UNIVERSITÄT
LEIPZIG

Faculty of Physics and
Earth Sciences

Course Program

Bachelor of Science

IPSP (3 years)

International Physics Study Program

For students enrolled between winter semester 2019/20
and summer semester 2022

(version of 1st October 2022)

This English translation is intended to allow English-speaking readers a better understanding of the Examination and Study Regulations. It is solely for information purposes – only the official German version is legally binding. Please check the Official Bulletins of Leipzig University for the official study and examination regulations and module descriptions.

1 Study Plan and Course Program

1.1 Study Plan – Bachelor of Science IPSP

The following plans and overviews refer to the study documents that are valid for students **enrolled between 1st October 2019 and 1st April 2022** into the 1st semester.

	Fundamentals (compulsory area)				Electives
Semester	Theoretical Physics (TP)	Experimental Physics (EP)	Labs	Mathematics (MA)	Non-Physics / Physics
1	TP1 – Classical Mechanics 1 **8 CP** / 4+2 SWS	EP1 – Mechanics **8 CP** / 4+2 SWS		MA1 – Mathematics 1 **9 CP** / 4+2 SWS	Non-Physics Electives **5 CP**
2	TP2 – Electro-dynamics 1 **8 CP** / 4+2 SWS	EP2 – Thermo- and Electrodynamics **8 CP** / 4+2 SWS		MA2 – Mathematics 2 **9 CP** / 4+2 SWS	Non-Physics Electives **5 CP**
3	TP3 – Classical Mechanics 2 & Electrodynamics 2 **8 CP** / 4+2 SWS	EP3 – Electromagn. waves / Foundations of Quantum Physics **8 CP** / 4+2 SWS	General Physics Laboratory 1 **5 CP** / 4 SWS	MA3 – Mathematics 3 **9 CP** / 4+2 SWS	
4	TP4 – Quantum Mechanics **8 CP** / 4+2 SWS	EP4 – Atomic and Molecular Physics **7 CP** / 4+2 SWS	General Physics Laboratory 2 **5 CP** / 4 SWS	Numerical Methods in Physics **5 CP** / 3+2 SWS	Non-Physics Electives **5 CP**
5	TP5 – Statistical Physics **8 CP** / 4+2 SWS	EP5 – Solid State Physics **7 CP** / 4+2 SWS			Non-Physics / Physics Electives **5 CP / 10 CP**
6	Bachelor's thesis **12 CP**		Advanced Laboratory Course **8 CP** / 6 SWS		Physics Electives **10 CP**

CP – credit points (equal to ECTS points); **SWS** – lecture hours per week (usually lecture/lab + seminar or exercises)

The fundamental modules are obligatory. Teaching content and goals are defined more or less generically in physics programs at German universities. They have arisen from the historical development of physics and thus have a historically developed relationship to each other in terms of content. The physics education at Leipzig University sets equal focus on the understanding of fundamentals in natural science by phenomenological and experimental as well as by theoretical and conceptual approaches.

It is advisable to follow the sequence of the individual modules; however, the modules are accessible and comprehensible independently of each other and even if the sequence of studies is altered. The general physics labs and the advanced lab are coordinated with the contents of the lectures in Experimental Physics and extend them by learning practical, metrological and data analytical skills.

The elective modules are divided into a non-physics elective area and physics-related modules. The non-physics electives comprise 20 CP and contain modules with interdisciplinary topics. In this area, modules of up to 10 CP can be chosen from the entire range of modules offered by Leipzig University (provided the teacher responsible for the module agrees), e.g. language or key qualification modules.

The physics-related electives comprise 20 CP too. This area contains modules for specialization in different areas of physics research such as Semiconductor Physics, Photonics and Quantum Technology, Soft-Matter Physics, Spin Resonance, Magnetism and Superconductivity, Materials Science or Astrophysics.

1.2 Course Table

Semester	Module Number	Module Title	CP
1 – 6		***Fundamental Modules (Compulsory Area)***	***128***
1	10-PHY-BIMA1	Mathematics 1 – Linear Algebra and Calculus of Functions of One Variable	9
1	12-PHY-BIEP1	Experimental Physics 1 – Mechanics	8
1	12-PHY-BIPTP1	Theoretical Physics 1 – Classical Mechanics 1	8
2	10-PHY-BIMA2	Mathematics 2 – Calculus of Functions of More Than One Variable	9
2	12-PHY-BIEP2	Experimental Physics 2 – Thermo- and Electro–dynamics	8
2	12-PHY-BIPTP2	Theoretical Physics 2 – Electrodynamics 1	8
3	10-PHY-BIMA3	Mathematics 3 – Vector Calculus and Partial Differential Equations	9
3	12-PHY-BIEP3	Experimental Physics 3 – Electromagnetic Waves and Foundations of Quantum Physics	8
3	12-PHY-BIGP1	General Physics Laboratory 1	5
3	12-PHY-BIPTP3	Theoretical Physics 3 – Classical Mechanics 2 and Electrodynamics 2	8
4	12-PHY-BWNUM	Numerical Methods in Physics	5
4	12-PHY-BIEP4	Experimental Physics 4 – Atomic and Molecular Physics	7
4	12-PHY-BIPGP2	General Physics Laboratory 2	5
4	12-PHY-BIPTP4	Theoretical Physics 4 – Quantum Mechanics	8
5	12-PHY-BIPEP5	Experimental Physics 5 – Solid State Physics	7
5	12-PHY-BIPTP5	Theoretical Physics 5 – Statistical Physics	8
6	12-PHY-BIFP	Advanced Laboratory Course	8
1 – 6		***Non-Physics Electives***	***20***
1	12-PHY-BIPC	Introduction to Chemistry	5
2	12-PHY-BIPCS *or*	Introduction to Computational Software# *or*	5
2	12-PHY-BWMS	Introduction to Computer-based Physical Modelling#	5
5/6	12-PHY-BIPP	Project Oriented Course – Subject-related Key Qualification	5
2/4/6	12-SQM-63	Women in STEM	5
1/3/5	12-SQM-64 *or*	Nachhaltige Entwicklung – Risikobewertung, Methoden und Modelle# *or*	5
1/3/5	12-PHY-BMWBNE1	Handlungskompetenz für nachhaltige Entwicklung – Grundlagenmodul#	10
1	30-PHY-BIPSQ1	Deutschkurs A1.1 (German Course A1.1)	5
2	30-PHY-BIPSQ2	Deutschkurs A1.2 (German Course A1.2)	5
3	30-PHY-BIPSQ3	Deutschkurs A2 (German Course A2)	5
1 – 6		any module(s) from other study programs*	10

4/5/6		***Physics-Related Electives *****	***20***
5	12-PHY-BW3MO1	Introduction to Photonics I	5
4/5/6	12-PHY-BMWMO2	Introduction to Polymer Physics	5
5	12-PHY-BW3CS1	Introduction to Computer Simulations I	5
5/6	12-PHY-BMWEMB	Introduction to Biophysical Methods	5
5	12-PHY-BW3HL1	Semiconductor Physics I	10
5	12-PHY-BW3HL2	Laboratory Work in Semiconductors I	5
5/6	12-PHY-BMWOFP1	Surface Physics, Nanostructures and Thin Films	5
5	12-PHY-BMWIOM2	Plasma Physics, Thin Film Deposition and Characterization	5
6	12-PHY-BMWIOM3	Microstructural Characterization	5
5	12-PHY-BMWQMAT	Quantum Matter	5
5	12-PHY-BW3QN1	Quantum Physics of Nanostructures	5
5	12-PHY-BMWQT1	Quantum Technology I	5
6	12-PHY-BMWQTPR	Quantum Technology – Lab Course	5
5	12-PHY-BW3MQ1	Spin Resonance I	5
4/6	12-PHY-BW3SU1	Superconductivity I	5
4/6	12-PHY-BW3XAS1	Stellar Physics	5
4/6	12-PHY-BMWXAS2	Stellar Physics Laboratory	5
5	12-PHY-BMWXAS3	Extragalactic Astronomy and Cosmology	5
5	12-PHY-BMWXAS4	Extragalactic Astronomy Laboratory	5

6		***Final Thesis***	***12***
6		Bachelor's Thesis	12
		Total	**180**

Only one of the two modules 12-SQM-64 and 12-PHY-BMWBNE1 as well as 12-PHY-BWMS and 12-PHY-BIPCS can be completed.

* Up to 10 CP of any module(s) offered in other study programs can be chosen according to valid cooperation agreements. Further modules can be approved by the examination board upon request.

** Please note, that not all electives can be offered once a year. Check out the Course Catalogue for the list of modules being offered in the upcoming semester.

2 Module Descriptions

2.1 Experimental Physics

Experimental Physics 1 – Mechanics

Module type	Recommended for	Module availability	Module number and ECTS
compulsory	1^{st} semester	every winter semester	**12-PHY-BIEP1** **8 CP**
Workload: 240 h	Tutorial hours: 90 h	Private study hours: 150 h	

Responsibility
Director of the Peter Debye Institute for Soft Matter Physics / Director of the Felix Bloch Institute for Solid State Physics
Teaching units (SWS / tutorial hours / private study hours)
- Lecture “Experimental Physics 1 - Mechanics” (4 SWS / 60 h / 90 h) - Exercise “Experimental Physics 1 - Mechanics” (2 SWS / 30 h / 60 h)
Participation requirements
None
Examinations (duration; weighting) and pre-examination requirements
Written exam (180 min; ×1) *Pre-examination requirements: Weekly exercises with tasks related to the module content. Points are awarded for solutions. 50% of the total points for the entire semester have to be achieved as prerequisite for admission to the exam.*

Objectives

Students grasp the basic terms, phenomena and concepts of mechanics. After active participation in the module they are able to analyze and solve problems from these areas independently. They can apply the acquired knowledge to typical experiments and transfer it to new problems. They are able to describe and discuss problems and solutions of tasks in mechanics using appropriate scientific terms.

Content

- kinematics and dynamics of the mass point, Newton’s laws, force
- Galilei transformation, accelerated reference systems, inertial forces
- special theory of relativity
- conservation laws: momentum, energy, angular momentum
- gravity and planetary motion
- systems of centres of mass, laws of impact
- statics and dynamics of rigid bodies
- oscillations, Fourier analysis
- waves, acoustics
- mechanics of deformable bodies
- mechanics of static and moving fluids
- frictional forces
- classical chaos

References

- M. Alonso / E. J. Finn: Physics, Addison-Wesley Longman
- D. Halliday / R. Resnick / J. Walker: Fundamentals of Physics, Wiley-VCH
- A. P. French "Special Relativity", The M.I.T. Introductory Physics Series

Experimental Physics 2 – Thermo- and Electrodynamics

<table>
<tr><td>Module type
compulsory</td><td>Recommended for
2nd semester</td><td>Module availability
every summer semester</td><td rowspan="2">Module number and ECTS
12-PHY-BIEP2
8 CP</td></tr>
<tr><td>Workload
240 h</td><td>Tutorial hours
90 h</td><td>Private study hours
150 h</td></tr>
<tr><td colspan="4">Responsibility
Director of the Peter Debye Institute for Soft Matter Physics / Director of the Felix Bloch Institute for Solid State Physics</td></tr>
<tr><td colspan="4">Teaching units (SWS / tutorial hours / private study hours)
- Lecture “Experimental Physics 2 - Thermo- and Electrodynamics” (4 SWS / 60 h / 90 h)
- Exercise “Experimental Physics 2 - Thermo- and Electrodynamics” (2 SWS / 30 h / 60 h)</td></tr>
<tr><td colspan="4">Participation requirements
None</td></tr>
<tr><td colspan="4">Examinations (duration; weighting) and pre-examination requirements
Written exam (180 min; ×1)
Pre-examination requirements: Weekly exercises with tasks related to the module content. Points are awarded for solutions. 50% of the total points for the entire semester have to be achieved as prerequisite for admission to the exam.</td></tr>
</table>

Objectives

Students grasp the basic terms, phenomena and concepts of thermo- and electrodynamics. After active participation in the module they are able to analyze and solve problems from these areas independently. They can apply the acquired knowledge to typical experiments and transfer it to new problems. They are able to describe and discuss problems and solutions of tasks in thermo- and electrodynamics using appropriate scientific terms.

