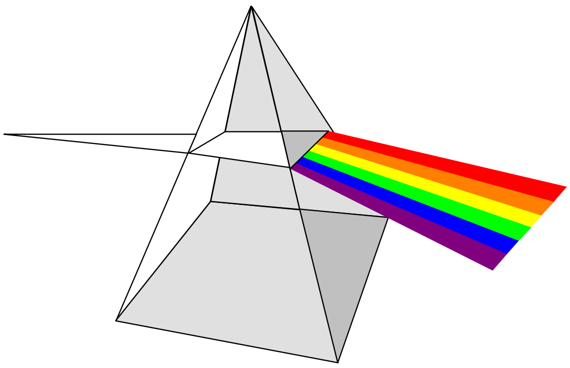
Westfälische
Wilhelms-Universität
Münster

Department of
Physics

Commented Course Program in Physics

BSc and MSc in Physics



February 2009

- Dekanat des Fachbereichs Physik -

INTRODUCTION

The Westfälische Wilhelms-Universität in Münster is located in the cultural centre of Westphalia in close vicinity to the Netherlands. The Treaty of Westphalia, signed in Münster in 1648, ended the Thirty Years' War and established the modern Netherlands. Therefore, we traditionally have strong ties to our Dutch neighbours. Nearly 50,000 students live in this town that is known as the country's bicycle capital. Its economy is based on the service industry and public administration. Students make up about 20% of city's population, ensuring a lively atmosphere. The Department of Physics warmly welcomes foreign students. We consider them an important factor in creating an open and colourful academic and social life on campus.

We invite foreign students to participate in courses offered by members of the department, comprising about 25 research groups, that cover a broad range of physics. These courses are open to full time, part time, and exchange students. Moreover, they are open to students studying physics, other natural sciences, mathematics and medicine, both at the undergraduate and graduate level.

As a guideline for the selection of appropriate courses the following list details the contents of lectures and laboratory courses, which are regularly taught during each academic year. Traditionally, the academic year at German universities is split into two semesters: a Winter Term beginning in mid-October and ending in mid-February, and a Summer Term beginning in mid-April and ending at the end of July. The sequence of courses is largely based on the assumption that students start their studies in the Winter Term of the academic year. In addition to the courses listed here, the department also offers a great number of seminars and special courses with changing subjects.

Most of the courses in the Bachelor program are taught in German. It is highly recommended that students have a basic working knowledge of German prior to entering the courses. In the laboratory courses, experiments are normally conducted in groups of two students under the supervision of an instructor. Here, English is accepted as a working language for the course work and reports. Courses in the Master program can be taught in English upon request.

In addition to the services provided by the Department of Physics, general support for foreign students is also provided through central university institutions, including the International Office (Akademisches Auslandsamt) and the Foreign Language Centre (Sprachenzentrum).

We look forward to seeing you in Münster.
Johannes P. Wessels
Department Chair
Münster, February 2009

CONTACT

Information for International Students

Advice for International Students

Mrs Inge Thomas
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Leonardo Campus 11
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e-mail: inge.thomas@uni-muenster.de
http://www.uni-muenster.de/Auslandsamt/incoming.html - German
http://www.uni-muenster.de/Auslandsamt/en/incoming.html - English

Admissions Requirement and Studies

Studierendensekretariat
Schlossplatz 2
D-48149 Münster
Tel. +49 (0) 251 / 83-2 22 37, -2 47 72
e-mail: studierendensekretariat@uni-muenster.de

for International Students (non EU-Citizens):
http://www.uni-muenster.de/Studierendensekretariat/ausl.html

for EU Citizens:
http://www.uni-muenster.de/Studierendensekretariat/bewerbung.html

Language Courses

Language Centre of the University of Münster
- Sprachenzentrum -
German as a Foreign Language
- Lehrgebiet Deutsch als Fremdsprache -
Hüfferstrasse 27 III
D-48149 Münster
Tel.: +49 (0) 251/83-3 21 08
Fax: +49 (0) 251/83-3 83 49
e-mail: lehrgebiet.daf@uni-muenster.de
http://spzwww.uni-muenster.de/studieninformation/ldaf/stuvo/dsh.php

