Theoretical Physics I and II)
Differential geometry

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding the general theory of relativity and its cosmological implications

Contents of the Course:
Relativity principle
Gravitation in relativistic mechanics
Curvilineal coordinates
Curvature and energy-momentum tensor
Einstein-Hilbert action and the equations of the gravitational field
Black holes
Gravitational waves
Time evolution of the universe
Friedmann-Robertson-Walker solutions

Recommended Literature:
S.Weinberg; Gravitation and Cosmology (J. Wiley & Sons 1972)
R. Sexl: Gravitation und Kosmologie, Eine Einführung in die Allgemeine Relativitätstheorie (Spektrum Akadem. Verlag 5. Aufl 2002)
L.D. Landau, E.M. Lifschitz; Course of Theoretical Physics Vol.2: Classical field theory (Butterworth-Heinemann 1995), also available in German from publisher Harry Deutsch

Modules:

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

Course: universitätbonn Quantum Field Theory (T)

Course No.: physics755

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:

Preparation:
Advanced quantum theory (physics606)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding quantum field theoretical methods, ability to compute processes in quantum electrodynamics (QED) and many particle systems

Contents of the Course:
Classical field theory
Quantization of free fields
Path integral formalism
Perturbation theory
Methods of regularization: Pauli-Villars, dimensional
Renormalizability
Computation of Feynman diagrams
Transition amplitudes in QED
Applications in many particle systems

Recommended Literature:
N. N. Bogoliubov, D.V. Shirkov; Introduction to the theory of quantized fields (J. Wiley & Sons 1959)
M. Kaku, Quantum Field Theory (Oxford University Press 1993)
M. E. Peskin, D.V. Schroeder; An Introduction to Quantum Field Theory (Harper Collins Publ. 1995)
L. H. Ryder; Quantum Field Theory (Cambridge University Press 1996)
S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)

Modules:

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

Course: universitätbonn Critical Phenomena (T)

Course No.: physics756

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:

Preparation:
Advanced quantum theory (physics606)
Theoretical condensed matter physics (physics617)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Acquisition of important methods to treat critical phenomena

Contents of the Course:
Mean Field Approximation and its Improvements
Critical Behaviour at Surfaces
Statistics of Polymers
Concept of a Tomonaga-Luttinger Fluid
Random Systems
Phase Transitions, Critical Exponents
Scale Behaviour, Conformal Field Theory
Special Topics of Nanoscopic Physics

Recommended Literature:
J. Cardy, Scaling and Renormalization in Statistical Physics (Cambridge University Press, 1996)
A. O. Gogolin, A. A. Nersesyan, A.N.Tsvelik; Bosonisation and strongly correlated systems (Cambridge University Press, 1998)

Modules:

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

Course: Effective Field Theory (T)

Course No.: physics757

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT/ST

Requirements:

Preparation:
Advanced quantum theory (physics606)
Quantum Field Theory (physics755)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding basic properties and construction of Effective Field Theories, ability to perform calculations in Effective Field Theories

Contents of the Course:
Scales in physical systems, naturalness
Effective Quantum Field Theories
Renormalization Group, Universality
Construction of Effective Field Theories
Applications: effective field theories for physics beyond the Standard Model, heavy quarks, chiral dynamics, low-energy nuclear physics, ultracold atoms

Recommended Literature:
S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)
J.F. Donoghue et al.; Dynamics of the Standard Model (Cambridge University Press 1994)
A.V. Manohar, M.B. Wise; Heavy Quark Physics (Cambridge University Press 2007)
P. Ramond, Journeys Beyond The Standard Model (Westview Press 2003)
D.B. Kaplan, Effective Field Theories (arXiv:nucl-th/9506035)
E. Braaten, H.-W. Hammer; Universality in Few-Body Systems with Large Scattering Length (Phys. Rep. 428 (2006) 259)

Modules:

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

Course: universitätbonn Quantum Chromodynamics (T)

Course No.: physics758

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT/ST

Requirements:

Preparation:
Advanced quantum theory (physics606)
Quantum Field Theory (physics755)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding basic properties of Quantum Chromodynamics, ability to compute strong interaction processes