Content

Thermodynamics

- diffusion, Brownian motion
- ideal gas, kinetic gas theory, Maxwell-Boltzmann distribution
- main theorems of thermodynamics, temperature, heat capacity
- closed and open systems, reversibility
- entropy, cyclic processes, thermodynamic machines, efficiency
- fundamentals of statistical physics, statistical definition of entropy, Boltzmann Distribution
- real gas and phase transitions
- thermal conductivity

Electro- and magnetostatics

- static electric fields: Coulomb's law, electric charge, electric field, potential and voltage, electric dipole, capacitor, dielectric displacement, Gaussian law
- static magnetic fields: current density, magnetic field, Biot-Savartes Law, forces on conductors, magnetic dipole, Ampere's Law
- moving charges: Charge carriers in electric and magnetic fields, Lorentz force
- electromagnetic properties of matter: metals, semiconductors, dielectrics

References

- M. Alonso / E. J. Finn: Physics, Addison-Wesley Longman
- D. Halliday / R. Resnick / J. Walker: Fundamentals of Physics, Wiley-VCH

Experimental Physics 3 – Electromagnetic Waves and Foundations of Quantum Physics

Module type	Recommended for	Module availability	Module number and ECTS
compulsory	3^{rd} semester	every winter semester	**12-PHY-BIEP3** **8 CP**
Workload 240 h	Tutorial hours 90 h	Private study hours 150 h	

Responsibility
Director of the Peter Debye Institute for Soft Matter Physics / Director of the Felix Bloch Institute for Solid State Physics

Teaching units (SWS / tutorial hours / private study hours)
- Lecture "Experimental Physics 3 - Electromagnetic Waves and Foundations of Quantum Physics" (4 SWS / 60 h / 90 h)
- Exercise "Experimental Physics 3 - Electromagnetic Waves and Foundations of Quantum Physics" (2 SWS / 30 h / 60 h)

Participation requirements
None

Examinations (duration; weighting) and pre-examination requirements
Written exam (180 min; ×1)

Pre-examination requirements: Weekly exercises with tasks related to the module content. Points are awarded for solutions. 50% of the total points for the entire semester have to be achieved as prerequisite for admission to the exam.

Objectives

Students grasp the basic terms, phenomena and concepts of optics and quantum physics. After active participation in the module they are able to analyze and solve problems from these areas independently. They can apply the acquired knowledge to typical experiments and transfer it to new problems. They are able to describe and discuss problems and solutions of tasks in optics and quantum physics using appropriate scientific terms.

Content

Electromagnetic waves
- electromagnetic waves: wave equation, electromagnetic spectrum, plane and spherical waves, energy transport and Poynting vector, polarization, reflection and transmission, Fresnel formulas, Hertzian dipole
- wave optics: Huygen's principle, diffraction, interference, coherence, interferometer, single and double slit, diffraction grating,

Geometrical optics:
- reflection, refraction, mirrors, lenses, prisms, optical instruments, dispersion, imaging errors

Fundamentals of quantum physics
- particle properties of light: photoelectric effect, blackbody radiation, photon gas, Planck's law of radiation
- structure of matter: Thomson's atomic model, Rutherford scattering, Rutherford's and Bohr's atomic models
- matter waves: Heisenberg principle of uncertainty, wave function, probability interpretation
- Schrödinger equation, quantum states, potential well, harmonic oscillator, tunnel effect, correspondence principle

References

- M. Alonso / E. J. Finn: Physics, Addison-Wesley Longman
- D. Halliday / R. Resnick / J. Walker: Fundamentals of Physics, Wiley-VCH

Experimental Physics 4 – Atomic and Molecular Physics

Module type	Recommended for	Module availability	Module number and ECTS
compulsory	4th semester	every summer semester	**12-PHY-BIEP4** **7 CP**
Workload: 210 h	Tutorial hours: 90 h	Private study hours: 120 h	

Responsibility
Director of the Peter Debye Institute for Soft Matter Physics / Director of the Felix Bloch Institute for Solid State Physics

Teaching units (SWS / tutorial hours / private study hours)
- Lecture "Experimental Physics 4 - Atomic and Molecular Physics" (4 SWS / 60 h / 80 h)
- Exercise "Experimental Physics 4 - Atomic and Molecular Physics" (2 SWS / 30 h / 40 h)

Participation requirements
None

Examinations (duration; weighting) and pre-examination requirements
Written exam (180 min; ×1)

Pre-examination requirements: Weekly exercises with tasks related to the module content. Points are awarded for solutions. 50% of the total points for the entire semester have to be achieved as prerequisite for admission to the exam.

Objectives

Students grasp the basic terms, phenomena and concepts of atomic and molecular physics. After active participation in the module they are able to analyze and solve problems from these areas independently. They can apply the acquired knowledge to typical experiments and transfer it to new problems. They are able to describe and discuss problems and solutions of tasks in atomic and molecular physics using appropriate scientific terms.

Content

Atomic physics:
- hydrogen atom: Schrödinger equation, orbitals, energy and angular momentum quantization
- spin and star-gerlach experiment, spin-orbit coupling, relativistic effects
- atoms with several electrons: Pauli principle, Hund's rules, systematics of atomic structure, periodic table
- atoms in external fields, spectroscopy, optical transitions, selection rules, laser
- fundamentals of quantum statistics: Fermi-Dirac and Bose-Einstein statistics, Bose- Einstein condensation

Molecular physics:
- H_2 molecule, molecular orbitals (LCAO)
- chemical bonds, hybridization, quantum chemistry
- rotation and vibration states of molecules, degrees of freedom
- molecular spectroscopy (IR-FTIR, Raman, Brillouin, NMR, fluorescence)

References

- M. Alonso / E. J. Finn: Physics, Addison-Wesley Longman
- C.J. Foot: Atomic Physics, Oxford Master Series
- H. Haken / H. C. Wolf: Molecular Physics and Elements of Quantum Chemistry, Springer
- A. P. Sutton: Electronic Structures of Materials, Oxford University Press
- C. Kittel / H. Krömer: Thermal Physics, W. H. Freeman
- H. B. Callen: Thermodynamics, Wiley
- T. L. Hill: An Introduction to statistical mechanics, Addison-Wesley

Experimental Physics 6 – Solid State Physics

Module type	Recommended for	Module availability	Module number and ECTS
compulsory	5th semester	every winter semester	**12-PHY-BIPEP5 7 CP**
Workload: 210 h	Tutorial hours: 90 h	Private study hours: 120 h	

Responsibility
Director of the Felix Bloch Institute for Solid State Physics

Teaching units (SWS / tutorial hours / private study hours)
- Lecture “Experimental Physics 6 - Solid State Physics” (4 SWS / 60 h / 80 h)
- Exercise “Experimental Physics 6 - Solid State Physics” (2 SWS / 30 h / 40 h)

Participation requirements
None

Examinations (duration; weighting) and pre-examination requirements
Oral exam (30 min; ×1)

Pre-examination requirements: Weekly exercises with tasks related to the module content. Points are awarded for solutions. 50% of the total points for the entire semester have to be achieved as prerequisite for admission to the exam.

Objectives

Students grasp the basic terms, phenomena and concepts of solid state physics. After active participation in the module they are able to analyze and solve problems from these areas independently. They can apply the acquired knowledge to typical experiments and transfer it to new problems. They are able to describe and discuss problems and solutions of tasks in solid state physics using appropriate scientific terms.

Content

- Drude model: free electron gas, Hall effect, frequency dependent conductivity, optical properties
- crystals: chemical bonds in solids, crystal structures, Bravais lattice and reciprocal lattice, diffraction methods
- lattice vibrations: classical and quantum theory of the harmonic lattice, phonons, density of states, thermal properties, elastic constants, spectroscopic methods
- conduction electrons in solids: Bloch's theorem, quasi-free electron model, band model, tight-binding model, electrical and thermal properties, magnetotransport phenomena, fundamentals of semiconductor physics and superconductivity

References

- C. Kittel "Introduction to Solid State Physics" Wiley
- J. Sólyom "Fundamentals of the Physics of Solids (Vol. 1 and 2)" Springer
- G. Grosso and G. P. Parravicini "Solid State Physics" Academic Press
- Ashcroft, Mermin "Solid State Physics" Holt-Saunders Int. Ed.
- Ibach, Lüth "Solid-State Physics" Springer
- Duan, Guojun "Introduction to Condensed Matter Physics Vol. 1" World Scientific

2.2 Theoretical Physics

Theoretical Physics 1 – Classical Mechanics 1

Module type	Recommended for	Module availability	Module number and ECTS
compulsory	1st semester	every winter semester	**12-PHY-BIPTP1** **8 CP**
Workload: 240 h	Tutorial hours: 90 h	Private study hours: 150 h	

Responsibility
Director of the Institute for Theoretical Physics
Teaching units (SWS / tutorial hours / private study hours)
- Lecture “Theoretical Physics 1 - Classical Mechanics 1” (4 SWS / 60 h / 100 h) - Exercise “Theoretical Physics 1 - Classical Mechanics 1” (2 SWS / 30 h / 50 h)
Participation requirements
None
Examinations (duration; weighting) and pre-examination requirements
Written exam (180 min; ×1) *Pre-examination requirements: Weekly exercises with tasks related to the module content. Points are awarded for solutions. 50% of the total points for the entire semester have to be achieved as prerequisite for admission to the exam.*

Objectives

The students
- learn basic principles of mechanics and can apply them to relevant problems;
- master basic calculation methods of classical mechanics;

Content

- Newton’s axioms, laws of conservation
- differentiating and integrating functions of one variable, calculating with complex numbers, solving ordinary differential equations
- non-inertial systems
- calculating with matrices and determinants, coordinate systems and rotations
- Kepler problem, mechanics of mass points and rigid bodies, small oscillations
- linear systems of equations, eigenvalue problems

References

- D. Kleppner and R.J. Kolenkov, "An Introduction to Mechanics", Cambridge University Press
- David Morin: Classical Mechanics, Cambridge
- John R. Taylor: Classical Mechanics, Univ. Sc. Books

Theoretical Physics 2 – Electrodynamics 1

Module type	Recommended for	Module availability	Module number and ECTS
compulsory	2nd semester	every summer semester	**12-PHY-BIPTP2 8 CP**
Workload: 240 h	Tutorial hours: 90 h	Private study hours: 150 h	
Responsibility: Director of the Institute for Theoretical Physics			
Teaching units (SWS / tutorial hours / private study hours): - Lecture "Theoretical Physics 2 - Electrodynamics 1" (4 SWS / 60 h / 100 h) - Exercise "Theoretical Physics 2 - Electrodynamics 1" (2 SWS / 30 h / 50 h)			
Participation requirements: none			
Examinations (duration; weighting) and pre-examination requirements: Written exam (180 min; ×1) *Pre-examination requirements: Weekly exercises with tasks related to the module content. Points are awarded for solutions. 50% of the total points for the entire semester have to be achieved as prerequisite for admission to the exam.*			

Objectives

The students
- know basic concepts of classical electrodynamics and can apply them to relevant issues;
- master basic calculation methods of classical electrodynamics;

Content

- Maxwell's equations, laws of conservation
- introduction into vector analysis in R^3: div, red, grad, area and volume integrals
- electrostatics and magnetostatics in vacuum and media, law of induction and quasi-stationary currents
- elementary solution methods for partial differential equations