Accommodation

Student Welfare Organisation - Studentenwerk Münster -
- Wohnraumverwaltung -
Bismarckallee 5
D-48151 Münster
Tel.: +49 (0) 251 / 83-7 95 60
e-mail: wohnen@studentenwerk-muenster.de
christiane.herding@studentenwerk-muenster.de
Tel.: +49 (0) 251 / 83-7 96 46
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http://www.studentenwerk-muenster.de/

Information for ERASMUS Students [Incoming and Outgoing]

Westfälische Wilhelms-Universität Münster
International Office – ERASMUS Office
Leonardo Campus 11
D-48149 Münster
http://www.uni-muenster.de/ERASMUS/

Information for students and teachers concerning ERASMUS activities; contact person for ERASMUS partner universities

1.) LLL Institutional Coordinator
Mrs Martina Hofer
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3.) For Outgoing students
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For Language Courses and accommodation see above.

Department of Physics

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Description of Modules for the Study Course

Physics

and

Physics with Specialisation “Scientific Instrumentation”

(Bachelor of Science)

Department of Physics
University of Münster

Recommended Study Organisation

<table>
<tr><th>Semester</th><th colspan="4">Modules</th></tr>
<tr><td>1. (WS)</td><td>Physics I
14 CP (PM)</td><td></td><td rowspan="2">Basics of Mathematics
18 CP (PM)</td><td rowspan="2">Interdisciplinary Studies
18 CP (WPM*)</td></tr>
<tr><td>2. (SS)</td><td>Physics II
14 CP (PM)</td><td></td></tr>
<tr><td>3. (WS)</td><td>Physics III
14 CP (PM)</td><td rowspan="2">Laboratory Course I
10 CP (PM)</td><td>Integration Theory
9 CP (PM)</td><td></td></tr>
<tr><td>4. (SS)</td><td>Atomic and Quantum Physics
10 CP (PM)</td><td></td><td>Applications of Physics
13 CP (PM)</td></tr>
<tr><td>5. (WS)</td><td>Structure of Matter
14 CP (PM)</td><td rowspan="2">Laboratory Course II
15 CP (PM)</td><td></td><td rowspan="2">Physical Differentiation
16 CP (WPM**)</td></tr>
<tr><td>6. (SS)</td><td>Autonomous Learning***
5 - 10 CP (WPM)</td><td>Exam Module
15 CP (WPM)</td></tr>
</table>

WS: Winter Term SS: Summer Term PM: Mandatory Module WPM: Elective Module

* Interdisciplinary module, which has a reasonable relation to the study of physics or will suit the professional qualification

** Study course physics: Quantum Theory and Statistical Physics,

Study course physics with specialisation “Scientific Instrumentation”: Applications of Physical Measurement Methods

*** This module must be taken if parts of studies and exams were performed at universities other than the University of Münster and total credit amounts to less than 180 CP.

Module Descriptions

Module	**Physics I: Dynamics of Particles and Particle Systems (mandatory)**
Semester	1st semester, WS
Person in charge	Dean of Studies
Components (course, duration, CP, term)	Physics I (lecture, 6 h/w, 6 CP, WS) Exercises for Physics I (4 h/w, 8 CP, WS)
Credit points/ Work load	14 CP / 420 h (150 h in-class, 270 h self-study)
Learning targets	Understanding of phenomena and processes in nature; comprehension, mathematical representation and critical reflection of physical laws Introduction to the basic concepts of physics: experimentation, mathematical description, numerical modelling and visualisation of mechanical and relativistic processes; knowledge of related experimental devices and measurement techniques
Contents	<u>Methodology of physics</u>: what is physics? The role of theory and experiment; physical quantities and unit systems; measurements and uncertainties; vectors and fields; complex numbers; expansions; differential equations <u>Dynamics of particles</u>: Newton's laws, force; momentum and angular momentum; oscillations; work and energy; the concept of fields; conservation laws; accelerating and rotating reference frames; motion in central force fields; extremal principles; Lagrangian and Hamiltonian formulations of mechanics <u>Particle systems</u>: centre of gravity and conservation laws; dynamics of rigid bodies; deformable bodies; dynamics of fluids and gases; linear oscillations; mechanical and acoustic waves; Doppler effect <u>Relativity</u>: constancy of the velocity of light; simultaneity; Lorentz transformation; time dilatation and length contraction; relativistic mechanics
Requirements to meet	Successful participation in "Exercises for Physics I"
Exam	3-hour written exam

