Module-Handbook
Master in Physics
PO von 2006

SS 2018

January 2018

We don’t offer each of these modules regularly.

For any update please see:

http://www.physik-astro.uni-bonn.de/teaching-de

Master in Physics, University of Bonn

1st Term			
physics600	physics605	physics610	physics700
Base Module: Laboratory Course	**Base Module: Theoretical Physics**	**Specialization I**	**Elective Advanced Lectures**
7 CP	7 CP	12 CP	(a)

2nd Term				
physics630	physics710	physics720	physics730	physics650
Specialization II	**Experimental Physics**	**Applied Physics**	**Theoretical Physics**	**Seminar**
12 CP	(a)			4 CP

3rd Term	
physics910	physics920
Scientific Exploration of Master Thesis Topic	**Methods and Project Planning**
15 CP	15 CP

4th Term
physics930
Master Thesis
30 CP

Notes: The students must achieve the indicated number of CP (Credit Points).
(a): In the modules 700, 710, 720, 730 at least 18 CP altogether must be achieved.

Abbreviations:

CP	Credit Points (*Leistungspunkte*)
ex.	exercises
hrs	hours
lab.	laboratory
Ma-PO	"Master-Prüfungsordnung" (Examination Regulations (Master Course))
n.a.	not applicable
ST	Summer Term
TH	Teaching Hours
WT	Winter Term
E	Experimental Physics
A	Applied Physics
T	Theoretical Physics

On proposal of the board of examination, the Dean may agree to further compulsory selectable (sub-) modules. The office of the board of examination will announce these compulsory selectable (sub-) modules agreed upon, electronically or by public notice, in due time before the beginning of the semester.

Note about programme language:
The M.Sc. in Physics programme is a programme in English language. At the discretion of the lecturer and the class German language may be used as the teaching language as well. Furthermore non-German speaking students are expected to learn German language on their own accord during the course of this programme.

Note to the points "Requirements" and "Preparation":
The point "Requirements" contains courses that have to be passed in order for the students to be able to participate in the module.
The point "Preparation" contains other courses whose content helps significantly towards the understanding of this course.

Note about module (submodule) examinations:
The details about the submodule examination will be announced by the lecturer before the start of the lecture
Please find updated versions of the module-handbook at http://www.physik-astro.uni-bonn.de

Table of Contents: M.Sc. in Physics (PO von 2006)

Module No.: physics600
Credit Points (CP): 7
Category: Required
Semester: 7.

Fachgruppe Physik und Astronomie Universität Bonn

Module: Base Module Laboratory Course

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Advanced Laboratory Course	physics601	7	Laboratory	210 hrs	WT/ST

Requirements:

Preparation:

Content:
Every student has to complete this Laboratory Course. The course consists of advanced experiments introducing into important subfields of contemporary experimental physics and astrophysics. The lab-course is accompanied by a seminar.

Aims/Skills:
The students shall gain insight in the conceptual and complex properties of relevant contemporary experiments. The students gain experience in setting up an experiment, data logging and data analysis. They experience the intricacies of forefront experimental research

Form of Testing and Examination:
Before carrying out an experiment, the students shall demonstrate to have acquired the necessary preparatory knowledge. Experiments are selected from the catalogue of laboratory set-ups offered. Cumulative lab-units of >= 9 are required.
Requirements for the submodule examination (written report for every laboratory): successful completion of the experiment and initial oral questioning

Length of Module: 1 semester

Maximum Number of Participants: 60

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Module: Base Module Laboratory Course

Module No.: physics600

Course: Advanced Laboratory Course

Course No.: physics601

Category	Type	Language	Teaching hours	CP	Semester
Required	Laboratory	English	3+2	7	WT/ST

Requirements:
Requirement for experiment 12 is astro800 Introduction to Astrophysics or an equivalent basic knowledge in astrophysics.

Preparation:
Recommended for experiment 13 is lecture astro841 Radio Astronomy: Tools, Applications, Impacts

Form of Testing and Examination:
Experiments are selected from the catalogue of laboratory set-ups offered. 9 cumulative lab-units (LU) are required. One of the experiments 1-3 is compulsory for physics students. The experiments 12-14 are compulsory for astrophysics students. Requirements for the module examination (written report for every laboratory): successful completion of the experiment and initial oral questioning

Length of Course:
1 semester

Aims of the Course:
The student shall gain insight in the intricate workings of physics in relevant advanced experiments. The student gains experience in the setting up of a proper experimental environment and experiences the intricacies of forefront experimental research and presenting his/her results.

Contents of the Course:
Advanced experiments are carried out. Experimenting time in units of 8 hrs, preparation time and report writing each ~15 hrs. Further details are listed in the catalogue of laboratories. The experiments are chosen among those being offered and after consultation with the head of the course.
In the accompanying seminar the students report about one experiment. This experiment will be selected after consultation with the head of the course.

Recommended Literature:
Hand outs and literature will be distributed with the registration for an experiment

Catalogue of laboratories: (subject to change, for an up to date catalogue see http://www.praktika.physik.uni-bonn.de/module/physics601)
1. Properties of Elementary Particles (Bubble Chamber events): 3 LU
2. Analysis of Decays of Heavy Vector Boson Z0: 3 LU
3. Atlas: 3 LU
4. Holography: 2 LU
5. Photovoltaic and Fuel Cell: 2 LU
6. Optical frequency doubling: 2 LU
7. Laser Spectroscopy: 2 LU
8. Photonic Crystals: 2 LU
9. Mößbauer-Effect: 1 LU
10. Nuclear Gamma-Gamma Angular Correlations: 1 LU
11. Beta+-Annihilation: 1 LU
12. Optical Astronomy: 3 LU
13. Wave propagation on coaxial cables and waveguides / Setup of a radio-astronomical receiver: 2 LU
14. Photometry of stars: 2 LU

Module No.: physics605
Credit Points (CP): 7
Category: Required
Semester: 7.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Base Module Theoretical Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Advanced Quantum Theory	physics606	7	Lect. + ex.	210 hrs	WT
2.	Advanced Theoretical Physics	physics607	7	Lect. + ex.	210 hrs	WT

Requirements:

Preparation:

Content:
The course provides fundamental knowledge needed for theoretical lectures in the Master course

Aims/Skills:
The M.Sc. Physics programme includes one obligatory module for all students. It includes a theoretical unit to extend the B.Sc. in Physics knowledge

Form of Testing and Examination:
Requirements for the module examination (written 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: When the student has (upon admission) demonstrated satisfactory knowledge of Advanced Quantum Theory already, the class Advanced Theoretical Physics may be taken instead

Module: Base Module Theoretical Physics

Module No.: physics605

Course: Advanced Quantum Theory

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Course No.: physics606

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

Requirements:

Preparation:
Theoretical courses at the Bachelor degree level

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

Length of Course:
1 semester

Aims of the Course:
Ability to solve problems in relativistic quantum mechanics, scattering theory and many-particle theory