References

- D.J. Griffiths "Introduction to Electrodynamics" Pearson Education 2008
- D. Jackson "Classical Electroynamics" John Wiley & Sons 1998

Theoretical Physics 3 – Classical Mechanics 2 and Electrodynamics 2

Module type	Recommended for	Module availability	Module number and ECTS
compulsory	3rd semester	every winter semester	**12-PHY-BIPTP3** **8 CP**
Workload: 240 h	Tutorial hours: 90 h	Private study hours: 150 h	
Responsibility: Director of the Institute for Theoretical Physics			
Teaching units (SWS / tutorial hours / private study hours): - Lecture “Theoretical Physics 2 - Classical Mechanics 2 and Electrodynamics 2” (4 SWS / 60 h / 100 h) - Exercise “Theoretical Physics 2 - Classical Mechanics 2 and Electrodynamics 2” (2 SWS / 30 h / 50 h)			
Participation requirements: None			
Examinations (duration; weighting) and pre-examination requirements: Written exam (180 min; ×1) *Pre-examination requirements: Weekly exercises with tasks related to the module content. Points are awarded for solutions. 50% of the total points for the entire semester have to be achieved as prerequisite for admission to the exam.*			

Objectives

The students
- know concepts of classical mechanics and electrodynamics and can apply them to relevant problems;
- gain an insight into the systematizing way of thinking and formal description of physical contents;
- are proficient in calculation methods of classical mechanics and electrodynamics;

Content

- constraints and D'Alembert's principle
- Lagrange equations of 1st and 2nd kind, Noether theorem, Hamiltonian principle
- Hamiltonian equations, canonic transformations, Hamilton-Jacobi equation, integrable systems
- special theory of relativity
- method of Green's functions for partial differential equations
- electromagnetic waves in vacuum and media, field of moving charges, radiation

References

- David Morin: Classical Mechanics, Cambridge
- John R. Taylor: Classical Mechanics, Univ. Sc. Books
- Jorge V. Jose: Classical Dynamics (A Contemporary Approach), Cambridge
- D.J. Griffiths, "Introduction to Electrodynamics", Pearson
- J.D. Jackson "Classical Electroynamics", Wiley

Theoretical Physics 4 – Quantum Mechanics

Module type	Recommended for	Module availability	Module number and ECTS
compulsory	4th semester	every summer semester	**12-PHY-BIPTP4** **8 CP**
Workload 240 h	Tutorial hours 90 h	Private study hours 150 h	

Responsibility
Director of the Institute for Theoretical Physics
Teaching units (SWS / tutorial hours / private study hours)
- Lecture “ Theoretical Physics 4 - Quantum Mechanics” (4 SWS / 60 h / 100 h) - Exercise “ Theoretical Physics 4 - Quantum Mechanics” (2 SWS / 30 h / 50 h)
Participation requirements
None
Examinations (duration; weighting) and pre-examination requirements
Written exam (180 min; ×1) *Pre-examination requirements: Weekly exercises with tasks related to the module content. Points are awarded for solutions. 50% of the total points for the entire semester have to be achieved as prerequisite for admission to the exam.*

Objectives

The students
- cover the basic concepts for the description of physical systems in quantum mechanics;
- know the concept and the formal apparatus of quantum mechanics as well as typical fields of application;
- can use it to address simple problems;

Content

- elementary phenomena, Schrödinger’s equation, superposition principle, states in Hilbert space
- observables, operators in Hilbert space, eigenvalue, spectrum, scattering, time evolution, uncertainty relation
- one-dimensional problems
- theory of angular momentum, spin
- central potentials, introduction into scattering theory and perturbation theory

References

- D.J. Griffiths "Introduction to Quantum Mechanics", Pearson Education 2005
- F. Schwabl "Quantum mechanics" Springer 2008

Theoretical Physics 5 – Statistical Physics

Module type	Recommended for	Module availability	Module number and ECTS
compulsory	5th semester	every winter semester	**12-PHY-BIPTP5** **8 CP**
Workload: 240 h	Tutorial hours: 90 h	Private study hours: 150 h	

Responsibility
Director of the Institute for Theoretical Physics

Teaching units (SWS / tutorial hours / private study hours)
- Lecture "Theoretical Physics 5 - Statistical Physics" (4 SWS / 60 h / 100 h)
- Exercise "Theoretical Physics 5 - Statistical Physics" (2 SWS / 30 h / 50 h)

Participation requirements
None

Examinations (duration; weighting) and pre-examination requirements
Written exam (180 min; ×1)

Pre-examination requirements: Weekly exercises with tasks related to the module content. Points are awarded for solutions. 50% of the total points for the entire semester have to be achieved as prerequisite for admission to the exam.

Objectives

The students
- can illustrate and explain the basic concepts of thermodynamics and statistical physics of equilibrium orally and written form;
- can use them to investigate and predict the behaviour of simple classical and quantum mechanical many-body systems in thermodynamic equilibrium;
- can examine and solve simple model problems independently and discuss their approach;

Content

- terms and principles of thermodynamics, thermodynamic potentials, equilibrium conditions, ideal and real gases, phase transitions
- basic concepts of kinetic gas theory, statistical mechanics of equilibrium, classical and quantum systems, approximation methods
- introduction into quantum statistics

References

- C. Kittel and H. Kroemer, "Thermal Physics", 2nd ed., Freeman
- M. Kardar, "Statistical Mechanics of Particles", Cambridge University Press, 2007

2.3 Laboratory Courses

General Physics Laboratory 1

Module type	Recommended for	Module availability	Module number and ECTS
compulsory	3rd semester	every winter semester	**12-PHY-BIGP1** **5 CP**
Workload 150 h	Tutorial hours 60 h	Private study hours 90 h	
Responsibility Head of the General Physics Laboratory			
Teaching units (SWS / tutorial hours / private study hours) - Laboratory “General Physics Laboratory 1” (4 SWS / 60 h / 90 h)			
Participation requirements Participation in the occupational health and safety training			
Examinations (duration; weighting) and pre-examination requirements Lab reports (10 opening tests, 10 written reports (preparation time 1 week); ×1)			

Objectives

The students
- acquire a deeper understanding of physical relations;
- know basic experimental techniques, important rules of report preparation and simple procedures of data analysis.

Content

In the basic physics laboratory 1 two experiments for data acquisition and data analysis as well as eight experiments from the fields of mechanics and electricity are to be carried out.

The practical course requires intensive preparation for each experiment so that the tasks can be executed independently.

References

- Y. Kraftmakher, Experiments and Demonstrations in Physics, World Scientific
- J.R. Taylor, An Introduction to Error Analysis

General Physics Laboratory 2

Module type	Recommended for	Module availability	Module number and ECTS
compulsory	4^{th} semester	every summer semester	**12-PHY-BIGP2** **5 CP**
Workload: 150 h	Tutorial hours: 60 h	Private study hours: 90 h	
Responsibility: Head of the General Physics Laboratory			
Teaching units (SWS / tutorial hours / private study hours): - Laboratory “General Physics Laboratory 2” (4 SWS / 60 h / 90 h)			
Participation requirements: Participation in the occupational health and safety training			
Examinations (duration; weighting) and pre-examination requirements: Lab reports (10 opening tests, 10 written reports (preparation time 1 week); ×1)			

Objectives

The students
- acquire a deeper understanding of physical relations;
- know basic experimental techniques, important rules of report preparation and simple procedures of data analysis;
- have developed the ability to critically evaluate the experimental results and set-ups;
- can present their results;
- have learned to work in a team and to communicate scientifically with each other.

Content

In the basic physics laboratory 2 ten experiments from the fields of thermodynamics, electricity, optics and atomic physics are to be carried out.

The practical course requires intensive preparation for each experiment so that the tasks can be executed independently.

References

- Y. Kraftmakher, Experiments and Demonstrations in Physics, World Scientific
- J.R. Taylor, An Introduction to Error Analysis

Advanced Laboratory Course

Module type	Recommended for	Module availability	Module number and ECTS
compulsory	6th semester	every summer semester	**12-PHY-BIFP** **8 CP**
Workload: 240 h	Tutorial hours: 90 h	Private study hours: 150 h	
Responsibility: Head of the Advanced Physics Laboratory			
Teaching units (SWS / tutorial hours / private study hours): - Laboratory "Advanced Physics Laboratory" (6 SWS / 60 h / 90 h)			
Participation requirements: Participation in the modules 12-PHY-BIEP1 to -BIEP4 or -BIGP1 and -BIGP2			
Examinations (duration; weighting) and pre-examination requirements: Lab reports (preparation time 2 weeks; ×1)			

Objectives

The students
- expand their knowledge of basic experimental procedures in modern physics and become familiar with sophisticated experimental techniques in the scientific environment of the faculty;
- gain their own experimental insights into spectroscopic standard methods and their theoretical models for the interpretation of results and can apply them independently;
- learn to adopt themselves with challenging scientific tasks, to implement them creatively, and to present and defend the physical principles and the obtained results.

Content

A total of 6 experiments must be completed in the advanced lab. The students select 6 experiments from the following experimental complexes:

- nuclear and electron spin resonance (NMR, EPR)
- optical pumping, laser spectroscopy
- molecular and lattice vibrations (IR1+2, Raman, FTIR)
- semiconductors (photoluminescence, Hall effect)
- electronic states (Franck-Hertz experiment, colour centres, Zeeman effect)
- structural analysis with X-ray scattering (XRD1+2)
- radioactivity (gamma, alpha decay)
- scanning probe microscopy (AFM, STM), mass spectrometry

The lab course requires intensive preparation for each experiment so that the tasks can be executed independently.

References

Further information can be found in the instruction manuals of the experiments (available at https://home.uni-leipzig.de/physfp/fprak_e.html)

2.4 Mathematics

Mathematics 1 – Linear Algebra and Calculus of Functions of One Variable

Module type	Recommended for	Module availability	Module number and ECTS
compulsory	1^{st} semester	every winter semester	**10-PHY-BIMA1** **9 CP**
Workload: 270 h	Tutorial hours: 90 h	Private study hours: 180 h	

Responsibility
Director of the Institute for Mathematics

Teaching units (SWS / tutorial hours / private study hours)
- Lecture "Linear Algebra and Calculus of Functions of One Variable" (4 SWS / 60 h / 110 h) - Exercise "Linear Algebra and Calculus of Functions of One Variable" (2 SWS / 30 h / 70 h)

Participation requirements
None

Examinations (duration; weighting) and pre-examination requirements
Written exam (120 min; ×1) *Pre-examination requirements: Weekly exercises with tasks related to the module content. Points are awarded for solutions. 50% of the total points for the entire semester have to be achieved as prerequisite for admission to the exam.*

Objectives

Students learn the basics of linear algebra and calculus. They are able to present and explain the acquired knowledge on concepts and terms orally and in writing and can apply it to typical problems in order to solve them independently and to justify their approach.