Module	**Physics II: Thermodynamics and Electromagnetism (mandatory)**
Semester	2nd semester, SS
Person in charge	Dean of Studies
Components (course, duration, CP, term)	Physics II (lecture, 6 h/w, 6 CP, SS) Exercises for Physics II (4 h/w, 8 CP, SS)
Credit points/ Work load	14 CP / 420 h (150 h in-class, 270 h self-study)
Learning targets	Understanding of phenomena and processes in nature; comprehension, mathematical representation and critical reflection of physical laws Introduction to basic concepts of physics: experimentation, mathematical description, numerical modelling and visualisation; application to thermodynamic and electromagnetic processes; knowledge of related experimental apparatuses and measurement techniques
Contents	Thermodynamics: kinetic theory of gases, distribution functions; temperature and heat; state variables; entropy and its statistical interpretation; the laws of thermodynamics; heat engines; transport phenomena; real gases; state of aggregation; phase transitions Electric charges and currents: basic phenomena; electric fields and potentials; voltage; electric fields in matter and at interfaces (electrostatic induction and dielectricity), dc circuits; electric work and power; conduction phenomena in solids, liquids and gases Electromagnetism: electric currents and magnetic fields; magnetic fields in matter; types of magnetisms; forces acting on current-carrying conductors; induction and induction devices; electromagnetism in vacuum and in matter; Lorentz force; Hall effect; ac resistances and circuits; oscillating circuits
Requirements to meet	Successful participation in “Exercises for Physics II”
Exam	3-hour written exam

Module	**Physics III: Waves and Quanta (mandatory)**
Semester	3rd semester, WS
Person in charge	Dean of Studies
Components (course, duration, CP, term)	Physics III (lecture, 6 h/w, 6 CP, WS) Exercises for Physics III (4 h/w, 8 CP, WS)
Credit points/ Work load	14 CP / 420 h (150 h in-class, 270 h self-study)
Learning targets	Understanding of phenomena and processes in nature; comprehension, mathematical representation and critical reflection of physical laws Introduction to the basic concepts of physics: experiment, mathematical description, numerical modelling and visualisation; application to optical, wave physical and quantum physical processes; knowledge of related experimental apparatuses and measurement techniques
Contents	Electromagnetic waves: Maxwell's equations, generation of electromagnetic waves, electromagnetic waves in vacuum, in insulators, and in conductors; wave propagation; wave packets; phase and group velocity; measurement of the velocity of light; relativistic formulation of electrodynamics Optics: Interaction of light with matter; polarisation and crystal optics; geometrical optics; optical instruments; wave optics; interference and diffraction; near-field and far-field optics; applications of interference and diffraction phenomena; Michelson-Morley experiment; nonlinear optics Quanta: black body radiation; Planck's law of radiation; photo effect; laser; Compton effect; wave-particle dualism; uncertainty relation; Franck-Hertz experiment; Stern-Gerlach experiment
Requirements to meet	Successful participation in "Exercises to Physics III"
Exam	3-hour written exam

Module	Laboratory Course I (mandatory)
Semester	3rd (WS) and 4th (SS) semester
Person in charge	Prof. Dr. M. Donath
Components (course, duration, CP, term)	1. Laboratory course in mechanics and electromagnetism (4 h/w, 5 CP, WS) 2. Laboratory course in optics, thermal und atomic physics (4 h/w, 5 CP, SS)
Credit points/ Work load	10 CP / 300 h (100 h laboratory course, 200 h preparation and follow-up work)
Learning targets	Inductive understanding of phenomena and processes in nature; basic comprehension of experimental methods in classical mechanics, thermal physics, electromagnetism, optics and atomic physics Practical experience in working with experimental setups for basic fields of experimental physics
Contents	Selected experiments in classical mechanics, thermal physics, electromagnetism, optics, and atomic physics
Requirements to meet	Successful completion of all required experiments in 1. and 2.
Exam	Preparation, execution and written analysis of all experiments completed within the module parts (1. and 2.) will be evaluated. Based on the evaluation a final grade is issued in both semesters. The average of the individual semester grades yields to the overall grade for the module.