Contents of the Course:
Born approximation, partial waves, resonances
advanced scattering theory: S-matrix, Lippman-Schwinger equation
relativistic wave equations: Klein-Gordon equation, Dirac equation
representations of the Lorentz group
many body theory
second quantization
basics of quantum field theory
path integral formalism
Greens functions, propagator theory

Recommended Literature:
L. D. Landau, E.M. Lifschitz; Course of Theoretical Physics Vol.3 Quantum Mechanics (Butterworth-Heinemann 1997)
J. J. Sakurai, Modern Quantum Mechanics (Addison-Wesley 1995)
F. Schwabl, Advanced Quantum Mechanics. (Springer, Heidelberg 3rd Ed. 2005)

Module: Base Module Theoretical Physics

Module No.: physics605

Course: Advanced Theoretical Physics

Course No.: physics607

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

Requirements:

Preparation:
3-year theoretical physics course with extended interest in theoretical physics and mathematics

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

Length of Course:
1 semester

Aims of the Course:
Introduction to modern methods and developments in Theoretical Physics in regard to current research

Contents of the Course:
Selected Topics in Modern Theoretical Physics for example:
Anomalies
Solitons and Instantons
Quantum Fluids
Bosonization
Renormalization Group
Bethe Ansatz
Elementary Supersymmetry
Gauge Theories and Differential Forms
Applications of Group Theory

Recommended Literature:
M. Nakahara; Geometry, Topology and Physics (Institute of Physics Publishing, London 2nd Ed. 2003)
R. Rajaraman; Solitons and Instantons, An Introduction to Solitons and Instantons in Quantum Field Theory (North Holland Personal Library, Amsterdam 3rd reprint 2003)
A. M. Tsvelik; Quantum Field Theory in Condensed Matter Physics (Cambridge University Press 2nd Ed. 2003)
A. Zee; Quantum Field Theory in a Nutshell (Princeton University Press 2003)

Module No.: physics610
Credit Points (CP): 12
Category: Elective
Semester: 7.

Fachgruppe Physik und Astronomie Universität Bonn

Module: Specialization I

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
Particle Physics						
1.	Particle Physics	physics611	6	Lect. + ex.	180 hrs	WT
2.	Accelerator Physics	physics612	6	Lect. + ex.	180 hrs	WT
3.	Physics of Particle Detectors	physics618	6	Lect. + ex.	180 hrs	WT
Condensed Matter and Photonics						
1.	Condensed Matter Physics	physics613	6	Lect. + ex.	180 hrs	WT
2.	Condensed Matter Physics I	CondMatter I	6	Lect. + ex.	180 hrs	WT
3.	Laser Physics and Nonlinear Optics	physics614	6	Lect. + ex.	180 hrs	WT
4.	Applied Photonics	physics619	6	Lect. + ex.	180 hrs	WT
5.	Advanced Atomic, Molecular, and Optical Physics	physics620	6	Lect. + ex.	180 hrs	WT
6.	Molecular Physics I	MolPhys I	6	Lect. + ex.	180 hrs	WT
Theoretical Physics						
1.	Theoretical Particle Physics	physics615	7	Lect. + ex.	210 hrs	WT
2.	Theoretical Hadron Physics	physics616	7	Lect. + ex.	210 hrs	WT
3.	Theoretical Condensed Matter Physics	physics617	7	Lect. + ex.	210 hrs	WT
4.	Solid State Theory I	TheoSolidSt	6	Lect. + ex.	180 hrs	WT

Requirements:

Preparation:
See with the description of the course

Content:
Teaching of advanced fundamentals of physics from two research areas of physics in Bonn

Aims/Skills:
The students will get acquainted with two research topics of today

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

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The student must achieve 12 CP from two different specialization areas (Particle Physics; Condensed Matter and Photonics; Theoretical Physics)

Module: Specialization I

Module No.: physics610

Course: universitätbonn Particle Physics

Course No.: physics611

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

Requirements:

Preparation:
Introductory particle physics and quantum mechanics courses

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 fundamentals of particle physics: properties of quarks and leptons and their interactions (electromagnetic, weak, strong), experiments that have led to this understanding, the Standard Model of particle physics and measurements that test this model, the structure of hadrons

Contents of the Course:
Basics: leptons and quarks, antiparticles, hadrons, forces / interactions, Feynman graphs, relativistic kinematics, two-body decay, Mandelstam variables, cross-section, lifetime
Symmetries and Conservation Laws. Positronium, Quarkonium. Accelerators and Detectors
Electromagnetic interactions: (g-2) experiments, lepton-nucleon scattering
Strong interactions: colour, gauge principle, experimental tests of QCD. Electroweak interactions and the Standard Model of particle physics: spontaneous symmetry breaking, Higgs mechanism, experimental tests of the Standard Model. Neutrino physics, neutrino oscillations; CP violation

Recommended Literature:
F Halzen, A. Martin; Quarks and Leptons (J. Wiley, Weinheim 1. Aufl. 1984)
C. Berger; Elementarteilchenphysik (Springer, Heidelberg 2. überarb. Aufl. 2006)
Perkins; Introduction to High Energy Physics (Cambridge University Press 4. Aufl. 2000)
D. Griffith; Introduction to Elementary Particle Physics (J. Wiley, Weinheim 1. Aufl. 1987)
A. Seiden; Particle Physics : A Comprehensive Introduction (2005)
Martin & Shaw; Particle Physics, Wiley (2nd edition, 1997)

Module: Specialization I

Module No.: physics610

Course: Accelerator Physics

Course No.: physics612

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

Requirements:

Preparation:

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

Length of Course:
1 semester

Aims of the Course:
Understanding of the functional principle of different types of particle accelerators
Layout and design of simple magneto-optic systems
Basic knowledge of radio frequency engineering and technology
Knowledge of linear beam dynamics in particle accelerators

Contents of the Course:
Elementary overview of different types of particle accelerators: electrostatic and induction accelerators, RFQ, Alvarez, LINAC, Cyclotron, Synchrotron, Microtron
Subsystems of particle accelerators: particle sources, RF systems, magnets, vacuum systems
Linear beam optics: equations of motion, matrix formalism, particle beams and phase space
Circular accelerators: periodic focusing systems, transverse beam dynamics, longitudinal beam dynamics
Guided tours through the ELSA accelerator of the Physics Institute and excursions to other particle accelerators (COSY, MAMI, HERA, ...) complementing the lecture

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)
Script of the Lecture "Particle Accelerators"
http://www-elsa.physik.uni-bonn.de/~hillert/Beschleunigerphysik/

Module: Specialization I

Module No.: physics610

Course: Physics of Particle Detectors

Course No.: physics618

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

Requirements:

Preparation:
Useful: physik510

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 basics of the physics of particle detectors, their operation and readout

Contents of the Course:
Physics of detectors and detection mechanisms, interactions of charged particles and photons with matter, ionization detectors, drift and diffusion, gas filled wire chambers, proportional and drift chambers, semiconductor detectors, microstrip detectors, pixel detectors, radiation damage, cerenkov detectors, transition radiation detectors, scintillation detectors (anorganic crystals and plastic scintillators), electromagnetic calorimeters, hadron calorimeters, readout techniques, VLSI readout and noise