Content

- basic concepts of linear algebra, groups, arithmetic with matrices
- convergence of sequences and series
- continuous functions
- differential calculus for functions of a variable
- integral calculation for functions of a variable, Riemann integral

References

- Serge Lang: Linear Algebra, Springer
- Serge Lang: A First Course in Calculus, Springer
- Kenneth A. Ross: Elementary Analysis, Springer
- Stephen Abbott: Understanding Calculus, Springer

Mathematics 2 – Calculus of Functions of More Than One Variable

Module type	Recommended for	Module availability	Module number and ECTS
compulsory	2nd semester	every summer semester	**10-PHY-BIMA2** **9 CP**
Workload: 270 h	Tutorial hours: 90 h	Private study hours: 180 h	

Responsibility
Director of the Institute for Mathematics
Teaching units (SWS / tutorial hours / private study hours)
- Lecture "Calculus of Functions of More Than One Variable" (4 SWS / 60 h / 110 h) - Exercise "Calculus of Functions of More Than One Variable" (2 SWS / 30 h / 70 h)
Participation requirements
None
Examinations (duration; weighting) and pre-examination requirements
Written exam (120 min; ×1) *Pre-examination requirements: Weekly exercises with tasks related to the module content. Points are awarded for solutions. 50% of the total points for the entire semester have to be achieved as prerequisite for admission to the exam.*

Objectives

Students acquire a basic understanding in the calculus of functions of more than one variable. They are able to present and explain the acquired knowledge orally and in writing and are able to apply it to typical problems in order to solve them independently and to justify their actions.

Content

- functional sequences: even convergence, power series
- differential calculus for functions of more than one variable: derivation of functions f: R^n → R^m, chain rule, resolution theorems, Taylor's theorem, extrema, parameter-dependent integrals
- introduction to ordinary differential equations and systems

References

- Serge Lang: Calculus of Several Variables, Springer
- Vladimir I. Arnol'd: Ordinary Differential Equations, Springer

Mathematics 3 – Vector Calculus and Partial Differential Equations

Module type	Recommended for	Module availability	Module number and ECTS
compulsory	3^{rd} semester	every winter semester	**10-PHY-BIMA3** **9 CP**
Workload 270 h	Tutorial hours 90 h	Private study hours 180 h	
Responsibility Director of the Institute for Mathematics			
Teaching units (SWS / tutorial hours / private study hours) - Lecture "Vector Calculus and Partial Differential Equations" (4 SWS / 60 h / 110 h) - Exercise "Vector Calculus and Partial Differential Equations" (2 SWS / 30 h / 70 h)			
Participation requirements None			
Examinations (duration; weighting) and pre-examination requirements Written exam (120 min; ×1) *Pre-examination requirements: Weekly exercises with tasks related to the module content. Points are awarded for solutions. 50% of the total points for the entire semester have to be achieved as prerequisite for admission to the exam.*			

Objectives

Students master the basics of vector analysis and know methods for solving partial differential equations. They are able to apply the acquired knowledge to typical problems, to solve them independently and to justify their approach.

Content

- vector analysis (rotation, divergence, gradient)
- curve integrals in R^n: rectifiable curves, curve integrals, path independence, potential fields
- area integrals and surface integrals: area integrals in R^n, variable transformation, surfaces, surface integrals, sets of Gauss and Stokes in R^3
- overview of the most important partial differential equations in physics, examples of solution methods

References

- Walter Rudin: Principles of Mathematical Analysis, McGraw-Hill
- Jon Pierre Fortney: A Visual Introduction to Differential Forms and Calculus on Manifolds, Springer
- Vladimir I. Arnol'd: Lectures on Partial Differential Equations, Springer

Numerical Methods in Physics

Module type	Recommended for	Module availability	Module number and ECTS
compulsory	4^{th} semester	every summer semester	**12-PHY-BWNUM 5 CP**
Workload: 150 h	Tutorial hours: 75 h	Private study hours: 75 h	

Responsibility
Director of the Institute for Theoretical Physics
Teaching units (SWS / tutorial hours / private study hours)
- Lecture “Numerical Methods in Physics” (3 SWS / 45 h / 30 h) - Exercise “Numerical Methods in Physics” (2 SWS / 30 h / 45 h)
Participation requirements
Basic programming knowledge in C or Fortran
Examinations (duration; weighting) and pre-examination requirements
Written exam (90 min; ×1) *Pre-examination requirements: Weekly exercises with tasks related to the module content. Points are awarded for solutions. 50% of the total points for the entire semester have to be achieved as prerequisite for admission to the exam.*

Objectives

After active participation, students are able to classify and evaluate numerical methods and to understand and critically question their application potential for physical problems. For this purpose, important applications in experimental and theoretical physics are explained using common examples and the specific implementation of numerical algorithms is analysed.

Content

- interpolation and extrapolation methods, sorting methods
- algorithms for extremal optimisation
- linear algebra: inversion of matrices, determination of eigenvalues
- solution method for nonlinear equations: zero determination, fixed point theorem
- numerical differentiation and integration
- "least squares" fitting procedure, statistical methods of analysis
- ("Fast") Fourier transform
- introduction to algebraic computer programs

References

- W.H. Press, S.A. Teukolsky, W.T. Vetterling, and B.P. Flannery, "Numerical Recipes 3rd Edition - The Art of Scientific Computing" (Cambridge University Press, Cambridge, 2007)

2.5 Non-Physics Electives

Up to 10 CP of any module(s) offered in other study programs can be chosen according to valid cooperation agreements. Further modules can be approved by the examination board upon request.

Introduction to Chemistry

Module type	Recommended for	Module availability	Module number and ECTS
elective	1st semester	every winter semester	**12-PHY-BIPC** **5 CP**
Workload: 150 h	Tutorial hours: 75 h	Private study hours: 75 h	

Responsibility
Head of the department “Magnetic Resonance of Complex Quantum Solids”
Teaching units (SWS / tutorial hours / private study hours)
- Lecture “Introduction to Chemistry” (3 SWS / 45 h / 45 h) - Exercise “Introduction to Chemistry” (2 SWS / 30 h / 30 h)
Participation requirements
None
Examinations (duration; weighting) and pre-examination requirements
Oral exam (30 min; ×1) *Pre-examination requirements: Weekly exercises with tasks related to the module content. Points are awarded for solutions. 50% of the total points for the entire semester have to be achieved as prerequisite for admission to the exam.*

Objectives

The students
- extend their basic scientific education;
- develop a basic understanding of the principles, models and methods of chemistry and the underlying nomenclature;
- are able to use their acquired knowledge to participate in advanced courses in this field;

Content

- structure of matter
- chemical bond, chemical equilibrium
- chemical reactions, stoichiometry, acids and bases
- energy of chemical reactions
- chemistry of the main group elements
- chemistry of the transition elements
- organic chemistry, functional groups
- organometallics
- macromolecules

References

- J. E. Brady / J. R. Holum: Chemistry. The Study of Matter and Its Changes, Wiley
- C. E. Mortimer: Chemie: Das Basiswissen der Chemie, Georg Thieme Verlag
- T. L. Brown / H. E. LeMay / B. E. Bursten; Chemistry. The Central Science, Pearson

Introduction to Computer-based Physical Modelling

Module type	Recommended for	Module availability	Module number and ECTS
elective	2^{nd} semester	every summer semester	**12-PHY-BWMS 5 CP**
Workload: 150 h	Tutorial hours: 60 h	Private study hours: 90 h	

Responsibility
Head of the department “Molecular Nanophotonics”

Teaching units (SWS / tutorial hours / private study hours)
- Lecture “Introduction to Computer-based Physical Modelling” (2 SWS / 30 h / 45 h) - Exercise “Introduction to Computer-based Physical Modelling” (2 SWS / 30 h / 45 h)

Participation requirements
Not for students who have already completed the module 12-PHY-BIPCS.

Examinations (duration; weighting) and pre-examination requirements
Portfolio (×1)

Objectives

The aim of this module is to become familiar with the programming language Python and to apply it to problems in physics. After active participation, the students are able to analyse and graphically display experimental data in Python, to simulate physical and non-physical problems, to solve them numerically and to display them graphically. A short introduction to machine learning is intended to sensitise the students to new procedures.

Content

- basics of the programming language Python
- documentation in Jupyter Notebooks
- data exchange with files
- graphical representation of scientific data
- fitting theoretical models to experimental data
- simple numerical solutions of differential equations and systems of differential equations
- the application of numerical methods to physical processes from statistical physics, mechanics, electrostatics and electrodynamics, optics and quantum mechanics
- brief introduction to machine learning methods

References

- A. Malthe-Sørenssen: Elementary mechanics using Python, Springer, 2015
- J. M. Kinder, P. A. Nelson: A student’s guide to Python for physical modeling, Princeton University Press, 2018
- H. P. Langtangen: A primer on scientific programming with Python, Springer, 2016
- R. Maeder: Programming in Mathematica, 3. Auflage, Addison-Wesley, 1997
- R. Gaylord, S. N. Kamin, P. R. Wellin: Introduction to programming with Mathematica, TELOS, 1993
- R. Maeder: Informatik für Mathematiker und Naturwissenschaftler, Addison-Wesley, 1993
- A. Géron: Hands-on machine learning with Scikit-Learn, Keras, and Tensor Flow, O’Reilly, 2020

Alternatively, the module “Introduction to Computational Software” (12-PHY-BIPCS) might be offered. Only 1 of the 2 modules can be completed in this study program.

Introduction to Computational Software

Module type	Recommended for	Module availability	Module number and ECTS
elective	2^{nd} semester	every summer semester	**12-PHY-BIPCS 5 CP**
Workload 150 h	Tutorial hours 60 h	Private study hours 90 h	

Responsibility
Director of the Peter Debye Institute for Soft Matter Physics / Director of the Felix Bloch Institute for Solid State Physics

Teaching units (SWS / tutorial hours / private study hours)
- Lecture “Introduction to Computational Software” (2 SWS / 30 h / 45 h) - Exercise “Introduction to Computational Software” (2 SWS / 30 h / 45 h)

Participation requirements
Not for students who have already completed the module 12-PHY-BWMS.

Examinations (duration; weighting) and pre-examination requirements
Oral exam (20 min; ×1)

Objectives

The aim of this module is to learn the basics of the programming language Python and to apply it to problems in physics. After active participation, the students are able to analyse and graphically display experimental data in Python, simulate physical and non-physics problems, solve them numerically and present them graphically. A short introduction to machine learning will sensitise the students to new methods.

Content

- programming with software packages
- symbolic calculation, numerical calculations, input and output of data and graphical representations

References

- M. Kofler / H.-G. Gräbe: Mathematica, Addison-Wesley
- R. Maeder: Programming in Mathematica, Addison-Wesley
- R. J. Gaylord / S. N. Kamin / P. R, Wellin: An Introduction to Programming with Mathematica, TELOS, Springer
- R. Maeder: Informatik für Mathematiker und Naturwissenschaftler, Addison-Wesley

Alternatively, the module “Introduction to Computer-based Physical Modelling” (12-PHY-BWMS) might be offered. Only 1 of the 2 modules can be completed in this study program.

Project Oriented Course – Subject-related Key Qualification

Module type elective	Recommended for 5^{th} semester	Module availability every winter semester	Module number and ECTS **12-PHY-BIPP** **5 CP**
Workload 150 h	Tutorial hours 60 h	Private study hours 90 h	
Responsibility Director of the Peter Debye Institute for Soft Matter Physics / Director of the Felix Bloch Institute for Solid State Physics			
Teaching units (SWS / tutorial hours / private study hours) - Laboratory "Project Internship" (4 SWS / 60 h / 90 h)			
Participation requirements Participation in the module series 12-PHY-BIEP1 until -BIEP4 and 12-PHY-BIPTP1 until -BIPTP4			
Examinations (duration; weighting) and pre-examination requirements Oral presentation (30 min; ×1) *Pre-examination requirements: Laboratory work (written report at the end of the internship)*			

Objectives

The students
- acquire a deeper understanding of physical relationships;
- have learned to implement physical ideas technically;
- can plan and implement a project independently;
- can present the course and results of a project;
- have learned to work in a team and to communicate scientifically with each other.