Module	**Atomic and Quantum Physics (mandatory)**
Semester	4th semester, SS
Person in charge	Dean of Studies
Components (course, duration, CP, term)	Introduction to Quantum Physics (lecture, 4 h/w, 4 CP, SS) Atomic and Molecular Physics (lecture, 2 h/w, 2 CP, SS) Exercises for Atomic and Quantum Physics (2 h/w, 4 CP, WS)
Credit points/ Work load	10 CP / 300 h (120 h in-class, 180 h self-study)
Learning targets	Basic understanding of quantum mechanics and atomic physics; Mathematical solutions of problems in quantum mechanics and atomic physics; Advanced knowledge of the quantum nature of matter
Contents	Quantum mechanics: Basic principles (wave-particle dualism, probability interpretation, Schrödinger equation, wave packets); simple potential problems; harmonic oscillator (eigenvalues and eigenfunctions); hydrogen atom (physics of angular momenta, radial equation, energy spectrum); atoms in electric and magnetic fields; spin (phenomena and formal description); approximation methods; indistinguishability (Bosons and Fermions) Atomic and molecular physics: atomic nature of matter; experimental methods of atomic physics; models of atoms; hydrogen atom; atoms with more than one electron; atoms in external fields; elementary structure of simple molecules; current topics in atomic and molecular physics
Requirements to meet	Successful participation in the exercises for “Atomic and Quantum Physics”
Exam	3-hour written exam

Module	**Structure of Matter (mandatory)**
Semester	5^{th} semester or later, WS and SS
Person in charge	Dean of Studies
Components (course, duration, CP, term)	Physics of Condensed Matter (lecture, 4 h/w, 4 CP, WS) Exercises for Physics of Condensed Matter (1 h/w, 2 CP, WS) Nuclear and Particle Physics (lecture, 3 h/w, 3 CP, WS) Exercises to Nuclear and Particle Physics (1 h/w, 2 CP, WS) Astrophysics and Cosmology (lecture, 1 h/w, 1 CP, WS) Seminar (2 h/w, 2 CP, WS, SS)
Credit points/ Work load	14 CP / 420 h (180 h in-class, 240 h self-study)
Learning targets	Advanced knowledge of the structure of matter
Contents	Physics of condensed matter: structure and bonding of solids, methods of structure determination, lattice vibrations (phonons), thermal, magnetic and optical properties of solids, electronic and optical properties of metals and semiconductors, semiconductor interfaces, superconductivity Nuclear and particle physics: interaction of radiation and matter, particle detectors and particle accelerators, drop and Fermi gas model, dispersion and nuclear reactions, gamma and beta disintegration, nuclear fission, nuclear fusion, nucleosynthesis, symmetries and conservation laws, quantum numbers, static quark model, basic interactions Cosmology and astrophysics: experimental methods, star formation, Hertzsprung-Russell diagram, neutron stars, black holes, Schwarzschild radius, supernovae, evolution of the universe, background radiation, structure formation, Hubble parameter
Requirements to meet	Successful participation in the exercises for “Physics of Condensed Matter” Successful participation in the exercises for “Nuclear and Particle Physics” Successful participation (including talk/presentation) in seminar
Exam	30-45 minute oral exam