Contents of the Course:
Quantum Chromodynamics as a Quantum Field Theory
Perturbative Quantum Chromodynamics
Topological objects: instantons etc.
Large N expansion
Lattice Quantum Chromodynamics
Effective Field Theories of Quantum Chromodynamics
Flavor physics (light and heavy quarks)

Recommended Literature:
S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)
M.E. Peskin, D.V. Schroeder; An Introduction to Quantum Field Theory (Westview Press 1995)
F.J. Yndurain; The Theory of Quark and Gluon Interactions (Springer 2006)
J.F. Donoghue et al.; Dynamics of the Standard Model (Cambridge University Press 1994)
E. Leader and E. Predazzi; An Introduction to Gauge Theories and Modern Particle Physics (Cambridge University Press 1996)

Modules:

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

Course: Computational Physics (T)

Course No.: physics760

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises and project work	English	2+2+1	7	WT/ST

Requirements:
Knowledge of a modern programming language (like C, C++)

Preparation:
Theoretical courses at the Bachelor degree level

Form of Testing and Examination:
successful participation in exercises,
presentation of an independently completed project

Length of Course:
1 semester

Aims of the Course:
ability to apply modern computational methods for solving physics problems

Contents of the Course:
Statistical Models, Likelihood, Bayesian and Bootstrap Methods
Random Variable Generation
Stochastic Processes
Monte-Carlo methods
Markov-Chain Monte-Carlo

Recommended Literature:
W.H. Press et al.: Numerical Recipes in C (Cambridge University Press)
http://library.lanl.gov/numerical/index.html
C.P. Robert and G. Casella: Monte Carlo Statistical Methods (Springer 2004)
Tao Pang: An Introduction to Computational Physics (Cambridge University Press)
Vesely, Franz J.: Computational Physics: An Introduction (Springer)
Binder, Kurt and Heermann, Dieter W.: Monte Carlo Simulation in Statistical Physics (Springer)
Fehske, H.; Schneider, R.; Weisse, A.: Computational Many-Particle Physics (Springer)

Modules:

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

Course: universitätbonn Supersymmetry (T)

Course No.: physics761

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

Requirements:
Quantum Field Theory I

Preparation:

Form of Testing and Examination:
Individual Oral Examinations

Length of Course:
1 semester

Aims of the Course:
Teach the students the basics of supersymmetric field theory and how it can be tested at the LHC.

Contents of the Course:
Superfields; Supersymmetric Lagrangians; MSSM; Testing the MSSM at the LHC

Recommended Literature:
Theory and phenomenology of sparticles: An account of four-dimensional N=1 supersymmetry in high energy physics.
M. Drees, (Bonn U.) , R. Godbole, (Bangalore, Indian Inst. Sci.) , P. Roy, (Tata Inst.) . 2004. 555pp.
Hackensack, USA: World Scientific (2004) 555 p.

Weak scale supersymmetry: From superfields to scattering events.
H. Baer, (Florida State U.) , X. Tata, (Hawaii U.) . 2006. 537pp.
Cambridge, UK: Univ. Pr. (2006) 537 p.

Modules:

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

Course: universitätbonn Transport in mesoscopic systems (T)

Course No.: physics762

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	5	WT/ST

Requirements:

Preparation:
Classical mechanics
Elementary thermodynamics and statistical physics (physik521)
Advanced quantum theory (physics606)
Introductory theoretical condensed matter physics (physics617)

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 essential transport phenomena in solids and mesoscopic systems
Acquisition of important methods for treating transport problems

Contents of the Course:
Linear response theory
Disordered and ballistic systems
Semiclassical approximation
Introduction to quantum chaos theory, chaos and integrability in classical and quantum mechanics
Elements of random matrix theory
Specific problems of mesoscopic transport (weak localization, universal conductance fluctuations, shot noise, spin-dependent transport, etc.)
Quantum field theory away from thermodynamic equilibrium