Content

The project internship course can be carried out in the departments of the Peter Debye Institute for Soft Matter Physics, the Felix Bloch Institute for Solid State Physics as well as the Institute for Theoretical Physics, in external research institutea or using the apparatus equipment of the Physics Laboratory courses.
Topics for project practicals are offered by announcements or on the websites of the participating institutes. Project internships can be carried out individually or in groups of two.
In the project internship, the students work out an individual approach to a problem in consultation with the supervisor as well as a time schedule for carrying out the experiments or calculations or simulations. The results are presented to the department members in a presentation.
The internship requires intensive self-study so that the tasks can be worked on with a high degree of independence.

The students
- establish an individual learning biography through an internship,
- apply and expand the competencies they have learned during their studies,
- acquire an initial orientation on the job market or in research-based institutions.

References

none

Women in STEM

Module type	Recommended for	Module availability	Module number and ECTS
elective (SQ)	$2^{nd}/4^{th}/6^{th}$ semester	every summer semester	**12-SQM-63** **5 CP**
Workload: 150 h	Tutorial hours: 30 h	Private study hours: 120 h	
Responsibility: Head of the department "Structure and Properties of Complex Materials"			
Teaching units (SWS / tutorial hours / private study hours): - Seminar with Exercise part "Women in STEM" (2 SWS / 30 h / 120 h)			
Participation requirements: English language skills comparable to level B2 according to the Common European Framework of Reference			
Examinations (duration; weighting) and pre-examination requirements: Portfolio (×1)			

Objectives

After active participation in the module, students will be able to assess the underrepresentation of women in certain natural sciences, especially in physics, and at certain qualification levels and to quantify and to understand related social mechanisms. They will be able to analyze approaches to gender equality work and make their own proposals for improving the advancement of women in the interest of equality. The students acquire competences in the areas of argumentation and discussions as well as presentation techniques and are able to work with scientific literature from other disciplines.

Content

Pointing out and analyzing existing structures in the natural sciences with regard to the existing under-representation of women, discussing the relation to the current social situation, also with regard to other underrepresented groups in society, and working out approaches to solutions. History and biographies of women in natural sciences using physics as an example. Students' own experiences from their previous life and studies.

Note on the course: Part of the tutorial time will be held in the form of two block courses.

Notes on the examination: Portfolio consisting of 5 essays on different seminar topics (preparation time 2 weeks each, length 1000 – 1500 words, which corresponds to about 1.5 – 2 pages using common formatting) and a presentation followed by a discussion (preparation time 5 weeks, presentation 20 min, discussion 10 min)

References

Recommendations for further references and literature will follow in the course.

Nachhaltige Entwicklung – Risikobewertung, Methoden und Modelle (Sustainable Development – Risk Assessment, Methods and Models)

Module type	Recommended for	Module availability	Module number and ECTS
elective (SQ)	1st/3rd/5th semester	every winter semester	**12-SQM-64** **5 CP**
Workload: 150 h	Tutorial hours: 45 h	Private study hours: 105 h	
Responsibility: Head of the „Leipziger Initiative für Nachhaltige Entwicklung (LINE)“			
Teaching units (SWS / tutorial hours / private study hours): - Lecture Series “Nachhaltige Entwicklung – Risikobewertung, Methoden und Modelle” (2 SWS / 30 h / 70 h) - E-Learning Course “Nachhaltige Entwicklung – Risikobewertung, Methoden und Modelle” (1 SWS / 15 h / 35 h)			
Participation requirements: Not for students who have already completed the module 12-PHY-BMWBNE1. Language of instruction is German.			
Examinations (duration; weighting) and pre-examination requirements: Essay (preparation time 6 weeks; ×1)			

Objectives

The students know the basics for considering complex social issues and are able to evaluate socially relevant issues using quantitative models. The students know the basics of sustainable development exemplarily for selected topics of sustainable development considering the Sustainable Development Goals (Agenda 2030). These 17 global goals for sustainable development of the 2030 Agenda were adopted by the global community in 2015. They are addressed to governments worldwide, but also to civil society, the private sector and academia.

In interaction with instructors, students learn:
- how positions can be communicated in a way that is accessible to those outside the field (professional competence, social competence),
- how to look at their own opinions from a variety of perspectives in a new way, how to consider and question them (self-competence),
- to learn and act independently and on their own responsibility (methodological competence).

Content

Lecturers from all faculties of the university give an insight into their current research on social issues. Each contribution highlights where and and how models, data, and their quantitative analysis can be used to better understand the problem and to develop strategies for solving the problem while accounting for sustainability. The module will conclude with an essay on a topic of the student's choice.

References

Recommendations for further references and literature will follow in the course.

Alternatively, the module “Handlungskompetenz für nachhaltige Entwicklung – Grundlagenmodul” (12-PHY-BMWBNE1) can be chosen. However, only 1 of the 2 modules can be completed in this study program.

Handlungskompetenz für nachhaltige Entwicklung – Grundlagenmodul (Action Competence for Sustainable Development – Fundamental Module)

Module type	Recommended for	Module availability	Module number and ECTS
elective	1st/3rd/5th semester	every winter semester	**12-PHY-BMWBNE1 10 CP**
Workload 300 h	Tutorial hours 75 h	Private study hours 225 h	

Responsibility
Head of the „Leipziger Initiative für Nachhaltige Entwicklung (LINE)“
Teaching units (SWS / tutorial hours / private study hours)
- Lecture Series “Nachhaltige Entwicklung – Risikobewertung, Methoden und Modelle” (2 SWS / 30 h / 70 h) - E-Learning Course “Nachhaltige Entwicklung – Risikobewertung, Methoden und Modelle” (1 SWS / 15 h / 35 h) - Seminar “Praxisseminar I” (1 SWS / 15 h / 60 h) - Seminar “Praxisseminar II” (1 SWS / 15 h / 60 h)
Participation requirements
Not for students who have already completed the module 12-SQM-64. Language of instruction is German.
Examinations (duration; weighting) and pre-examination requirements
Oral presentation (45 min) and written report (preparation time 4 weeks); weighting ×1

Objectives

The students know the basics for considering complex social issues and are able to evaluate socially relevant issues using quantitative models. The students know the basics of sustainable development and apply acquired competencies in an exemplary manner to selected topics of sustainable development, taking into account the Sustainable Development Goals. These 17 global goals for sustainable development of the 2030 Agenda were adopted by the global community in 2015. They are addressed to governments worldwide, but also to civil society, the private sector and academia.

In interaction with instructors, students learn:

- communicate their points of view in such a way that they can be understood by non-experts (professional competence, social competence),
- to take a fresh look at their own points of view from a variety of perspectives, to consider and to question them (self-competence),
- to learn and act independently and on their own responsibility (methodological competence),
- the use of data, models and statistics to develop and evaluate concrete approaches to actions (mathematical-methodical competence).

Content

Lecturers from all faculties of the university give an insight into their current research on social issues. Each contribution highlights where and and how models, data, and their quantitative analysis can be used to better understand the problem and to develop strategies for solving the problem while accounting for sustainability. The module will conclude with an essay on a topic of the student's choice.
In the first Praxisseminar, solution strategies are developed for selected examples of socially relevant problems. The Seminar is completed with an essay (written elaboration) on a topic of the student's choice.
The results developed in this essay are presented, discussed and validated in a presentation in the second Praxisseminar.

In the module, sustainable action is thus presented in writing in relation to socially relevant issues, the own results are presented in an oral scientific discussion and feedback is given on the results of the other participants.

This fundamental module lays the foundation on which more advanced courses for the interdisciplinary university certificate "Action Competence for Sustainable Development" build on. In total, the certificate is based on 3 modules with a total of 20 CP: fundamental module, advanced module and real lab.

References	Recommendations for further references and literature will follow in the course.

Alternatively, the module "Nachhaltige Entwicklung – Risikobewertung, Methoden und Modelle" (12-SQM-64) can be chosen. However, only 1 of the 2 modules can be completed in this study program.

Deutschkurs A1.1 (German Course A1.1)

Module type	Recommended for	Module availability	Module number and ECTS
elective	1st semester	every winter semester	**30-PHY-BIPSQ1** **5 CP**
Workload 150 h	Tutorial hours 90 h	Private study hours 60 h	
Responsibility Studienkolleg Sachsen			
Teaching units (SWS / tutorial hours / private study hours) - Language course "Grundkurs Deutsch für Studierende ohne Vorkenntnisse A1.1" (6 SWS / 90 h / 60 h)			
Participation requirements Participation in the initial language test (first lecture); language of instruction is German			
Examinations (duration; weighting) and pre-examination requirements Komplexprüfung – Combined Exam (60 min; written part 45 min and oral part 15 min; ×1)			

Objectives

Students acquire basic knowledge of the German language up to level A1.1 (partial achievement of level A1 of the Common European Framework of Reference). Students develop elementary skills in the areas of reading comprehension, listening comprehension, and oral and written communication in German. As a supplement to the subject-related part of the bachelor's program in English, the German course enables better access to the new cultural environment and facilitates integration into everyday study life.

Content

At the end of the module, students achieve level A1.1, a partial achievement of level A1 of the Common European Framework of Reference. In the language course, elementary skills are developed in the areas of reading comprehension, listening comprehension and oral and written communication in German. communication in German. The course is based on a course book and workbook, the purchase of which is strongly recommended.

A language test will be taken in the first class. If students already have previous knowledge of the German language, they can, depending on the available places, participate directly in the module "Deutschkurs A2" or in the German courses of the levels B1 / B2 / C1.

Note on the examination: The "Komplexprüfung" (combined exam) consists of a written part (45 min) and an oral part (15 min). Points are awarded for both parts and a grade is given according to the total number of points.

References

In the course uses a course- and workbook is used. The purchase is strongly recommended. Recommendations for further references and literature will follow in the course.

Deutschkurs A1.2 (German Course A1.2)

<table>
<tr><td>Module type
elective</td><td>Recommended for
2nd semester</td><td>Module availability
every summer semester</td><td rowspan="2">Module number and ECTS
30-PHY-BIPSQ2
5 CP</td></tr>
<tr><td>Workload
150 h</td><td>Tutorial hours
90 h</td><td>Private study hours
60 h</td></tr>
<tr><td colspan="4">Responsibility
Studienkolleg Sachsen</td></tr>
<tr><td colspan="4">Teaching units (SWS / tutorial hours / private study hours)
- Language course “Aufbaukurs Deutsch für Studierende A1.2” (6 SWS / 90 h / 60 h)</td></tr>
<tr><td colspan="4">Participation requirements
Completion of the module 30-PHY-BIPSQ1; language of instruction is German</td></tr>
<tr><td colspan="4">Examinations (duration; weighting) and pre-examination requirements
Written Exam (90 min; ×3) and Oral Exam (15 min; ×1)</td></tr>
</table>

Objectives

Students acquire further basic knowledge of the German language and reach level A1 of the Common European Framework of Reference for Languages when completing the module.

Students can understand and use familiar, everyday expressions and very simple sentences needed in daily life. They can introduce themselves and others and ask and answer questions about themselves and others. They can express themselves on a simple level provided the other person talks slowly and clearly and is prepared to help.

Access to the new cultural environment and integration into the daily study routine will be further improved.

Content

At the end of the module students reach level A1 of the Common European Framework of Reference for Languages. In the language course the elementary skills in the areas of reading comprehension, listening comprehension and oral and written communication in German are further developed.

The language course includes the following contents:

- reading and understanding short, simple texts, which contain a highly frequented vocabulary and a certain amount of internationally known words
- spoken comprehension, when spoken very slowly and carefully and when long pauses allow time to grasp the meaning
- to communicate in a simple way, but communication may require slowly repeating, rephrasing and corrections
- asking and answering simple questions, phrasing of or reacting to simple questions
- cope with very short contact conversations by using common polite forms of greeting or salutation
- issuing invitations and apologies and responding to them
- communicate wishes and concerns in a simple, direct exchange of limited information on familiar matters
- ask for or give information in writing about the person or a simple matter
- learning limited vocabulary related to specific everyday needs
- introduction to first simple grammatical structures and sentence patterns
- learn the pronunciation of a very limited repertoire in order to be understood despite a noticeable accent

The course is based on a course book and workbook, the purchase of which is strongly recommended.

