Specialization: Experimental Physics - physics61a

Module No.	**physics61a**
Category	Elective
Credit Points (CP)	6
Semester	1.

Module: Specialization: Experimental Physics

Module Elements:

Nr	Course	Course No.	CP	Type	Teaching hours	Semester
1	Particle Physics	physics611	6	Lect. + ex.	3+1	WT
2	Accelerator Physics	physics612	6	Lect. + ex.	3+1	WT
3	Physics of Particle Detectors	physics618	6	Lect. + ex.	3+1	WT
4	Condensed Matter Physics	physics613	6	Lect. + ex.	3+1	WT
5	Advanced Atomic, Molecular, and Optical Physics	physics620	6	Lect. + ex.	3+1	WT
6	Quantum Optics	physics631	6	Lect. + ex.	3+1	WT
7	Condensed Matter Physics I	CondMatter I	6	Lect. + ex.	3+1	WT
8	Molecular Physics I	MolPhys I	6	Lect. + ex.	3+1	WT

Requirements for Participation:

Form of Examination: see with the course

Content: Fundamentals in experimental physics in Bonn or Cologne

Aims/Skills: The students will get acquainted with modern research topics

Course achievement/Criteria for awarding cp's: see with the course

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: Note: The student must achieve at least 24 CP out of all 6 Specialization Modules

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Particle Physics - physics611

Course	**Particle Physics**
Course No.	physics611

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

Requirements for Participation:

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)

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Accelerator Physics - physics612

Course	**Accelerator Physics**
Course No.	physics612

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

Requirements for Participation:

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/

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Physics of Particle Detectors - physics618

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 for Participation:

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)

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Condensed Matter Physics - physics613

Course	**Condensed Matter Physics**
Course No.	physics613

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

Requirements for Participation:

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

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Advanced Atomic, Molecular, and Optical Physics - physics620

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 for Participation:

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

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Quantum Optics - physics631

Course	**Quantum Optics**
Course No.	physics631

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

Requirements for Participation:

Preparation:

Form of Testing and Examination:

Examination written or oral (announced at the beginning of the module).

Prerequisite for participation in the exam: successful work within 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:

Quantization of the electromagnetic field, single-mode quantum optics

Representations of the light field; Quasi-probabilities

Coherence, correlation functions;

Nonclassical light

Interaction of quantized radiation and atoms;

Introduction to quantum information

Recommended Literature:

R. Loudon; The quantum theory of light (Oxford University Press 2000)

G. J. Milburn, D. F. Walls; Quantum Optics (Springer 1994)

C. Gerry, P. Knight; Introductory quantum optics (Cambridge University Press 2004)

D. Meschede; Optics, Light and Lasers (Wiley-VCH, 3rd ed. 2017)

M. O. Scully, M. S. Zubairy; Quantum Optics (Cambridge 1997)

P. Meystre, M. Sargent; Elements of Quantum Optics (Springer 1999)

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Condensed Matter Physics I - CondMatter I

Course	**Condensed Matter Physics I**
Course No.	CondMatter I

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

Requirements for Participation:

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

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Molecular Physics I - MolPhys I

Course	**Molecular Physics I**
Course No.	MolPhys I

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

Requirements for Participation:

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)

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