Recommended Literature:
K. Richter, Semiclassical Theory of Mesoscopic Quantum Systems, Springer, 2000
(http://www.physik.uni-regensburg.de/forschung/richter/richter/pages/research/springer-tracts-161.pdf)
M. Brack, R. K. Bhaduri, Semiclassical Physics, Westview Press, 2003
S. Datta, Electronic Transport in Mesoscopic Systems, Cambrige University Press, 1995
M. C. Gutzwiller, Chaos in Classical and Quantum Mechanics, Springer, New York, 1990
F. Haake, Quantum signatures of chaos, Springer, 2001
M. L. Mehta, Random matrices, Elsevier, 2004
J. Imry, Introduction to mesoscopic physics, Oxford University Press
Th. Giamarchi, The physics of one-dimensional systems, Oxford University Press

Modules:

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

Course: Advanced Topics in String Theory (T)

Course No.: physics763

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:

Preparation:
Quantum Field Theory (physics755)
Group Theory (physics751)
Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)
Theoretical Particle Physics (physics615)
Superstring Theory (physics752)

Form of Testing and Examination:
active participation in exercises, written examination

Length of Course:
1 semester

Aims of the Course:
Detailed discussion of modern string theory as a candidate of a unified theory in regard to current research

Contents of the Course:
Realistic compactifications
Interactions
Effective actions
Heterotic strings in four dimensions
Intersecting D-branes

Recommended Literature:
D. Lüst, S. Theisen: Lectures on String Theory (Springer, New York 1989)
S. Förste: Strings, Branes and Extra Dimensions, Fortsch. Phys. 50 (2002) 221, hep-th/0110055
C. Johnson: D-Brane Primer (Cambridge University Press 2003)
M. Green, J. Schwarz, E. Witten: Superstring Theory I & II (Cambridge University Press 1988)
H.P. Nilles: Supersymmetry and Phenomenology (Phys. Reps. 110C (1984)1)
J. Polchinski: String Theory I & II (Cambridge University Press 2005)

Modules:

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

Course: Advanced Topics in Field and String Theory (T)

Course No.: physics764

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:
Prerequisite knowledge of Quantum Field Theory, Superstring Theory, and General Relativity is helpful.

Preparation:
Quantum Field Theory (physics755)
Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)
Superstring Theory (physics752)

Form of Testing and Examination:
active participation in exercises, oral or written examination

Length of Course:
1 semester

Aims of the Course:
An introduction into modern topics in Mathematical High Energy Physics in regard to current research areas

Contents of the Course:
String and Supergravity Theories in various dimensions
Dualities in Field Theory and String Theory
Topological Field Theories and Topological Strings
Large N dualities and integrability

Recommended Literature:
Selected review articles an arXiv.org [hep-th]
J. Polchinski: String Theory I & II
S. Weinberg: Quantum Theory of Fields

Modules:

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

Course: Advanced Topics in Quantum Field Theory (T)

Course No.: physics765

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:
Prerequisite knowledge of Quantum Field Theory

Preparation:
Quantum Field Theory (physics755)
Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)

Form of Testing and Examination:
active participation in exercises, oral or written examination

Length of Course:
1 semester

Aims of the Course:
Covers advanced topics in Quantum Field Theory that are relevant for current developments in the field.

Contents of the Course:
TBA

Recommended Literature:
Selected articles on arXiv.org [hep-th]
TBA

Modules:

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

Course: Physics of Higgs Bosons (T)

universitätbonn

Course No.: physics766

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:
Theoretical Particle Physics (physics615)

Form of Testing and Examination:
Requirement for the examination (written or oral): successful participation in the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding the physics of electroweak symmetry breaking, and the interpretations of the recently discovered signals for the existence of a Higgs boson

Contents of the Course:
Spontaneous symmetry breaking
The Higgs mechanism
The Higgs boson of the Standard Model
Experimental situation
Extended Higgs sectors
Precision calculations

Recommended Literature:
J. Gunion, H.E. Haber, G.L. Kane and S. Dawson: The Higgs Hunter's Guide (Frontiers of Physics, 2000)
A. Djouadi: Anatomy of Electroweak Symmetry Breaking I (Phys. Rep. 457 (2008) 1, hep-ph/0503173)
A. Djouadi: Anatomy of Electroweak Symmetry Breaking II (Phys. Rep. 459 (2008) 1, hep-ph/0504090)

Modules:

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

Course: Computational Methods in Condensed Matter Theory (T)

Course No.: physics767

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT/ST

Requirements:

Preparation:
Quantum Field Theory (physics755)
Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)
Advanced Theoretical Condensed Matter Physics (physics638)

Form of Testing and Examination:
Active participation in exercises, written examination

Length of Course:
1 semester

Aims of the Course:
Detailed discussion of computational tools in modern condensed matter theory

Contents of the Course:
Exact Diagonalization (ED)
Quantum Monte Carlo (QMC)
(Stochastic) Series expansion (SSE)
Density Matrix Renormalization (DMRG)
Dynamical Mean Field theory (DMFT)

Recommended Literature:
will be given in the lecture

Modules:

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

Course: General Relativity for Experimentalists (T)

Course No.: physics768

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT/ST

Requirements:

Preparation:
Theoretische Physik I & II, Analysis I & II

Form of Testing and Examination:
Weekly homework sets (50% required), Final exam

Length of Course:
1 semester

Aims of the Course:
The students shall learn the basics of general relativity and be able to apply it to applications such as experimental tests of GR, GPS, astrophysical objects and simple issues in cosmology.

Contents of the Course:
Review of special relativity
Curved spacetime of GR
Experimental tests of GR
GPS
Black holes
Gravitational waves
Introductory cosmology

Recommended Literature:
GRAVITY, by James Hartle
A FIRST COURSE IN GENERAL RELATIVITY, by Bernard Schutz
EXPLORING BLACK HOLES, by Taylor and Wheeler

Modules:

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

Course: Lattice QCD (T)

universitätbonn

Course No.: physics769

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST/WT

Requirements:

Preparation:
Quantum Mechanics 1+2, Quantum Field Theory 1

Form of Testing and Examination:
Written / oral examination

Length of Course:
1 semester

Aims of the Course:
To give an introduction to the quantum field theory on the lattice

Contents of the Course:
- Introduction: Quantum mechanics on the lattice
- Numerical algorithms
- Spin systems on the lattice: The Ising model
- Scalar field theory on the lattice: Discretization; Perturbation theory; Continuum limit
- Gauge fields: Link variables; Plaquette action; Wilson loop and confinement
- Fermions on the lattice: Fermion doubling; Different formulations for lattice fermions; Axial anomaly; Chiral fermions
- Use of Effective Field Theory methods: Extrapolation in the quark masses; Resonances in a finite volume

Recommended Literature:
J. Smit, Introduction to quantum fields on a lattice: A robust mate, Cambridge Lect. Notes Phys. (2002)

I. Montvay and G. Münster, Quantum Fields on a Lattice, Cambridge Monographs on Mathematical Physics, Cambridge University Press 1994

C. Gattringer and Ch. Lang, Quantum Chromodynamics on the Lattice: An Introductory Presentation Series: Lecture Notes in Physics, Vol. 788

H.J. Rothe, Lattice Gauge Theories: An Introduction, World Scientific, (2005)

Modules:

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

Course: universitätbonn Random Walks and Diffusion (T)

Course No.: physics7502

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

Requirements:

Preparation:
Quantum mechanics and Thermodynamics

Form of Testing and Examination:
Requirements for the (written or oral) examination: Successful work within the exercises

Length of Course:
1 semester

Aims of the Course:
The aim of the course is to introduce the student to random processes and their application to diffusion phenomena

Contents of the Course:
Basics of probability theory, Master equation and Langevin equation, Law of large numbers and Central Limit Theorem, First passage problems, Large scale dynamics, Dynamical scaling.

Recommended Literature:
Will be announced in the first lecture

Modules:

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

Course: Selected Topics in Modern Condensed Matter Theory (T)

universitätbonn

Course No.: physics7503

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:
+ Introductory Condensed Matter Theory
+ Quantum Mechanics
+ Statistical Physics

Form of Testing and Examination:
oral or written examination

Length of Course:
1 semester

Aims of the Course:
Knowledge of topics of contemporary condensed matter research
Knowledge of theoretical methods of condensed matter physics

Contents of the Course:
Covers topics and methods of contemporary research, such as
+ Feynman diagram technique
+ Phase transitions and critical phenomena
+ Topological aspects of phenomena in condensed matter physic

Recommended Literature:
R. D. Mattuck, A Guide to Feynman Diagrams in the Many-Body Problem
N. Goldenfeld, Lectures on Phase Transitions and the Renormalization Group
B. A. Bernevig, Topological Insulators and Topological Superconductors

The course can be taken in parallel to physics617 Theoretical Condensed Matter Physics.