References

In the course uses a course- and workbook is used. The purchase is strongly recommended. Recommendations for further references and literature will follow in the course.

Deutschkurs A2 (German Course A2)

Module type	Recommended for	Module availability	Module number and ECTS
elective	3rd semester	every winter semester	**30-PHY-BIPSQ3** **5 CP**
Workload: 150 h	Tutorial hours: 90 h	Private study hours: 60 h	
Responsibility: Studienkolleg Sachsen			
Teaching units (SWS / tutorial hours / private study hours): - Language course “Aufbaukurs Deutsch für Studierende A2” (6 SWS / 90 h / 60 h)			
Participation requirements: Completion of the modules 30-PHY-BIPSQ1 and 30-PHY-BIPSQ2 or an equivalent result for direct entry into the module 30-PHY-BIPSQ3 in the initial language test; language of instruction is German			
Examinations (duration; weighting) and pre-examination requirements: Written Exam (90 min; ×3) and Oral Exam (15 min; ×1)			

Objectives

Students expand their basic knowledge of the German language and achieve level A2 of the Common European Framework of Reference for Languages when completing the module.
Students can understand sentences and frequently used expressions related to areas of most immediate relevance (e.g. personal and family information, shopping, work, local area). They can communicate in simple, routine situations involving a simple and direct exchange of information on familiar and routine matters. They can describe in simple terms their background and education, the immediate environment and matters in areas of immediate need.
Access to the new cultural environment will be further facilitated, thus giving them access to the academic offers of Leipzig University in the future.

Content

At the end of the module students reach level A2 of the Common European Framework of Reference for Languages. In the language course the basic skills in reading comprehension, listening comprehension and oral and written communication in German are improved.

The language course includes the following contents:
- reading and understanding (uncomplicated) factual texts on topics related to own interests and areas of expertise
- find out specific information in simple texts and recognize structures
- understanding short oral texts or narratives
- understanding the most important points when talking in clearly articulated standard language about familiar things that are normally encountered at work, in education or during leisure time
- practising simple routine conversations and easy communications in structured situations and short conversations, asking and answering questions, expressing personal opinions and exchanging information on familiar topics
- giving or asking for simple information of immediate relevance in personal letters and messages
- expressing in writing on a simple matter
- practising simple grammatical structures and sentence patterns
- improving pronunciation in general in order to be understood despite a noticeable accent;

The course is based on a course book and workbook, the purchase of which is strongly recommended.

References

In the course uses a course- and workbook is used. The purchase is strongly recommended. Recommendations for further references and literature will follow in the course.

2.6 Physics Electives

Please note, that not all electives can be offered once a year. Check out the Course Catalogue for the list of modules being offered in the upcoming semester.

Introduction to Photonics I

Module type	Recommended for	Module availability	Module number and ECTS
elective	5^{th} semester	every winter semester	**12-PHY-BW3MO1** **5 CP**
Workload	Tutorial hours	Private study hours	
150 h	45 h	105 h	
Responsibility			
Head of the department “Molecular Nanophotonics”			
Teaching units (SWS / tutorial hours / private study hours)			
- Lecture “Introduction to Photonics I” (2 SWS / 30 h / 45 h) - Exercise “Introduction to Photonics I” (1 SWS / 15 h / 60 h)			
Participation requirements			
None			
Examinations (duration; weighting) and pre-examination requirements			
Oral exam (30 min; ×1)			

Objectives

The studens
- get introduced to the principles of optics on a deeper level;
- learn special calculus for optics;
- obtain an overview of the building blocks that actively and optically manipulate light;
- gain insight into the properties of single photons and the preparation of them;
- learn basic concepts of quantum optics and quantum cryptography.

Content

During the courses of the module, students deepen their knowledge of ray-, wave and electromagnetic optics. In particular active optical building blocks, for example belonging to the field of electro- and acusto-optics, will be discussed.

Furthermore, the students will be introduced to the field of photon-optics and problems of photon statistics, single photon sources and quantum optics/quantum cryptography will be discussed.

During the seminar, calculations concerning up to date research will be discussed and using examples the experimental realisation of various measuring techniques will be explained.

References

- B. E. A. Saleh / M. C. Teich: Fundamentals of Photonics, Wiley
- D. Meschede: Optics, Light and Lasers: The Practical Approach to Modern Aspects of Photonics and Laser Physics, Wiley-VCH
- L. Mandel / E. Wolf: Optical Coherence and Quantum Optics, Cambridge University Press
- E. Hecht: Optics, Addison-Wesley

Introduction to Polymer Physics

Module type	Recommended for	Module availability	Module number and ECTS
elective	4th/5th/6th semester	irregular cycle	**12-PHY-BMWMO2 5 CP**
Workload 150 h	Tutorial hours 60 h	Private study hours 90 h	
Responsibility: Head of the department "Molecular Nanophotonics"			
Teaching units (SWS / tutorial hours / private study hours): - Lecture "Introduction to Polymer Physics" (2 SWS / 30 h / 45 h) - Seminar "Introduction to Polymer Physics" (2 SWS / 30 h / 45 h)			
Participation requirements: None			
Examinations (duration; weighting) and pre-examination requirements: Oral exam (20 min; ×1) *Pre-examination requirements: Successful presentation in the seminar (20 min)*			

Objectives

The students acquire knowledge about the structure and the structural and dynamic properties of polymers as well as about physical methods that are used for the experimental analysis and investigation of polymers. With the gained knowledge, students will be able to understand, discuss and evaluate state of the art literature in the field of polymer science. They can present a method of polymer physics in a lecture and find, select and classify the corresponding literature.

Content

Lecture: The starting point of the lecture is the structure and dynamics of polymers. Based on these properties, different experimental methods for their investigation are introduced. The following topics are covered:

Structure of polymers:
- Structure and dynamics of polymers
- Glass transition, semi-crystalline systems, mesophase separation

Structure elucidation methods:
- Infrared spectroscopy
- Atomic force microscopy
- X-ray and neutron scattering

Methods for the determination of dynamics:
- Dielectric spectroscopy
- Shear rheology (mechanical spectroscopy)
- Photon correlation spectroscopy

Seminar: Analyses of publications and presentation on selected methods.

References

- G. Strobl: The Physics of Polymers: Concepts for Understanding Their Structures and Behavior (Springer)
- B. Stuart: Infrared Spectroscopy: Fundamentals and Applications (Wiley)

Introduction to Computer Simulation I

Module type	Recommended for	Module availability	Module number and ECTS
elective	5th semester	every winter semester	**12-PHY-BW3CS1 5 CP**
Workload: 150 h	Tutorial hours: 60 h	Private study hours: 90 h	

Responsibility
Head of the department “Computer oriented quantum field theory”
Teaching units (SWS / tutorial hours / private study hours)
- Lecture “Introduction to Computer Simulation I” (2 SWS / 30 h / 45 h) - Exercise “Introduction to Computer Simulation I” (2 SWS / 30 h / 45 h)
Participation requirements
None
Examinations (duration; weighting) and pre-examination requirements
Written exam (60 min; ×1) *Pre-examination requirements: Weekly exercises with tasks related to the module content. Points are awarded for solutions. 50% of the total points for the entire semester have to be achieved as prerequisite for admission to the exam.*

Objectives

After active participation in this module, the students are able to classify the essential concepts and methods of computer simulations and to analyse different strategies for problem solving. They are familiar with common procedures and their application to examples in statistical physics. The students are able to develop their own programme codes for model problems, test their performance and check the validity by comparing them with known limiting cases.

Content

Molecular modelling of many-particle systems:

- Basic concepts of statistical physics (statistical totals and averaging, distribution and correlation functions, thermodynamic functions and transport coefficients)
- Computer simulations of many-particle systems (basic methods and algorithms, statistical-mechanical evaluations)
- Molecular dynamics (MD) in the NVE ensemble and with thermalisation (NVT)
- Metropolis Monte-Carlo (MC)
- Evaluations and relation to experiment
- Applications of MD and MC methods to simple systems

References

- M.P. Allen and D.J. Tildesley, Computer simulation of liquids, Clarendon Press, Oxford, 1987.
- R. Haberlandt, S. Fritzsche, G. Peinel, K. Heinzinger, Molekulardynamik - Grund- lagen und Anwendungen, mit Kapitel von H.L. Vörtler, Abriss der Monte-Carlo- Methode, Vieweg , Wiesbaden, 1995
- D. Frenkel and B. Smit, Understanding Molecular Simulations; From Algorithms to Applications, Academic Press, San Diego, London, 2002

Experimental Methods of Biophysics

Module type	Recommended for	Module availability	Module number and ECTS
elective	5^{th} semester	irregular cycle	**12-PHY-BMWEMB** **5 CP**
Workload 150 h	Tutorial hours 60 h	Private study hours 90 h	
Responsibility Head of the department “Molecular Biophysics”			
Teaching units (SWS / tutorial hours / private study hours) - Lecture “Experimental Methods of Biophysics” (2 SWS / 30 h / 45 h) - Seminar “Experimental Methods of Biophysics” (2 SWS / 30 h / 45 h)			
Participation requirements None			
Examinations (duration; weighting) and pre-examination requirements Oral exam (20 min; ×1) *Pre-examination requirements: Successful presentation in the seminar (20 min)*			

Objectives

The students acquire knowledge of basic physical techniques that are used for the analysis and investigation of biological systems. With the acquired knowledge, the students receive an introduction to the structure of biological matter. They will be able to understand, discuss and evaluate literature in which biophysical techniques are applied. The students can present a method of biophysics in a lecture and obtain, select and classify the corresponding literature.

Content

Lecture: Starting point of the lecture are different methods of biophysics for the investigation of structure and dynamics of biological systems and processes. The following topics are covered:

- Structure of cells
- Structure and dynamics of biomolecules
- Production and separation of biological molecules and complexes
- Mass spectrometry
- Optical spectroscopy (absorption spectroscopy, circular dichroism, fluorescence spectroscopy, vibrational spectroscopy)
- Light microscopic techniques
- Force spectroscopy
- Nuclear magnetic resonance spectroscopy
- Light and X-ray scattering
- Structure determination techniques (electron microscopy, X-ray crystallography)
- Calorimetric methods
- Numerical methods of structure modelling and bioinformatics

Seminar: Analysis of publications and presentation of selected methods.

References

- B. E. A. Saleh / M. C. Teich: Fundamentals of Photonics, Wiley
- D. Meschede: Optics, Light and Lasers: The Practical Approach to Modern Aspects of Photonics and Laser Physics, Wiley-VCH
- L. Mandel / E. Wolf: Optical Coherence and Quantum Optics, Cambridge University Press
- E. Hecht: Optics, Addison-Wesley

Semiconductor Physics I

Module type	Recommended for	Module availability	Module number and ECTS
elective	5th semester	every winter semester	**12-PHY-BW3HL1** **10 CP**
Workload: 300 h	Tutorial hours: 75 h	Private study hours: 225 h	
Responsibility: Head of the “Semiconductor Physics Group”			
Teaching units (SWS / tutorial hours / private study hours): - Lecture “Semiconductor Physics I” (4 SWS / 60 h / 120 h) - Exercise “Semiconductor Physics I” (1 SWS / 15 h / 105 h)			
Participation requirements: None			
Examinations (duration; weighting) and pre-examination requirements: Written exam (180 min; ×1) *Pre-examination requirements: Bi-weekly homework assignments related to the module content. Points are awarded for solutions. 50% of the total points for the entire semester have to be achieved as prerequisite for admission to the exam.*			

Objectives

The students
- build on a solid basic education in physics to explore a field of research at one of our physics institutes;
- acquire the basics of semiconductor physics.