Recommended Literature:
Wermes: Skriptum and web-based Teaching Module
K. Kleinknecht; Detectors for Particle Radiation (Cambridge University Press 2nd edition 1998)
W.R. Leo; Techniques for Nuclear and Particle Detection (Springer, Heidelberg 2nd ed. 1994)
H. Spieler, Semiconductor detector system (Oxford University Press 2005)
L. Rossi, P. Fischer, T. Rohe, N. Wermes, Pixel Detectors: From Fundamentals to Applications (Springer 2006)

Module: Specialization I

Module No.: physics610

Course: Condensed Matter Physics

Course No.: physics613

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

Requirements:

Preparation:

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

Length of Course:
1 semester

Aims of the Course:
Understanding of the concepts of condensed matter physics

Contents of the Course:
Crystallographic structures: Bravais lattices, Millers indices, crystallographic defects, structural analysis;
Chemical bonds: van der Waals bond, covalent bond, hybridisation, ionic bond, metallic bond, Hydrogen bridge bond;
Lattice vibrations: acoustic and optical phonons, specific heat, phonon-phonon interaction;
Free electrons in the solid state: free electron gas, Drude model, Fermi distribution, specific heat of the electrons;
Band structure: metals, semiconductors, insulators, effective masses, mobility of charge carrier, pn-transition, basic principles of diodes, bipolar and unipolar transistors;
Superconductivity: basic phenomena, Cooper pairs, BSC-theory and its consequences;
Magnetic properties: diamagnetism, Langevin-theory of paramagnetism, Pauli-paramagnetism, spontaneous magnetic order, molecular field, Heisenberg-exchange;
Nuclear solid state physics: Hyperfine interaction, Mössbauer spectroscopy, perturbed angular correlation, positron annihilation, typical applications.

Recommended Literature:
N. W. Ashcroft , N. D. Mermin , Solid State Physics (Brooks Cole 1976) ISBN-13: 978-0030839931
N. W. Ashcroft , N. D. Mermin, Festkörphysik (Oldenbourg 2001) ISBN-13: 978-3486248340
H. Ibach, H. Lüth, Solid-State Physics (Springer 2003) ISBN-13: 978-3540438700
H. Ibach, H. Lüth, Festkörperphysik (Springer 2002) ISBN-13: 978-3540427384
C. Kittel, Einführung in die Festkörperphysik (Oldenbourg 2006) ISBN-13: 978-3-486-57773-5
W. Demtröder, Experimentalphysik, Bd. 3. Atome, Moleküle und Festkörper (Springer 2005) ISBN-13: 978-3540214731
K. Kopitzki, P. Herzog Einführung in die Festkörperphysik (Vieweg+Teubner 2007) ISBN-13: 978-3835101449
L. Bergmann, C. Schaefer, R. Kassing, Lehrbuch der Experimentalphysik 6.: Festkörper (Gruyter 2005) ISBN-13: 978-3110174854
W. Buckel, R. Kleiner, Supraleitung (Wiley-VCH 2004) ISBN-13: 978-3527403486

Module: Specialization I

Module No.: physics610

Course: Condensed Matter Physics I

Course No.:

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

Requirements:

Preparation:
Basic knowledge in condensed matter physics and quantum mechanics

Form of Testing and Examination:
Oral or written examination

Length of Course:
2 semesters

Aims of the Course:
Comprehensive introduction to the basic principles of solid state physics and to some experimental methods. Examples of current research will be discussed.

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

Module: Specialization I

Module No.: physics610

Course: Laser Physics and Nonlinear Optics

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Course No.: physics614

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

Requirements:

Preparation:

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

Length of Course:
1 semester

Aims of the Course:
To make the students understand laser physics and nonlinear optics and enable them to practically apply their knowledge in research and development.
Pivotal experiments will be shown during the lecture. The acquired knowledge will be dealt with in depth in the exercise groups. An additional offer: interested students may build and investigate a nitrogen laser device.

Contents of the Course:
Laser physics: advanced geometric optics and wave optics (ABCDmatrix, Gauss rays, wave guides). Light-matter interaction (spontaneous/ excited processes, inversion, light intensification). Principle of the laser; mode of operation and properties of lasers (standing wave-/ring laser, mode condition, hole burning). Continuous wave laser (gas, solid states), pulsed laser (Q-switching, mode coupling), optical properties of semiconductors, semiconductor laser; dynamic properties of laser light (Schawlow-Townes line width, chaotic laser radiation). Petawatt laser, white light laser, free electron laser, laser application in telecommunications, metrology and material processing;
Nonlinear Optics: Frequency doubling, sum-, difference frequency generation, parametric oscillators, phase matching (critical, non-critical, quasi), photorefraction, nonlinear Kerr effect, 4-wave mixing.

Recommended Literature:
D. Meschede; Optik, Licht und Laser (Teubner, Wiesbaden 2. überarb. Aufl. 2005)
F. K. Kneubühl; Laser (Teubner, Wiesbaden 6th edition 2005)
J. Eichler, H.J. Eichler; Laser (Springer, Heidelberg 5th edition 2003)
R. Boyd; Nonlinear Optics (Academic Press 2003)
R. Menzel; Photonics (Springer, Berlin 2001)
Y.-R. Shen; The principles of nonlinear optics (Wiley, New York (u.a.) 1984)

Module: Specialization I

Module No.: physics610

Course: Applied Photonics

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Course No.: physics619

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

Requirements:

Preparation:

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

Length of Course:
1 semester

Aims of the Course:
To make the students understand physical and technological foundations of photonics and enable them to practically apply their knowledge in research and development.

Contents of the Course:
Optics: Rays, Beams, Waves;
Waveguides, Fibers
Light sources; Detectors; Imaging devices
Optical amplification; Acoustooptics, electrooptics
Photonic circuits, optical communication
Optical Metrology (angle, distance, velocity, density...);
Material Processing (cutting, welding, lithography, lasers in medicine)

Recommended Literature:
D. Meschede; Optik, Licht und Laser (Teubner, Wiesbaden 2. überarb. Aufl. 2005)
A. Yariv; Photonics: Optical Electronics in Modern Communications (Oxford Univ. Press 6th edition 2006)
B. Saleh, M. Teich; Fundamentals of Photonics (John Wiley & Sons, New York, 1991)
C. Yeh; Applied Photonics (Academic Press, 1994)
R. Menzel; Photonics (Springer, Berlin 2001)

Module: Specialization I

Module No.: physics610

Course: Advanced Atomic, Molecular, and Optical Physics

Course No.: physics620

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

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 aim of the course is to give the students a deeper insight to the field of atomic, molecular and optical (AMO) physics. Building on prior knowledge from the Bachelor courses it will cover advanced topics of atomic and molecular physics, as well as the interaction of light and matter.