Modules:

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

Course: universitätbonn Theory of Superconductivity and Superfluidity (T)

Course No.: physics7504

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	5	WT/ST

Requirements:

Preparation:
Quantum Mechanics, Thermodynamics and Statistics, Quantum Field Theory

Form of Testing and Examination:
Requirements for the (written or oral) examination: Successful participation in the exercises

Length of Course:
1 semester

Aims of the Course:
The goal of the course is to introduce students to the theory of superconductivity and superfluidity.

Contents of the Course:
Phenomenological theory of basic superconductivity, type I and type II superconductivity, vortices and their dynamics, Meissner-Ochsenfeld Effekt, microscopic theory of superconductivity: Gor'kov equation, BCS theory, Migdal theorem, strong coupling theory of superconductivity: Eliashberg equation, Andreev scattering, Josephson effect, Anderson theorem: impurity scattering, Collective excitations in superconductors and superfluids, Anderson (Higgs) mechanism for the mass generation. Superfluidity in 3He, superconductivity in heavy fermion compounds, high temperature superconductivity and open questions.

Recommended Literature:
Will be announced in the first lecture

Modules:

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

Course: universitätbonn 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: universitätbonn

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: universitätbonn 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: universitätbonn 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: 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**
physics730 **Theoretical Physics**

Course: Relativity and Cosmology I (T)

Course No.:

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

Requirements:

Preparation:
Training in theoretical physics at the B.Sc. level

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Introduction into Einstein's theory of general relativity and its major applications

Contents of the Course:
Gravity as a manifestation of geometry
Introduction to differential geometry
Einstein field equations
The Schwarzschild solution
Experimental tests
Gravitational waves

Recommended Literature:
T. Padmanabhan, Gravitation: Foundation and Frontiers
J. B. Hartle, Gravity: An introduction to Einstein's general relativity

Modules:

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

Course: Relativity and Cosmology II (T)

Course No.:

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

Requirements:

Preparation:
Training in theoretical physics at the B.Sc. level

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Application of Einstein's theory of general relativity to black holes and cosmology

Contents of the Course:
Black holes
Introduction to cosmology
The early Universe

Recommended Literature:
V. Mukhanov, Physical Foundations of Cosmology
T. Padmanabhan, Gravitation: Foundation and Frontiers
J. B. Hartle, Gravity: An introduction to Einstein's general relativity

Modules:	physics700 **Elective Advanced Lectures**
	physics730 **Theoretical Physics**

Course: Quantum Field Theory I (T)

Course No.:

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

Requirements:

Preparation:
Training in theoretical physics at the B.Sc. level

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Methods of quantum field theory are in use in almost all areas of modern physics. Strongly oriented towards applications, this course offers an introduction based on examples and phenomena taken from the area of solid state physics.

Contents of the Course:
Second quantization and applications
Functional integrals
Perturbation theory
Mean-field methods

Recommended Literature:
A. Altland and B.D. Simons, Condensed Matter Field Theory (Cambridge University Press, Cambridge, second edition: 2010)

Modules:	physics700 **Elective Advanced Lectures** physics730 **Theoretical Physics**

Course: Quantum Field Theory II (T)

Course No.:

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

Requirements:

Preparation:
Quantum Field Theory I

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Quantum field theory is one of the main tools of modern physics with many applications ranging from high-energy physics to solid state physics. A central topic of this course is the concept of spontaneous symmetry breaking and its relevance for phenomena like superconductivity, magnetism or mass generation in particle physics.

Contents of the Course:
Correlation functions: formalism, and their role as a bridge between theory and experiment
Renormalization
Topological concepts

Recommended Literature:
A. Altland and B.D. Simons, Condensed Matter Field Theory (Cambridge University Press, Cambridge, second edition: 2010)

Modules:

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

Course: Geometry in Physics (T)

Course No.:

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

Requirements:

Preparation:
Training in theoretical physics at the B.Sc. level

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
The course introduces the background in differential geometry necessary to understand the geometrically oriented languages of modern theoretical physics. Applications include the coordinate invariant formulation of electrodynamics, phase space and symplectic mechanics, and a brief introduction to the foundations of general relativity.