Content

The basics of semiconductor physics are explained, including crystal structure, lattice vibrations, band structure, doping, transport phenomena, surfaces, optical properties, charge carrier recombination and heterostructures.

References

- M. Grundmann, The Physics of Semiconductors, Springer
- K. Seeger, Halbleiterphysik I und II, Vieweg und Teubner

Laboratory Work in Semiconductors I

Module type	Recommended for	Module availability	Module number and ECTS
elective	5^{th} semester	every winter semester	**12-PHY-BW3HL2** **5 CP**
Workload 150 h	Tutorial hours 30 h	Private study hours 120 h	
Responsibility: Head of the "Semiconductor Physics Group"			
Teaching units (SWS / tutorial hours / private study hours): - Laboratory "Laboratory Work in Semiconductors I" (2 SWS / 30 h / 120 h)			
Participation requirements: None			
Examinations (duration; weighting) and pre-examination requirements: Lab reports (8 experiments, 4 written reports (preparation time 4 weeks), 8 oral exams; ×1)			

Objectives

The students

- acquire theoretical and experimental knowledge of basic fabrication and characterisation methods in modern semiconductor physics;
- can independently apply and evaluate standard methods of experimental semiconductor physics;
- learn to familiarise themselves with problems in semiconductor physics, to solve them creatively and to present and defend the obtained results.

Content

This lab course accompanies the module Semiconductor Physics I. Experiments are carried out on state-of-the-art equipment of the semiconductor physics group, which is also in daily use in current research projects.

The module builds on the competences gained in this bachelor programme on performing experiments and complements the qualification in the field of semiconductor physics.

The students carry out 8 different experiments per semester according to a specified schedule. The lab course HLP (I) covers the growth of thin films (Pulsed Laser Deposition) and basic characterisation methods of modern semiconductor research on structure (SEM, RHEED, XRD), electrical transport (Hall effect), radiative recombination (photoluminescence), dielectric function (ellipsometry) and ferroic properties (ferroelectric and magnetic hysteresis).

The preparation for the experiments is done with the help of detailed scripts. The experiments are carried out under the guidance of a supervisor. The evaluation of the experiments is carried out by means of a report and an oral test - each of which is graded.

References

- M. Grundmann: The Physics of Semiconductors, An Introduction including Devices and Nanophysics Springer, Heidelberg, 2006; Revised and extended 2nd edition 2009.

Surface Physics, Nanostructures and Thin Films

<table>
<tr><td>Module type
elective</td><td>Recommended for
5th/6th semester</td><td>Module availability
irregular cycle</td><td rowspan="2">Module number and ECTS
12-PHY-BMWOFP1
5 CP</td></tr>
<tr><td>Workload
150 h</td><td>Tutorial hours
60 h</td><td>Private study hours
90 h</td></tr>
<tr><td colspan="4">Responsibility
Head of the department “Surface Physics”</td></tr>
<tr><td colspan="4">Teaching units (SWS / tutorial hours / private study hours)
- Lecture “Surface Physics, Nanostructures and Thin Films” (2 SWS / 30 h / 45 h)
- Seminar “Surface Physics, Nanostructures and Thin Films” (2 SWS / 30 h / 45 h)</td></tr>
<tr><td colspan="4">Participation requirements
None</td></tr>
<tr><td colspan="4">Examinations (duration; weighting) and pre-examination requirements
Oral exam (30 min; ×1)
Pre-examination requirements: Successful presentation in the seminar (30 min)</td></tr>
</table>

Objectives

After active participation in the module, the students have a comprehensive overview on the physical fundamentals of surfaces, nanostructures and thin films, as well as on their application in future-oriented areas. Based on this, they will be able to further develop their education independently in the mentioned areas by means of technical literature, in order to finally work independently. On the other hand, the participants are familiarised with the central "soft skills" of literature research, preparation of a scientific presentation and presentation techniques.

Content

Lecture:

- crystal structure, thermodynamics, electronic properties of surfaces
- surface kinetics, structure formation, surface reactions
- functionalisation of surfaces and interaction with biological cells and tissues, biocompatibility
- preparation and characterisation of well-defined surfaces
- nanoclusters, -rods and -tubes, synthesis (miniaturisation - top-down process, printing / self-organisation - bottom-up process), structure, thermodynamics, kinetics, electronic and magnetic properties
- quantum mechanical basics of low-dimensional nanostructures
- functional nanostructures for biological and medical applications
- physical fundamentals of thin films, growth modes, epitaxy, mechanical stresses in thin films, ion and electron beam assisted methods of synthesis and analysis, functional thin films

Seminar:

Accompanying the lecture, presentations are assigned on special topics in the field of application of functional surfaces, thin films and nanostructures. The focus is on applications in the fields of medicine, energy and information processing.

References

- H. Ibach, "Physics of Surfaces and Interfaces", Springer 2006
- B. Bushan, "Handbook of Nanotechnology", Springer, 2017

Plasma Physics, Thin Film Deposition and Characterization

Module type	Recommended for	Module availability	Module number and ECTS
elective	5^{th} semester	every winter semester	**12-PHY-BMWIOM2 5 CP**
Workload: 150 h	Tutorial hours: 60 h	Private study hours: 90 h	
Responsibility: Head of the department “Applied Physics”			
Teaching units (SWS / tutorial hours / private study hours): - Lecture “Plasma Physics, Thin Film Deposition and Characterization” (2 SWS / 30 h / 45 h) - Seminar “Plasma Physics, Thin Film Deposition and Characterization” (2 SWS / 30 h / 45 h)			
Participation requirements: None			
Examinations (duration; weighting) and pre-examination requirements: Oral exam (30 min; ×1)			

Objectives

The students
- gain an overview of the generation of plasmas and their interaction with surfaces
- get to know typical applications of plasmas and will apply basic measurement methods professionally
- get an introduction to modern procedures for the experimental production of thin films
- systematically develop basic principles of advanced methods for the characterisation of surfaces

Content

- history of Plasma Physics
- fundamentals of plasma physics
- plasma-wall interaction
- plasma and ion sources
- deposition technologies for thin films
- physics of thin films
- delected methods of surface and thin film analysis

References

- F.F. Chen, Plasma Physics and Controlled Fusion, Plenum Press, New York, 1984.
- Lieberman, M.A., Lichtenberg, A.J.: "Principles of Plasma Discharges and Materials Processing", Wiley 1994
- H. Bubert, H. Jenett (Eds.) "Surface and Thin Film Analysis, Principles, Instrumentation, Application", Wiley-VCH Verlag 2002
- H. Ibach, "Physics of Surfaces and Interfaces", Springer, 2006

Microstructural Characterization

<table>
<tr><td>Module type
elective</td><td>Recommended for
6th semester</td><td>Module availability
every summer semester</td><td rowspan="2">Module number and ECTS
12-PHY-BMWIOM3
5 CP</td></tr>
<tr><td>Workload
150 h</td><td>Tutorial hours
45 h</td><td>Private study hours
105 h</td></tr>
<tr><td colspan="4">Responsibility
Head of the department “Applied Physics”</td></tr>
<tr><td colspan="4">Teaching units (SWS / tutorial hours / private study hours)
- Lecture “Microstructural Characterization” (2 SWS / 30 h / 45 h)
- Seminar “Microstructural Characterization” (1 SWS / 15 h / 60 h)</td></tr>
<tr><td colspan="4">Participation requirements
None</td></tr>
<tr><td colspan="4">Examinations (duration; weighting) and pre-examination requirements
Oral exam (30 min; ×1)
Pre-examination requirements: Successful presentation in the seminar (25 min)</td></tr>
</table>

Objectives

Students acquire knowledge of scientific analysis methods (based on electron microscopy techniques) used in micro- and nanostructure characterisation of materials. With the acquired knowledge, the students are able to select optimal analytical methods for the structural and chemical characterisation of complex materials. They deepen their knowledge by giving a presentation in the seminar and by the demonstration of various techniques on scientific equipment.

Content

Basics of transmission and scanning electron microscopy (structure, e-sources, e-optics, resolution); sample preparation (conventional, FIB); analytical methods (imaging, diffraction, image simulation); analytical electron microscopy (EDX, EELS); examples from own research

References

- D. Brandon and W.D. Kaplan, Microstructural Characterization of Materials, 2nd Edition, John Willey and Sons Ltd., 2008
- R.F. Egerton, Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, Springer International Publishing, 2016
- D.B. Willams and C.B. Carter, Transmission electron microscopy: A Textbook for Materials Science, Plenum Publishing Corporation, 2009
- J.M. Zhou, J.C.H. Spence, Advanced Transmission Electron Microscopy: Imaging and Diffraction in Nanoscience, Springer-Verlag New York, 2017

Quantum Matter

Module type	Recommended for	Module availability	Module number and ECTS
elective	5^{th} semester	every winter semester	**12-PHY-BMWQMAT 5 CP**
Workload: 150 h	Tutorial hours: 60 h	Private study hours: 90 h	
Responsibility: Head of the department “Quantum Optics”			
Teaching units (SWS / tutorial hours / private study hours): - Lecture “Quantum Matter” (2 SWS / 30 h / 45 h) - Seminar “Quantum Matter” (2 SWS / 30 h / 45 h)			
Participation requirements: None			
Examinations (duration; weighting) and pre-examination requirements: Oral exam (30 min; ×1) *Pre-examination requirements: Presentation in the seminar (25 min) with written summary (3 weeks)*			

Objectives

The students are introduced into a current research area of the physics institutes and expand existing knowledge of fundamental physical concepts of quantum mechanics and optics. With the acquired knowledge, the students are enabled to understand, discuss and evaluate the specialist literature from the field of modern atomic physics. They can present relevant examples from this field in a lecture and obtain, select and classify the relevant literature.

Content

In this module, various experiments in modern atomic physics are discussed, including those from the following areas:

- cooling atomic gases down to a few nanokelvin
- atomic Bose-Einstein condensates and degenerate Fermi gases
- BEC-BCS crossover, polarons and quantum thermodynamics
- atoms in optical lattices: quantum simulation of Bose-Hubbard Hamiltonians
- hybrid atom-solid systems: cavity-QED for fundamental tests of quantum mechanics
- precision measurements with atomic sensors: electromagnetism, gravitation and fundamental constants

References

References will be annouced in the lectures

Quantum Physics of Nanostructures

Module type	Recommended for	Module availability	Module number and ECTS
elective	5th semester	irregular cycle	**12-PHY-BW3QN1 5 CP**
Workload 150 h	Tutorial hours 60 h	Private study hours 90 h	
Responsibility Director of the Institute of Theoretical Physics			
Teaching units (SWS / tutorial hours / private study hours) - Lecture “ Quantum Physics of Nanostructures” (3 SWS / 45 h / 45 h) - Exercise “Quantum Physics of Nanostructures” (1 SWS / 15 h / 45 h)			
Participation requirements None			
Examinations (duration; weighting) and pre-examination requirements Oral presentation (30 min; ×1)			

Objectives

Students learn the essential concepts and theoretical description of quantum effects on the nanoscale.