Contents of the Course:
Atomic physics: Atoms in external fields; QED corrections: Lamb-Shift; Interaction of light and matter: Lorentz oscillator, selection rules; magnetic resonance; Coherent control

Molecular physics: Hydrogen Molecule; Vibrations and rotations of molecules; Hybridization of molecular orbitals; Feshbach Resonances; Photoassociation; Cold Molecules

Bose Condensation; Matterwave Optics

Recommended Literature:
C. J. Foot, Atomic Physics, Oxford University Press 2005
H. Haken, The physics of atoms and quanta, Springer 1996
S. Svanberg, Atomic and molecular spectroscopy basic aspects and practical applications, Springer 2001
W. Demtröder, Molecular Physics, Wiley VCH 2005
T. Buyana, Molecular physics, World Scientific 1997
W. Demtröder, Atoms, Molecules and Photons, Springer 2010
P, Meystre, Atom Optics, Springer 2010

Module: Specialization I

Module No.: physics610

Course: Molecular Physics I

Course No.:

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

Requirements:

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

Form of Testing and Examination:
Oral Examination

Length of Course:
1 semester

Aims of the Course:
In the first part of the core courses the students learn the main concepts of molecular physics: separation of electronic, vibrational and rotational motion. Simple molecular spectra can be analyzed on the basis of the problem class. Fundamental group theory is used to predict vibrational and rotational spectra of more complex molecules.

This module prepares for topics of current research in molecular physics and provides the basis for the preparation of the master thesis.

Contents of the Course:
- Basics of molecular spectroscopy, phenomenology, diatomic molecules
- Born-Oppenheimer Approximation, separation of rotation and vibration
- Molecular Dipole moment and rotational transitions
- Rotational spectra and the rigid rotor approach
- Selection rules, parallel and perpendicular type spectra
- Nuclear spin statistics
- Hyperfine structure of molecular lines

Recommended Literature:
Bernath, "Spectra of Atoms and Molecules", Oxford University Press)
Townes Schawlow, "Microwave Spectroscopy" (Dover Publications)
Gordy & Cook, Microwave Spectra" (Wiley)
Engelke, "Aufbau der Moleküle" (Teubner)
P. R. Bunker and Per Jensen: "Molecular Symmetry and Spectroscopy, 2nd Edition", (NRC Research Press, Ottawa)

Module: Specialization I

Module No.: physics610

Course: Theoretical Particle Physics

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Course No.: physics615

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

Requirements:

Preparation:
Advanced quantum theory (physics606)
Quantum field theory (physics755)
Group theory (physics751)

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 standard model of elementary particle physics and its extensions (unified theories)

Contents of the Course:
Classical field theory, gauge theories, Higgs mechanism;
Standard model of strong and electroweak interactions;
Supersymmetry and the supersymmetric extension of the standard model;
Grand unified theories (GUTs);
Neutrino physics;
Cosmological aspects of particle physics (dark matter, inflation)

Recommended Literature:
T. P. Cheng, L.F. Li: Gauge theories of elementary particle physics (Clarendon Press, Oxford 1984)
M. E. Peskin, D.V. Schroeder; An introduction to quantum field theory (Addison Wesley, 1995)
J. Wess; J. Bagger; Supersymmetry and supergravity (Princeton University Press 1992)

Module: Specialization I

Module No.: physics610

Course: Theoretical Hadron Physics

Course No.: physics616

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

Requirements:

Preparation:
Advanced quantum theory (physics606)
Quantum field theory (physics755)
Group theory (physics751)

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 theory of strong interaction, hadron structure and dynamics

Contents of the Course:
Meson and Baryon Spectra: Group theoretical Classification, Simple Quark Models
Basics of Quantum Chromodynamics: Results in Perturbation Theory
Effective Field Theory
Bethe-Salpeter Equation

Recommended Literature:
F. E. Close, An Introduction to Quarks and Partons (Academic Press 1980)
F. Donoghue, E. Golowich, B.R. Holstein; Dynamics of the Standard Model (Cambridge University Press 1994)
C. Itzykson, J.-B. Zuber; Quantum Field Theory (Dover Publications 2005)
S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)

Module: Specialization I

Module No.: physics610

Course: Theoretical Condensed Matter Physics

Course No.: physics617

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

Requirements:

Preparation:
Advanced Quantum Theory (physics606)
Quantum Field Theory (physics755)
Group theory (physics751)

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 theoretical standard methods and understanding important phenomena in the Physics of Condensed Matter

Contents of the Course:
Crystalline Solids: Lattice structure, point groups, reciprocal lattice
Elementary excitations of a crystal lattice: phonons
Electrons in a lattice; Bloch theorem, band structure
Fermi liquid theory
Magnetism
Symmetries and collective excitations in solids
Superconductivity
Integer and fractional quantum Hall effects

Recommended Literature:
N. W. Ashcroft, N.D. Mermin, Solid State Physics (Saunders College 1976)
P. M. Chaikin, T.C. Lubensky; Principles of Condensed Matter Physics (Cambridge University Press 1997)
W. Nolting; Grundkurs Theoretische Physik Band 7: Vielteilchentheorie (Springer, Heidelberg 2002)
Ch. Kittel; Quantentheorie der Festkörper (Oldenburg Verlag, München 3. Aufl. 1989)

Module: Specialization I

Module No.: physics610

Course: Solid State Theory I

Course No.:

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

Requirements:

Preparation:
training in theoretical physics at the B.Sc. level, experimental solid state physics

Form of Testing and Examination:
written or oral examination

Length of Course:
1 semester

Aims of the Course:
this course gives an introduction to the physics of electrons and phonons in solids together with theoretical concepts and techniques as applied to these systems.

Contents of the Course:
The lecture investigates basic concepts to describe solids and their excitations. Various applications are discussed with emphasis on experimental and theoretical research directions of the physics department in Cologne.

Recommended Literature:
Ashcroft/ Mermin: "Solid State Physics"

Module No.: physics630
Credit Points (CP): 12
Category: Elective
Semester: 8.

Fachgruppe Physik und Astronomie Universität Bonn

Module: Specialization II

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
Particle Physics						
1.	Physics of Hadrons	physics632	6	Lect. + ex.	180 hrs	ST
2.	High Energy Collider Physics	physics633	6	Lect. + ex.	180 hrs	ST
3.	Advanced Topics in High Energy Particle Physics	physics639	6	Lect. + ex.	180 hrs	ST
Condensed Matter and Photonics						
1.	Quantum Optics	physics631	6	Lect. + ex.	180 hrs	ST
2.	Magnetism/Superconductivity	physics634	6	Lect. + ex.	180 hrs	ST
3.	Laser Spectroscopy	physics635	6	Lect. + ex.	180 hrs	ST
4.	Photonic Devices	physics640	6	Lect. + ex.	180 hrs	ST
5.	Molecular Physics II	MolPhys II	6	Lect. + ex.	180 hrs	ST
Theoretical Physics						
1.	Advanced Theoretical Particle Physics	physics636	7	Lect. + ex.	210 hrs	ST
2.	Advanced Theoretical Hadron Physics	physics637	7	Lect. + ex.	210 hrs	ST
3.	Advanced Theoretical Condensed Matter Physics	physics638	7	Lect. + ex.	210 hrs	ST

Requirements:

Preparation:

Content:
In depth knowledge on the basics of the research programme in physics at Bonn University

Aims/Skills:
The students shall learn the basics as well as the present state of current research in the fields

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

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The student must achieve 12 CP from one or two specialization areas.