Contents of the Course:
exterior calculus
manifolds
Lie groups
fibre bundles

Recommended Literature:
M. Göckeler & T. Schücker, Differential geometry, gauge theory, and gravity, Cambridge University Press, 1987.

Modules:

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

Course: Topology for Physicists (T)

Course No.:

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

Requirements:

Preparation:
Bachelor of physics or mathematics; the basics of exterior calculus are assumed

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
This course gives an introduction to various topological concepts and results that play an important role in modern theoretical physics.

Contents of the Course:
Elements of homotopy theory: homeomorphic spaces, homotopic maps, fundamental group, covering spaces, homotopy groups, long exact homotopy sequence of a fibration
Homology and cohomology: Poincare lemma, Mayer-Vietoris sequence, Cech-deRham complex, Hurewicz isomorphism theorem, spectral sequences
Vector bundles and characteristic classes: Euler form, Thom isomorphism, Chern classes
Applications: Berry phase; Dirac monopole problem; visualization of closed differential forms by Poincare duality; cohomology of electrical conductance; supersymmetry and Morse theory; index theorems; homotopy classification of topological insulators

Recommended Literature:
R. Bott and L.W. Tu: Differential forms in algebraic topology (Springer, 1982)
A.S. Schwarz, Topology for physicists (Springer, 1994)

Modules:	physics700 **Elective Advanced Lectures** physics710 **Experimental Physics**

Course: Nuclear physics II (E)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	3	5	WT

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 of nuclear reactions, fission and fusion.

Contents of the Course:
- Kinematics in nuclear reactions
- Cross section
- Rutherford scattering
- Scattering in quantum mechanics
- The Born approximation
- Partial wave analysis
- Inelastic scattering, resonances
- Optical model
- Direct, compound, spallation and fragmentation reactions
- Neutron sources and detectors
- Neutron cross sections
- Fission
- Nuclear reactors
- Fusion
- Solar fusion
- Man-made thermonuclear fusion
- Controlled thermonuclear fusion

Recommended Literature:
A script for parts of the course will be distributed during the course.
K.S. Krane, Introductory nuclear physics, chapters 11-14

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**

Course: Particle physics (E)

Course No.:

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

Requirements:

Preparation:
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:
Introduction into particle physics, accelerators and detectors

Contents of the Course:
- Relativistic kinematics
- Interaction of radiation with matter
- Particle accelerators
- Targets and detectors
- Symmetries in particle physics
- QED
- Weak interaction, neutrinos
- Quark model
- QCD
- Standard model
- Cosmology

Recommended Literature:
A script for course will be available on-line

D.H. Perkins: Introduction to High Energy Physics, Cambridge University Press, ISBN 0521621968
H. Frauenfelder, E.M. Henley: Subatomic Physics, Prentice Hall, ISBN 0138594309
F. Halzen: A.D. Martin: Quarks and Leptons, John Wiley and Sons, ISBN 0471887412
D. Griffiths: Introduction to Elementary Particles, John Wiley and Sons ISBN: 0471603864
B. Povh, K. Rith, C. Scholz, F. Zetsche: Teilchen und Kerne, Springer-Verlag, ISBN 3540659285
C. Berger: Elementarteilchenphysik, Springer-Verlag, ISBN 3-540-41515-7

Modules:

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

Course: Groundbreaking experiments in nuclear physics (E)

Course No.:

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

Requirements:

Preparation:
Basic knowledge in Nuclear Physics

Form of Testing and Examination:
Part of 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 of original publications of fundamental experiments in nuclear physics. The students should participate actively in the course.

Contents of the Course:
- Discovery of radioactivity
- Rutherford and his many discoveries using alpha sources
- The discovery of the neutron and deuteron
- Determination of magnetic moments
- Hofstadters electron scattering experiments
- The use of cosmic rays to discover mesons
- Fermi work in neutron physics
- Properties of neutrinos
- Mößbauereffekt

Recommended Literature:
Will be distributed during the course.