Module	Applications of Physics (mandatory)
Semester	4th semester or later
Person in charge	Dean of Studies
Components (course, duration, CP, term)	Applied Physics, (lecture, 4 h/w, 4 LP, WS) Exercises for Applied Physics (2 h/w, 4 LP, WS) Computer Laboratory (2-4 h/w, 3 LP, WS, SS) Seminar (2 h/w, 2 LP, WS, SS)
Credit points/ Work load	13 CP/ 390 h (150 h in-class study, 240 h self-study)
Learning targets	Basic knowledge in electronics, optoelectronics, automatic control engineering and communication technology; Practice in analog and digital standard methods; Analysis of data by use of computers; Comprehension of interaction between physics and engineering technologies
Contents	Applied Physics: Electronic and optoelectronic components; analog and digital electronic circuits, steering and controlling; data analysis; basics of systems technology (methods in Fourier space); stochastic processes and noise; digital and analog signal processing; correlation procedures; storage and transformation of information; temporal, spatial and spatio-temporal information; linear and nonlinear systems; use of basic physics in information technology, life science, energy production and environmental studies Computer Laboratory (one of the following): 1) Computer-controlled measurement and processing by use of an adapted standard language (recording of voices, music, noise etc., Fourier analysis including time domain windows, analog and digital signal filtering, correlation functions, practical use of sampling theorem) 2) Use of micro computers, operating systems, network communications, development of scientific programs, graphical demonstration of data, numerical solution of physical problems, problems of accuracy and approximation, calculation of simple functions, numerical differentiation and integration, demonstration and interpolation of data – random numbers, Monte-Carlo method
Requirements to meet	Successful participation in the exercises for “Applied Physics” Submission of completed lab reports Successful participation (including talk/presentation) in seminar
Exam	30-45 minute oral exam

Module	**Laboratory Course II (mandatory)**
Semester	5^{th} and 6^{th} semester, WS and SS
Person in charge	Dean of Studies
Components (course, duration, CP, term)	1. Exercises in the Institute of Physics (2,5 h/w, 3,75 CP, WS SS) 2. Exercises in the Institute of Applied Physics (2,5 h/w, 3,75 CP, WS, SS) 3. Exercises in the Institute of Nuclear Physics (2,5 h/w, 3,75 CP, WS, SS) 4. Exercises in the Institute of Material Physics (2,5 h/w, 3,75 CP, WS, SS)
Credit points/ Work load	15 CP/ 450 h (150 h in-class, 300 h self-study)
Prerequisites	Modules Physics I, Physics II and Experimental Exercises I Recommended: Modules Physics III, Atomic and Quantum Physics and Application of physics
Learning targets	Advanced analog and digital metrological methods and analysis of data using computers, acquisition of practical skills on ambitious experimental set-ups for different topics in experimental physics Advanced atom and solid state physics, devices and measuring methods of atomic and solid state physics Basic electronics, optoelectronics, controlling, and information technologies Advanced nuclear and particle physics, nuclear-physical devices and measuring methods Functional materials, devices and measuring methods in material physics
Contents	Selected experiments to learn about measuring techniques and experimental and theoretical aspects of different sections of physics
Requirements to meet	Successful completion including lab report of all required experiments
Exam	Preparation, completion and report of each experiment will be graded. Overall grade for the module is determined by averaging on individual grades

Module	**Exam Module (elective)**
Semester	6th semester, WS and SS
Person in charge	Supervisor of Bachelor thesis
Components (course, duration, CP, term)	In agreement with the person in charge special lectures, exercises, seminars, self-studies (3 CP) Self-directed work on the bachelor thesis (12 CP)
Credit points/ Work load	15 CP/ 450 h (in-class and self-study)
Learning targets	In courses related to the bachelor thesis or through private studies, the student will be introduced into scientific research and the functional and methodical basics for the bachelor thesis. With the bachelor thesis, the student should demonstrate the ability to deal with a current problem of physics using scientific methods within the given timeline and to present the results appropriately.
Requirements to meet	Preparation of written thesis and final talk about the thesis lasting 30 minutes. The two examiner of the thesis have to be present during oral presentation.
Exam	The module grade is the grade of the bachelor thesis