Module: Specialization II

Module No.: physics630

Course: Physics of Hadrons

Course No.: physics632

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

Requirements:

Preparation:
Completed B.Sc. in Physics, with experience in electrodynamics, 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 many-body structure of hadrons, understanding structural examinations with electromagnetic probes, introduction into experimental phenomenology

Contents of the Course:
Structure Parameters of baryons and mesons; hadronic, electromagnetic and weak probes; size, form factors and structure functions; quarks, asymptotic freedom, confinement, resonances; symmetries and symmetry breaking, hadron masses;
quark models, meson and baryon spectrum; baryon spectroscopy and exclusive reactions; missing resonances, exotic states

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)
K. Gottfried, F. Weisskopf; Concepts of Particle Physics (Oxford University Press 1986)

Module: Specialization II

Module No.: physics630

Course: universitätbonn High Energy Collider Physics

Course No.: physics633

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

Requirements:

Preparation:
physics611 (Particle Physics)

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

Length of Course:
1 semester

Aims of the Course:
In depth treatment of particle physics at high energy colliders with emphasis on LHC

Contents of the Course:
Kinematics of electron-proton and proton-(anti)proton collisions,
Electron-positron, electron-hadron and hadron-hadron reactions, hard scattering processes,
Collider machines (LEP, Tevatron and LHC) and their detectors (calorimetry and tracking),
the Standard Model of particle physics in the nutshell, fundamental questions posed to the LHC,
spontaneous symmetry breaking and experiment,
QCD and electroweak physics with high-energy hadron colliders,
Physics of the top quark, top cross section and mass measurements,
Higgs Physics at the LHC (search strategies, mass measurement, couplings),
Supersymmetry and beyond the Standard Model physics at the LHC
Determination of CKM matrix elements, CP violation in K and B systems,
Neutrino oscillations

Recommended Literature:
V. D. Barger, R. Phillips; Collider Physics (Addison-Wesley 1996)
R. K. Ellis, W.J. Stirling, B.R. Webber; QCD and Collider Physics (Cambridge University Press 2003)
D. Green; High PT Physics at Hadron Colliders (Cambridge University Press 2004)
C. Berger; Elementarteilchenphysik (Springer, Heidelberg 2nd revised edition 2006)
A. Seiden; Particle Physics A Comprehensive Introduction (Benjamin Cummings 2004)
T. Morii, C.S. Lim; S.N. Mukherjee Physics of the Standard Model and Beyond (World Scientific 2004)

Module: Specialization II

Module No.: physics630

Course: Advanced Topics in High Energy Particle Physics

Course No.: physics639

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

Requirements:

Preparation:
physics611 (Particle Physics)

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

Length of Course:
1 semester

Aims of the Course:
To discuss advanced topics of high energy particle physics which are the subject of current research efforts and to deepen understanding of experimental techniques in particle physics.

Contents of the Course:
Selected topics of current research in experimental particle physics. Topics will be updated according to progress in the field. For example:
- LHC highlights
- CP-violation experiments
- Experimental challenges in particle and astroparticle physics
- Current questions in neutrino physics

Recommended Literature:
A. Seiden; Particle Physics: A Comprehensive Introduction (Cummings 2004)
R.K. Ellis, B.R. Webber, W.J. Stirling; QCD and Collider Physics (Cambridge Monographs on Particle Physics 1996)
C. Burgess, G. Moore; The Standard Model: A Primer (Cambridge University Press 2006)
F. Halzen, A. Martin; Quarks and Leptons (J. Wiley, Weinheim 1998)
C. Berger; Elementarteilchenphysik (Springer, Heidelberg, 2. überarb. Aufl. 2006)

Module: Specialization II

Module No.: physics630

Course: Quantum Optics

Course No.: physics631

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

Requirements:

Preparation:

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

Length of Course:
1 semester

Aims of the Course:
Make the students understand quantum optics and enable them to practically apply their knowledge in research and development.

Contents of the Course:
Bloch Vector, Bloch equations,
Quantization of the electromagnetic field; representations;
coherence, correlation functions; single-mode quantum optics; squeezing;
interaction of quantized radiation and atoms;
two & three level atoms; artificial atoms;
quantum information
Laser cooling; quantum gases

Recommended Literature:
R. Loudon; The quantum theory of light (Oxford University Press 2000)
G. J. Milburn, D. F. Walls; Quantum Optics (Springer 1994)
D. Meschede; Optik, Licht und Laser (Teubner, Wiesbaden 2nd edition. 2005)
M. O. Scully, M. S. Zubairy; Quantum Optics (Cambridge 1997)
P. Meystre, M. Sargent; Elements of Quantum Optics (Springer 1999)
U. Leonhardt; Measuring the quantum state of light (Cambridge University Press,Cambridge 1997)
W. Vogel, D.-G. Welsch; Quantum Optics (Wiley VCH, 3rd edition 2006)

Module: Specialization II

Module No.: physics630

Course: Magnetism/Superconductivity

Course No.: physics634

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	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:
To give an introduction to the standard theories of both fields as major example of collective phenomena in condensed-matter physics and comparison with experiments

Contents of the Course:
Magnetism:
orbital and spin magnetism without interactions, exchange interactions, phase transitions, magnetic ordering and domains, magnetism in 1-3 dimensions, spin waves (magnons), itinerant magnetism, colossal magnetoresistance
Superconductivity:
macroscopic aspects, type I and type II superconductors, Ginzburg-Landau theory, BCS theory, Josephson effect, superfluidity, high-temperature superconductivity

Recommended Literature:
L. P. Lévy: Magnetism and superconductivity (Springer; Heidelberg 2000)
P. Mohn: Magnetism in the Solid State - An Introduction (Springer, Heidelberg 2005)
J. Crangle: Solid State Magnetism, Van Nostrand Reinhold (Springer, New York 1991)
C. N. R. Rao, B. Raveau: Colossal Magnetoresistance [...] of Manganese Oxides (World Scientific 2004)
J. F. Annett: Superconductivity, super fluids and condensates (Oxford University Press 2004)
A. Mourachkine: High-Temperature Superconductivity in Cuprates [...] (Springer/Kluwer, Berlin 2002)

Module: Specialization II

Module No.: physics630

Course: Laser Spectroscopy

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Course No.: physics635

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	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:
Make the students understand the principles of spectroscopy and enable them to practically apply their knowledge in research and development.

Contents of the Course:
Spectroscopy phenomena - time and frequency domain;
high resolution spectroscopy;
pulsed spectroscopy; frequency combs;
coherent spectroscopy; nonlinear spectroscopy: Saturation, Raman spectroscopy, Ramsey spectroscopy.
Single molecule spectroscopy; spectroscopy at interfaces & surfaces
Advanced optical imaging;
spectroscopy of cold atoms;
atomic clocks; atom interferometry

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

Module: Specialization II

Module No.: physics630

Course: Photonic Devices

Course No.: physics640

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

Requirements:

Preparation:

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:
To make the students understand physical and technological foundations of photonics and enable them to practically apply their knowledge in research and development.