Modules:

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

Course: Condensed Matter Physics II (E)

Course No.:

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

Requirements:

Preparation:
Basic knowledge in condensed matter physics and quantum mechanics

Form of Testing and Examination:
Oral examination

Length of Course:
2 semesters

Aims of the Course:
Advanced topics in condensed matter physics with examples of current research.

Contents of the Course:
The entire course (Condensed Matter I & II, given in 2 semesters) covers the following topics:
Crystal structure and binding
Reciprocal space
Lattice dynamics and thermal properties
Electronic structure (free-electron gas, Fermi surface, band structure)
Semiconductors and metals
Transport properties
Dielectric function and screening
Superconductivity
Magnetism

Recommended Literature:
Skriptum (available during the course)
Ashcroft/Mermin: Solid State Physics
Kittel: Introduction to Solid State Physics
Ibach/Lüth: Festkörperphysik

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).

Modules:	physics700 **Elective Advanced Lectures** physics730 **Theoretical Physics**

Course: Statistical physics far from equilibrium (T)

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 generic behavior of fluctuation-dominated systems far from equilibrium, and acquaintance with the basic mathematical tools used for their description.

Contents of the Course:
Stochastic methods
Transport processes
Scale-invariant growth
Pattern formation far from equilibrium

Recommended Literature:
P.L. Krapivsky, S. Redner and E. Ben-Naim: A kinetic view of statistical physics (Cambridge University Press, 2010)
M. Kardar, Statistical Physics of Fields (Cambridge University Press, 2007)

Modules:

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

Course: Disordered systems (T)

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 novel types of behaviour that arise in systems with quenched disorder, as well as the specific mathematical challenges associated with their theoretical description.

Contents of the Course:
Disorder average
Replica methods
Percolation
Phase transitions in disordered systems
Localization
Glassy dynamics

Recommended Literature:
D. Stauffer and A..Aharony, Introduction to Percolation Theory (Taylor & Francis, London 1994)
K.H. Fischer and J.A. Hertz, Spin Glasses (Cambridge University Press, Cambridge 1991)
K. Binder and W. Kob, Glassy Materials and Disordered Solids (World Scientific, Singapore 2005)
T. Nattermann, lecture notes

Modules:

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

Course: Nonequilibrium physics with interdisciplinary applications (T)

Course No.:

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

Requirements:

Preparation:
Statistical mechanics

Form of Testing and Examination:
Oral examination or term paper

Length of Course:
1 semester

Aims of the Course:
Acquaintance with basic concepts of nonequilibrium physics; ability to apply the basic methods for the investigation of nonequilibrium problems; application of physics-based models to interdisciplinary problems.

Contents of the Course:
Principles of nonequilibrium physics
Stochastic systems and their desription (master equation, Fokker-Planck equation,..)
Analytical and numerical methods
Nonequilibrium phase transitions
Applications to traffic, pedestrian dynamics, economic systems, biology, pattern formation,..

Recommended Literature:
A. Schadschneider, D. Chowdhury, K. Nishinari: Stochastic Transport in Complex Systems (Elsevier, 2010)
P.L. Krapivsky, S. Redner, E. Ben-Naim: A Kinetic View of Statistical Physics (Cambridge University Press, 2010)
V. Privman (Ed.): Nonequilibrium Statistical Mechanics in One Dimension (Cambridge University Press, 1997)
N.G.Van Kampen: Stochastic Processes in Physics and Chemistry (Elsevier, 1992)

Modules:

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

Course: Probability theory and stochastic processes for physicists (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	3	4	WT

Requirements:

Preparation:
Statistical mechanics on the bachelor level

Form of Testing and Examination:
Oral examination or term paper

Length of Course:
1 semester

Aims of the Course:
Acquaintance with probabilistic concepts and stochastic methods commonly used in the theory of disordered systems and nonequilibrium phenomena, as well as in interdisciplinary applications of statistical physics.

Contents of the Course:
Limit laws and extremal statistics
Point processes
Markov chains and birth-death processes
Stochastic differential equations and path integrals
Large deviations and rare events

Recommended Literature:
D. Sornette: Critical Phenomena in Natural Sciences (Springer, 2004)
N.G.Van Kampen: Stochastic Processes in Physics and Chemistry (Elsevier, 1992)