Content

- quantum wires and quantum dots
- quantum interference
- dephasing, i.e. transition from quantum mechanical to classical behaviour
- Aharonov-Bohm effect and persistent currents
- Graphene
- Quantum Hall effect
- mesoscopic superconductivity

References

- Y. Imry, Introduction to mesoscopic physics, Oxford University Press
- T. Ihn, Semiconductor Nanostructures, Oxford University Press
- E. Akkermans and G. Montambaux, Mesoscopic Physics of Electrons and Photons, Cambridge University Press
- Y.V. Nazarov and Y.M. Blanter, Quantum Transport: Introduction to Nanoscience, Cambridge University Press

Quantum Technology 1

Module type	Recommended for	Module availability	Module number and ECTS
elective	5^{th} semester	every winter semester	**12-PHY-BMWQT1** **5 CP**
Workload: 150 h	Tutorial hours: 45 h	Private study hours: 105 h	

Responsibility
Head of the department “Applied Quantum Systems”

Teaching units (SWS / tutorial hours / private study hours)
- Lecture “Ion beams and their use in material analysis and modification” (2 SWS / 30 h / 45 h)
- Seminar “Ion beams and their use in material analysis and modification” (1 SWS / 15 h / 60 h)

Participation requirements
None

Examinations (duration; weighting) and pre-examination requirements
Oral exam (30 min; ×1)

Pre-examination requirements: Presentation in the seminar (15 min)

Objectives

After successful participation in the module, students are able
- to - building on a solid basic education in physics - introduce themselves into a current application of ion beams in science and technology, and to present it to other students and scientists
- to explain and to evaluate methods and challenges of ion beam technology
- to apply the acquired knowledge to hypothetical application scenarios

Content

The lecture deals with the generation and application of ion beams. In the field of ion implantation, the classical applications in the field of semiconductor technology are demonstrated and at the same time the foundations for understanding the application of ion beams for the generation of quantum mechanical systems are laid. Another focus of the lecture is on the teaching of ion beam analysis techniques.

Topics: accelerator technology, interaction of ions with matter, ion implantation, ion beam analysis

References

- Schatz/Weidinger "Nukleare Festkörperphysik", Teubner
- Demtröder "Experimentalphysik 4", Springer

Further references will be annouced in the lectures.

Quantum Technology – Lab Course

Module type	Recommended for	Module availability	Module number and ECTS
elective	6^{th} semester	every summer semester	**12-PHY-BMWQTPR 5 CP**
Workload: 150 h	Tutorial hours: 45 h	Private study hours: 105 h	

Responsibility
Head of the department “Applied Quantum Systems”

Teaching units (SWS / tutorial hours / private study hours)
- Laboratory “Quantum Technology Lab Course” (3 SWS / 45 h / 105 h)

Participation requirements
Participation in the module 12-PHY-BMWQT1

Examinations (duration; weighting) and pre-examination requirements
Presentation (30 min) with written summary (3 weeks); ×1 *Pre-examination requirements: Lab reports*

Objectives

After successful participation in the lab course, students are able

- to apply ion beam analysis, modification and optical measurement methods independently
- to recognise new informations from physical measurements, discuss them in a coherent work and present them to other students and scientists
- organise themselves in a group and coordinate tasks

Content

The focus of the lab course is on experiments to deepen the knowledge acquired in the corresponding lectures by practical application. For this purpose, the students are provided with material that serves to prepare them for experiments in the field of ion radiation and optics at defect centres. In addition, a more in-depth introduction to the measurement programmes required for evaluation takes place is given.

Topics: accelerator technology, interaction of ions with matter, ion implantation, ion beam analysis and modification methods, methods for generating and characterising individual defect centres, confocal microscopy

References

- Schatz/Weidinger "Nukleare Festkörperphysik", Teubner
- Demtröder "Experimentalphysik 4", Springer

Further material prepared by the Applied Quantum Systems group

Spin Resonance I

Module type	Recommended for	Module availability	Module number and ECTS
elective	5^{th} semester	every winter semester	**12-PHY-BW3MQ1 5 CP**
Workload 150 h	Tutorial hours 60 h	Private study hours 90 h	
Responsibility Head of the department “Magnetic Resonance of Complex Quantum Solids”			
Teaching units (SWS / tutorial hours / private study hours) - Lecture “Spin Resonance I” (2 SWS / 30 h / 45 h) - Exercise “Spin Resonance I” (2 SWS / 30 h / 45 h)			
Participation requirements None			
Examinations (duration; weighting) and pre-examination requirements Written exam (90 min; ×1)			

Objectives

The students
- acquire basic knowledge in the field of spin resonance
- learn the basics of the quantum theory of spin resonance
- learn the basics of experimental proof

Content

- Dirac formulation of the quantum theory of spin resonance
- density operator formalism for spin resonance
- fundamentals of high-frequency measurements
- electronic detection and digital recording of near-noise high-frequency signals

References

- Slichter, C.P. Principles of Magnetic Resonance
- M. H. Levitt, Spin Dynamics

Superconductivity I

Module type	Recommended for	Module availability	Module number and ECTS
elective	4th/6th semester	every summer semester	**12-PHY-BW3SU1** **5 CP**
Workload 150 h	Tutorial hours 45 h	Private study hours 105 h	
Responsibility Head of the department “Superconductivity and Magnetism”			
Teaching units (SWS / tutorial hours / private study hours) - Lecture “Superconductivity I” (2 SWS / 30 h / 70 h) - Exercise “Superconductivity I” (1 SWS / 15 h / 35 h)			
Participation requirements None			
Examinations (duration; weighting) and pre-examination requirements Oral exam (45 min; ×1) *Pre-examination requirements: Homework on four exercise sheets. Points are awarded for the assessed exercise sheets. 50% of the total points have to be achieved as prerequisite for admission to the exam.*			

Objectives

The students
- build on a solid basic education in physics to explore a field of research at the institutes of physics
- become familiar with the most important phenomena of superconductivity
- become familiar with typical applications of superconductivity

Content

- phenomenology of Type I and Type II superconductors
- London theory of superconductivity
- Ginzburg-Landau theory
- problem of anchoring flux lines and their significance for applications

References

- D.R. Tilley and J. Tilley: Superfluidity and Superconductivity
- M. Tinkham: Introduction to Superconductivity
- R.P. Huebener: Magnetic Flux Structures in Superconductors
- P.G. de Gennes: Superconductivity of Metals and Alloys
- W. Buckel und R. Kleiner, Supraleitung

Stellar Physics

Module type	Recommended for	Module availability	Module number and ECTS
elective	$4^{th}/6^{th}$ semester	every summer semester	**12-PHY-BW3XAS1** **5 CP**
Workload 150 h	Tutorial hours 60 h	Private study hours 90 h	

Responsibility
Head of the department “Applied Quantum Systems” in cooperation with the Thuringian State Observatory Tautenburg
Teaching units (SWS / tutorial hours / private study hours)
- Lecture “Stellar Physics” (2 SWS / 30 h / 45 h) - Seminar “Stellar Physics” (2 SWS / 30 h / 45 h)
Participation requirements
None
Examinations (duration; weighting) and pre-examination requirements
Oral exam (25 min; ×1) *Pre-examination requirements: Presentation in the seminar (30 min)*

Objectives

The students:
- acquire basic physical knowledge about the structure and development of stars
- learn about and assess modern astronomical observation methods
- open up themselves for a current field of research

Content

- observable physical properties of stars
- theory of stellar structure and evolution
- properties of stellar end stages
- scenario of the formation of stars and planetary systems
- extrasolar planets

References

- Francis LeBlanc, An Introduction to Stellar Astrophysics
- G.S. Bisnovatyi-Kogan, Fundamental Concepts and Stellar Equilibrium
- G.S. Bisnovatyi-Kogan, Stellar Evolution and Stability

Stellar Pysics Laboratory

Module type	Recommended for	Module availability	Module number and ECTS
elective	$4^{th}/6^{th}$ semester	every summer semester	**12-PHY-BMWXAS2 5 CP**
Workload 150 h	Tutorial hours 30 h	Private study hours 120 h	
Responsibility Head of the department "Applied Quantum Systems" in cooperation with the Thuringian State Observatory Tautenburg			
Teaching units (SWS / tutorial hours / private study hours) - Laboratory "Stellar Physics Laboratory" (2 SWS / 30 h / 120 h)			
Participation requirements Participation in the module 12-PHY-BW3XAS1			
Examinations (duration; weighting) and pre-examination requirements Lab report (one report, preparation time 6 weeks; ×1)			

Objectives

The students:
- acquire the basic knowledge of modern observational techniques in the field of stellar spectroscopy
- learn how to prepare and perform observations
- learn how to evaluate stellar spectra.

Content

In the first part, students learn how to specify what should be observed, how it should be done, and what results are expected. In this part, students also learn how astronomical spectrographs and which detectors are used in optical astronomy and how they work. Students will learn how to use the telescope software.
In the second part the students perform measurements with the 2 m Alfred-Jensch- telescope (working place: observatory Tautenburg).
In the third part the students will learn how to evaluate Echelle spectra and which physical quantities of the stars can be derived from such spectra.

References

- Francis LeBlanc, An Introduction to Stellar Astrophysics
- Rirchard O. Gray und Christopher J. Corbally, Stellar Spectral Classification

Extragalactic Astronomy and Cosmology

Module type	Recommended for	Module availability	Module number and ECTS
elective	5th semester	every winter semester	**12-PHY-BMWXAS3** **5 CP**
Workload: 150 h	Tutorial hours: 60 h	Private study hours: 90 h	

Responsibility
Head of the department “Applied Quantum Systems” in cooperation with the Thuringian State Observatory Tautenburg
Teaching units (SWS / tutorial hours / private study hours)
- Lecture “Extragalactic Astronomy and Cosmology” (2 SWS / 30 h / 45 h) - Seminar “Extragalactic Astronomy and Cosmology” (2 SWS / 30 h / 45 h)
Participation requirements
None
Examinations (duration; weighting) and pre-examination requirements
Oral exam (30 min; ×1) *Pre-examination requirements: Presentation in the seminar (30 min)*

Objectives

The students:

- Have basic knowledge regarding the structure of galaxies, their manifestations and evolution, the large-scale structure in the universe, and know the formulation of cosmological world models and their verification by observations,
- know the basic physical relationships underlying these phenomena,
- know some modern astronomical observation methods and
- are able to access a current field of research.

Content

- structure of the Milky Way
- basic cosmological world models and their verification by observations
- structure, evolution and classification of galaxies, especially active galactic nuclei
- galaxy clusters and large-scale structure in the universe
- evidence for the presence of dark matter and dark energy
- important, current observational projects in various wavelength ranges

References

- P. Schneider, Extragalactic Astronomy and Cosmology, Springer 2015
- A. Liddle, An Introduction into Modern Cosmology, Wiley 2003

Extragalactic Astrophysics Laboratory

Module type	Recommended for	Module availability	Module number and ECTS
elective	5^{th} semester	every summer semester	**12-PHY-BMWXAS4** **5 CP**
Workload: 150 h	Tutorial hours: 30 h	Private study hours: 90 h	

Responsibility
Head of the department “Applied Quantum Systems” in cooperation with the Thuringian State Observatory Tautenburg
Teaching units (SWS / tutorial hours / private study hours)
- Laboratory “Extragalactic Astronomy Laboratory” (2 SWS / 30 h / 120 h)
Participation requirements
Participation in the module 12-PHY-BMWXAS3
Examinations (duration; weighting) and pre-examination requirements
Lab report (one report, preparation time 6 weeks; ×1)

Objectives

The students:
- know some modern observational methods of extragalactic astronomy,
- are proficient in various methods of displaying and analyzing observational data, especially in the radio, infrared, optical, and X-ray wavelengths,
- know statical methods for analyzing data and can quantify uncertainties in analysis results,
- know different resources especially of freely available data ("open data") for multi-wavelength analysis of extragalactic sources

Content

- observation methods of radio, infrared, optical astronomy and X-ray astronomy
- display of observations in the different wavelength ranges with e.g. ds9 and CASA
- creation of images, e.g. with Python/astropy
- determination of absolute magnitudes as well as their uncertainties
- working with larger ensembles
- interpretation of galaxy spectra, classification of galaxies
- analysis of single objects using multiwavelength observations

References

- Laboratory instructions