Contents of the Course:
Optics: Rays, Beams, Waves; Fourieroptics;
Light sources; Detectors; Imaging devices
Waveguides, Fibers; Photonic Crystals; Metamaterials;
Optical amplification; Acoustooptics, electrooptics;
Photonic circuits, optical communication
Applications

Recommended Literature:
D. Meschede; Optik, Licht und Laser (Teubner, Wiesbaden 2. überarb. Aufl. 2005)
A. Yariv; Photonics: Optical Electronics in Modern Communications (Oxford Univ. Press 6th edition 2006)
B. Saleh, M. Teich; Fundamentals of Photonics (John Wiley & Sons, New York, 1991)
C. Yeh; Applied Photonics (Academic Press, 1994)
R. Menzel; Photonics (Springer, Berlin 2001)

Module: Specialization II

Module No.: physics630

Course: Molecular Physics II

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	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:
In the second part of the core courses more complex issues of molecular spectra are introduced. The students will be enabled to analyze spectra of complex molecules which are subject to couplings between electronic, vibrational and rotational motions.
In the special courses basic and advanced molecular physics are applied to atmospherical and astronomical environments.
This module prepares for topics of current research in molecular physics and provides the basis for the preparation of the master thesis.

Contents of the Course:
- Vibrational modes of polyatomic molecules
- Fundamentals of point group symmetry
- Vibrational dipole moment and selection rules
- Characteristic ro-vibrational spectra of selected molecules
- Breakdown of Born-Oppenheimer Approximation
- Coupling of rotation and vibration
- Coupling of angular momenta in molecular physics

Recommended Literature:
Bernath, "Spectra of Atoms and Molecules", Oxford University Press)
Townes Schawlow, "Microwave Spectroscopy" (Dover Publications)
Gordy & Cook, Microwave Spectra" (Wiley)
Engelke, "Aufbau der Moleküle" (Teubner)
P. R. Bunker and Per Jensen: "Molecular Symmetry and Spectroscopy, 2nd Edition", (NRC Research Press, Ottawa)

Module: Specialization II

Module No.: physics630

Course: Advanced Theoretical Particle Physics

Course No.: physics636

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

Requirements:

Preparation:
Theoretical Particle Physics (physics615)

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

Length of Course:
1 semester

Aims of the Course:
Survey of methods of theoretical high energy physics beyond the standard model, in particular supersymmetry and extra dimensions in regard to current research

Contents of the Course:
Introduction to supersymmetry and supergravity,
Supersymmetric extension of the electroweak standard model,
Supersymmetric grand unification,
Theories of higher dimensional space-time,
Unification in extra dimensions

Recommended Literature:
J. Wess; J. Bagger; Supersymmetry and supergravity (Princeton University Press 1992)
H. P. Nilles, Supersymmetry, Supergravity and Particle Physics, Physics Reports 110 C (1984) 1
D. Bailin; A. Love; Supersymmetric Gauge Field Theory and String Theory (IOP Publishing Ltd. 1994)
M. F. Sohnius; Introducing supersymmtry, (Phys.Res. 128 C (1985) 39)
P. Freund; Introduction to Supersymmetry (Cambridge University Press 1995)

Module: Specialization II

Module No.: physics630

Course: Advanced Theoretical Hadron Physics

Course No.: physics637

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

Requirements:

Preparation:
physics616 (Theoretical Hadron Physics)

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 methods of theoretical hadron physics in regard to current research

Contents of the Course:
Quantum Chromodynamics: Nonperturbative Results, Confinement
Lattice Gauge Theory
Chiral Perturbation Theory
Effective Field Theory for Heavy Quarks

Recommended Literature:
F. E. Close; An Introduction Quarks and Partons (Academic Press 1980)
F. Donoghue, E. Golowich, B. R. Holstein, Dynamics of the Standard Model (Cambridge University Press 1994)
C. Itzykson, J.-B. Zuber; Quantum Field Theory (Dover Publications 2006)
A. V. Manohar, M. B. Wise; Heavy Quark Physics (Cambridge University Press 2000)
S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)

Module: Specialization II

Module No.: physics630

Course: Advanced Theoretical Condensed Matter Physics

Course No.: physics638

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

Requirements:

Preparation:
physics617 (Theoretical Condensed Matter Physics)

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 methods of theoretical condensed matter physics and their application to prominent examples in regard to current research

Contents of the Course:
Bosonic systems:
Bose-Einstein condensation
Photonics

Quantum dynamics of many-electrons systems:
Feynman diagram technique for many-particle systems at finite temperature
Quantum magnetism, Kondo effect, Renormalization group techniques
Disordered systems: Electrons in a random potential
Superconductivity

Recommended Literature:
A. A. Abrikosov, L.P. Gorkov; Methods of Quantum Field Theory in Statistical Physics (Dover, New York 1977)
W. Nolting; Grundkurs Theoretische Physik Band 7: Vielteilchentheorie (Springer, Heidelberg 2002)
A. C. Hewson, The Kondo Problem to Heavy Fermions (Cambridge University Press, 1997)
C. Itzykson, J.-M. Drouffe; Statistical Field Theory (Cambridge University Press 1991)
J. R. Schrieffer; Theory of Superconductivity (Benjamin/Cummings, Reading/Mass, 1983)

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.

Module: Elective Advanced Lectures

Module No.: physics700

Course: Internships in the Research Groups

Course No.: physics799

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

Requirements:
Students are asked to contact one of the BCGS lecturers prior to the start of their internship. Lecturers provide help if needed to find a suitable research group and topic. Not all groups may have internships available at all times, thus participation may be limited.

Preparation:
A specialization lecture from the research field in question or equivalent preparation.

Form of Testing and Examination:
A written report or, alternatively, a presentation in a meeting of the research group.

Length of Course:
4-6 weeks

Aims of the Course:
Students conduct their own small research project as a part-time member of one of the research groups in Bonn. The students learn methods of scientific research and apply them to their project.

Contents of the Course:
One of the following possible items:
- setting up a small experiment,
- analyzing data from an existing experiment,
- simulating experimental situations,
- numerical or analytical calculations in a theory group.

Recommended Literature:
provided by the supervisor within the research group.

Module No.: physics710
Credit Points (CP):
Category: Elective
Semester: 8.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Experimental Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Selected 700-courses from catalogue type "E" (Experimental) or "E/A" (E/Applied)	see catalogue	3-6	see catalogue	90-180 hrs	ST/WT
2.	Courses from Cologne marked "E"	see catalogue	3-5	see catalogue	90-150 hrs	WT/ST
3.	Also possible classes from M.Sc. in Astrophysics					

Requirements:

Preparation:

Content:
Advanced lectures in experimental physics from the catalogue of selected courses

Aims/Skills:
Preparation for Master's Thesis work; broadening of scientific knowledge

Form of Testing and Examination:
If the lecture is offered with exercises: requirements for the submodule examination (written or oral examination): successful work with exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

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

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

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Applied Physics

Module Elements:

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

Requirements:

Preparation:

Content:
Advanced lectures in applied physics from the catalogue of selected courses

Aims/Skills:
Preparation for Master's Thesis work; broadening of scientific knowledge

Form of Testing and Examination:
If the lecture is offered with exercises: requirements for the submodule examination (written or oral examination): successful work with exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

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

Module No.: physics730
Credit Points (CP):
Category: Elective
Semester: 8.

Fachgruppe Physik und Astronomie Universität Bonn

Module: Theoretical Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Selected 700-courses from catalogue type "T" (Theoretical)	see catalogue	3-7	see catalogue	90-210 hrs	ST/WT
2.	Courses from Cologne marked "T"	see catalogue	4-8	see catalogue	120-240 hrs	WT/ST
3.	Also possible classes from M.Sc. in Astrophysics					

Requirements:

Preparation:

Content:
Advanced lectures in theoretical physics from the catalogue of selected courses.

Aims/Skills:
Preparation for Master's Thesis work; broadening of scientific knowledge

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

Module No.: physics650
Credit Points (CP): 4
Category: Elective
Semester: 8.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Seminar

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Seminars on Current Topics in Particle Physics		4	seminar	120 hrs	ST
2.	Seminars on Current Topics in Condensed Matter and Photonics		4	seminar	120 hrs	ST
3.	Seminars on Current Topics in Theoretical Physics		4	seminar	120 hrs	ST

Requirements:

Preparation:

Content:
Topics from the research areas covered by the research group, including current journal literature

Aims/Skills:
The students shall learn to explore a specific scientific topic with the help of libraries and electronic media. The presentation must be concise and structured

Form of Testing and Examination:
Presentation of the topic

Length of Module: 1 semester

Maximum Number of Participants: 20 per seminar

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Module No.: physics910
Credit Points (CP): 15
Category: Required
Semester: 9.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Scientific Exploration of the Master Thesis Topic

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Scientific Exploration of the Master Thesis Topic	physics911	15		450 hrs	WT

Requirements:
Successful completion of 40 credit points from the first year of the Master phase, including the Base Modules physics600 and physics605 and the Specialization Modules physics610 and physics630

Preparation:

Content:
Under guidance of the supervisor of the Master Thesis topic, the student shall explore the science field, read the relevant recent literature, and perhaps participate in further specialised classes and in seminars. The student shall write an essay about the acquired knowledge, which may serve as the introduction part of the M.Sc. thesis

Aims/Skills:
The student shall demonstrate to have understood the scientific question to be studied in the Master Thesis

Form of Testing and Examination:
Essay

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

Module No.:	physics920
Credit Points (CP):	15
Category:	Required
Semester:	9.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Methods and Project Planning

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Methods and Project Planning	physics921	15		450 hrs	WT

Requirements:
Successful completion of 40 credit points from the first year of the Master phase, including the Base Modules physics600 and physics605 and the Specialization Modules physics610 and physics630

Preparation:

Content:
Under guidance of the supervisor of the planned Master Thesis topic, the student shall acquire knowledge about the methods required to carry out the Master Thesis project. This may include the participation in specialised seminars or specialised classes for the master programme. The student shall plan the steps needed to successfully complete the Master Thesis

Aims/Skills:
The student shall demonstrate to have understood the methods to be used in the Master Thesis research. The project plan has to be presented

Form of Testing and Examination:
Short proposal for Master Thesis

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

Module No.: physics930
Credit Points (CP): 30
Category: Required
Semester: 10.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Master Thesis

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Master Thesis	physics931	30		900 hrs	ST

Requirements:
Successful completion of the preparatory phase for the Master Thesis (physics910 and physics920)

Preparation:

Content:
Under guidance of the supervisor of the Master Thesis topic, the student shall carry out the research of the Master Thesis project

Aims/Skills:
The student shall demonstrate to be able to do research

Form of Testing and Examination:
Master Thesis and oral presentation

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

Catalogue of

700-courses in

Particle Physics

Modules:

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

Course: 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: 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: 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: 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)

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: Intensive Week: Advanced Topics in High Energy Physics (E)

Course No.: physics719

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

Requirements:

Preparation:
Fundamentals of particle physics

Form of Testing and Examination:
Seminar talk

Length of Course:
1 - 2 weeks

Aims of the Course:
This course is about an advanced, current topic in particle physics. The students will gain insights into recent developments in particle physics and participate in lectures, seminars talks and laboratory projects.

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

Recommended Literature:
Will be given in the lecture.

Modules:

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

Course: universitätbonn 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:
Requirements for the examination (written or oral): submission of 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

Catalogue of

700-courses in

Condensed Matter &

Photonics

Modules:

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

Course: universitätbonn Low Temperature Physics (E/A)

Course No.: physics731

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

Requirements:

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

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

Length of Course:
1 semester

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

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

Recommended Literature:
O.V. Lounasmaa; Experimental Principles and Methods Below 1K (Academic Press, London 1974)
R.C. Richardson, E.N. Smith; Experimental Techniques in Condensed Matter Physics at Low Temperatures (Addison-Wesley 1988)
F. Pobell, Matter and Methods at Low Temperatures (Springer-Verlag, Heidelberg 2. Aufl. 1996)

Modules:

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

Course: Optics Lab (E/A)

Course No.: physics732

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

Requirements:

Preparation:

Form of Testing and Examination:
Credit points can be obtained after completion of a written report.

Length of Course:
4-6 weeks

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

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

Contents of the Course:
Practical training/internship in a research group, which can have several aspects:
- setting up a small experiment
- testing and understanding the limits of experimental components
- simulating experimental situations

Recommended Literature:
Will be given by the supervisor

Modules:

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

Course: universitätbonn Holography (E/A)

Course No.: physics734

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

Requirements:

Preparation:

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

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

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

Recommended Literature:
Lecture notes;
P. Hariharan; Optical Holography - Principles, Techniques, and Applications (Cambridge University Press, 2nd Edition, 1996)
P. Hariharan; Basics of Holography (Cambridge University Press 2002)
J. W. Goodman; Introduction to Fourier Optics (McGraw-Hill Education - Europe 2nd Ed. 2000)
A. Yariv; Photonics (Oxford University Press 6th Ed. 2006)

Modules:

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

Course: Laser Cooling and Matter Waves (E)

universitätbonn

Course No.: physics735

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

Requirements:

Preparation:
Basic thermodynamics: fundamentals of quantum mechanics, fundamentals of solid state physics

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
The in-depth lecture shows, in theory and experiments, the fundamentals of laser cooling. The application of laser cooling in atom optics, in particular for the preparation of atomic matter waves, is shown. New results in research with degenerated quantum gases enable us to gain insight into atomic many particle physics

Contents of the Course:
Outline: Light-matter interaction; mechanic effects of light; Doppler cooling; polarization gradient cooling, magneto-optical traps; optical molasses; cold atomic gases; atom interferometry; Bose-Einstein condensation of atoms; atom lasers; Mott insulator phase transitions; mixtures of quantum gases; fermionic degenerate gases

Recommended Literature:
P. v. d. Straten, H. Metcalf; Laser Cooling (Springer, Heidelberg 1999)

Modules:

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

Course: Crystal Optics (E/A)

Course No.: physics736

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

Requirements:

Preparation:

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

Length of Course:
1 semester

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

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

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

Modules:

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

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**
physics720 **Applied Physics**

Course: Modern Spectroscopy (E/A)

Course No.: physics741

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

Requirements:

Preparation:
Fundamentals of Optics, Fundamentals of Quantum Mechanics

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

Length of Course:
1 semester

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

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

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

Modules:

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

Course: 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)

Catalogue of

700-courses in

Theoretical Physics

Modules:

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

Course: universitätbonn Ultracold Atomic Gases (E/T)

Course No.: physics742

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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

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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.

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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: 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

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: 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: 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: universitätbonn 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: 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: Quantum Field Theory for Condensed Matter Physics (T)

universitätbonn

Course No.: physics759

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

Requirements:
Quantum mechanics I (physik421)

Preparation:
Quantum mechanics II (physics606), Thermodynamics and statistical physics (physik521)
Can be heard in parallel to physics617: "Theoretical Condensed Matter Physics"

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

Length of Course:
1 semester

Aims of the Course:
Knowledge of quantum field theory of interacting many-body systems at finite temperature
Knowledge of quantum field theory for non-equilibrium systems
Ability to construct and evaluate perturbation theory using Feynman diagram

Contents of the Course:
Fock space and occupation number representation for bosons and fermions
Green's functions: analytical properties and their relation to observable quantities
Elementary linear response theory
Equations of motion
Perturbation theory in thermodynamic equilibrium: Feynman diagrams, Matsubara technique
Perturbation theory away from equilibrium: Keldysh technique
Infinite resummations of perturbation expansions
Exemplary application to model system

Recommended Literature:
W. Nolting, Grundkurs Theoretische Physik 7: Vielteilchen-Theorie (Springer, Heidelberg 2009)
A. A. Abrikosov, L. P. Gorkov, I. E. Dzyaloshinskii, Methods of Quantum Field Theory in Statistical Physics (Dover, New York 1975 and later editions)
Xiao-Gang Wen, Quantum Field Theory of Many-Body Systems, Oxford Graduate Texts (Oxford University Press, Oxford 2004)
A. Altland and B. Simons, Condensed Matter Field Theory (Cambridge University Press, Cambridge 2006)

Modules:

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

Course: universitätbonn 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: 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: 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)

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: 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)

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: 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

Catalogue of

700-courses in

Special Topics

Modules:

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

Course: Environmental Physics & Energy Physics (A)

Course No.: physics771

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

Requirements:

Preparation:
Physik I-V (physik110-physik510)

Form of Testing and Examination:
Active contributions during term and written examination

Length of Course:
1 semester

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

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

Recommended Literature:
Diekmann, B., Heinloth, K.: Physikalische Grundlagen der Energieerzeugung, Teubner 1997
Hensing, I., Pfaffenberger, W., Ströbele, W.: Energiewirtschaft, 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:

universitätbonn

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: 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

Cologne Courses in General Relativity and Quantum Field Theory

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)

Cologne Courses in Nuclear and Particle Physics

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.

Cologne Courses in Condensed Matter Physics

Module: Specialization I

Module No.: physics610

Course: Condensed Matter Physics I

Course No.:

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

Requirements:

Preparation:
Basic knowledge in condensed matter physics and quantum mechanics

Form of Testing and Examination:
Oral or written examination

Length of Course:
2 semesters

Aims of the Course:
Comprehensive introduction to the basic principles of solid state physics and to some experimental methods. Examples of current research will be discussed.

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**

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)

Cologne Courses in

Molecular Physics

Module: Specialization I

Module No.: physics610

Course: Molecular Physics I

Course No.:

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

Requirements:

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

Form of Testing and Examination:
Oral Examination

Length of Course:
1 semester

Aims of the Course:
In the first part of the core courses the students learn the main concepts of molecular physics: separation of electronic, vibrational and rotational motion. Simple molecular spectra can be analyzed on the basis of the problem class. Fundamental group theory is used to predict vibrational and rotational spectra of more complex molecules.

This module prepares for topics of current research in molecular physics and provides the basis for the preparation of the master thesis.

Contents of the Course:
- Basics of molecular spectroscopy, phenomenology, diatomic molecules
- Born-Oppenheimer Approximation, separation of rotation and vibration
- Molecular Dipole moment and rotational transitions
- Rotational spectra and the rigid rotor approach
- Selection rules, parallel and perpendicular type spectra
- Nuclear spin statistics
- Hyperfine structure of molecular lines

Recommended Literature:
Bernath, "Spectra of Atoms and Molecules", Oxford University Press)
Townes Schawlow, "Microwave Spectroscopy" (Dover Publications)
Gordy & Cook, Microwave Spectra" (Wiley)
Engelke, "Aufbau der Moleküle" (Teubner)
P. R. Bunker and Per Jensen: "Molecular Symmetry and Spectroscopy, 2nd Edition", (NRC Research Press, Ottawa)

Module: Specialization II

Module No.: physics630

Course: Molecular Physics II

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	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:
In the second part of the core courses more complex issues of molecular spectra are introduced. The students will be enabled to analyze spectra of complex molecules which are subject to couplings between electronic, vibrational and rotational motions.
In the special courses basic and advanced molecular physics are applied to atmospherical and astronomical environments.
This module prepares for topics of current research in molecular physics and provides the basis for the preparation of the master thesis.

Contents of the Course:
- Vibrational modes of polyatomic molecules
- Fundamentals of point group symmetry
- Vibrational dipole moment and selection rules
- Characteristic ro-vibrational spectra of selected molecules
- Breakdown of Born-Oppenheimer Approximation
- Coupling of rotation and vibration
- Coupling of angular momenta in molecular physics

Recommended Literature:
Bernath, "Spectra of Atoms and Molecules", Oxford University Press)
Townes Schawlow, "Microwave Spectroscopy" (Dover Publications)
Gordy & Cook, Microwave Spectra" (Wiley)
Engelke, "Aufbau der Moleküle" (Teubner)
P. R. Bunker and Per Jensen: "Molecular Symmetry and Spectroscopy, 2nd Edition", (NRC Research Press, Ottawa)

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).

Cologne Courses in Statistical and Biological Physics

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)

Cologne Courses in Theoretical Solid State Physics

Module: Specialization I

Module No.: physics610

Course: Solid State Theory I

Course No.:

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

Requirements:

Preparation:
training in theoretical physics at the B.Sc. level, experimental solid state physics

Form of Testing and Examination:
written or oral examination

Length of Course:
1 semester

Aims of the Course:
this course gives an introduction to the physics of electrons and phonons in solids together with theoretical concepts and techniques as applied to these systems.

Contents of the Course:
The lecture investigates basic concepts to describe solids and their excitations. Various applications are discussed with emphasis on experimental and theoretical research directions of the physics department in Cologne.

Recommended Literature:
Ashcroft/ Mermin: "Solid State Physics"

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)