Module	**Basics of Mathematics (mandatory)**
Semester	1st (WS) and 2nd (SS) semester
Person in charge	Dean of Studies (mathematics)
Components (course, duration, CP, term)	Mathematics for physicists I (lecture, 4 h/w, 5 CP, WS) Exercises for mathematics for physicists I (2 h/w, 4 CP, WS) Mathematics for physicists II (lecture, 4 h/w, 5 CP, SS) Exercises for mathematics for physicists II (2 h/w, 4 CP, SS)
Credit points/ Work load	18 CP / 540 h (180 h in-class, 360 h self-study)
Learning targets	Basic concept of analysis and linear algebra and ability to solve related problems
Contents	Complete induction, mathematical nomenclature Vector space: dimension, subspace, linear systems of equations Real numbers: convergence of series and progressions, Euclidean and standardized vector spaces, Complex numbers, exp and log, radicals, powers, trigonometric functions, unitary vector spaces Differentiable functions with one variable, mean value theorem and applications, curves, differentiable functions with multiple variables, gradients, vector fields Integration in one-dimension: antiderivative, Taylor theorem, improper integrals, arc length, line integrals Series of functions: different types of convergence, standardized vector spaces, topology of metrical spaces, permutation of limiting value processes Linear transformation: dimension formula, matrix representation, determinants, volumes, vector product, eigenvalue, normal forms Differentiable representations: inverse theorem , implicit functions, Lagrange multiplier
Requirements to meet	Successful participation in the exercises for “mathematics for physicists I” Successful participation in the exercises for “mathematics for physicists II” Passed exam at the end of the Winter semester “mathematics for physicists I”
Exam	Normally two hour final exam following the lecture “mathematics for physicists II”

Module	**Integration Theory (mandatory)**
Semester	3rd semester, WS
Person in charge	Dean of Studies (mathematics)
Components (course, duration, CP, term)	Mathematics for physicists III (lecture, 4 h/w, 5 CP, WS) Exercises for mathematics for physicists III (2 h/w, 4 CP, WS)
Credit points/ Work load	9 CP / 270 h (90 h in-class, 180 h self-study)
Prerequisites	Content of the module “basics of mathematics”
Learning targets	Basic concept of integration theory and ability to solve related problems
Contents	<u>Ordinary differential equations</u>: Picard-Lindelöf theorem, linear differential equation, examples. <u>Measure and integration theory</u>: measure continuation theorem, the Lebesgue integral, convergence theorems, theorem of Fubini The integral theorems of Stokes, Gauß and Green in two- and three-dimensions. <u>Theory of functions</u>: Cauchy integral theorem, power series, residual theorem Fourier series, convergence in the mean, L^2 as Hilbert space and Fourier transformation
Requirements to meet	Successful participation in the exercises for “mathematics for physicist III”
Exam	Normally two hour exam.

Module	Quantum Theory and Statistical Physics (elective)
Semester	5th (WS) and 6th (SS) semester
Person in charge	Dean of Studies
Components (course, duration, CP, term)	Quantum Theory (lecture, 4 h/w, 4 CP, WS) Exercises for Quantum Theory (2 h/w, 4 CP, WS) Statistical Physics (lecture, 4 h/w, 4 CP, SS) Exercises for Statistical Physics (2 h/w, 2 LP, SS)
Credit points/ Work load	16 CP / 480 h (180 h in-class, 300 h self-study)
Learning targets	Advanced understanding of quantum theory and statistical physics to describe systems on the basis of their fundamental microscopic properties Advanced knowledge of the mathematical structure of quantum theory and the statistical approach to many-particle systems Mathematical solutions to problems in quantum theory and statistical physics
Contents	Quantum theory: mathematical framework of quantum theory; symmetries and conservation laws; postulates and measurement process; addition of angular momentum and spin-orbit coupling; approximation methods for time-independent and time-dependent problems, Fermi's golden rule; stationary scattering theory; second quantisation; quantised light field and spontaneous emission; EPR paradox, hidden variables and Bell's inequality Statistical physics: fundamentals of probability theory and mathematical statistics; statistical description of many-particle systems; statistical ensembles; relation between statistical physics and phenomenological thermodynamics; entropy and information; thermodynamic potentials; classical ideal gas; ideal quantum gases (Fermi and Bose gas); real gases; magnetic systems and phase transitions; statistics and kinetics of non-equilibrium systems; transport processes
Requirements to meet	Successful participation in the exercises for "Quantum Theory" Successful participation in the exercises for "Statistical Physics" Successful written tests at the end of each of the Exercises
Exam	30-45 minute oral exam

Module	**Application of Physical Measurement Methods (elective)**
Semester	5th and 6th semester, WS and SS
Person in charge	Dean of Studies
Components (course, duration, CP, term)	6 module parts in four-week block courses
Credit points/ Work load	16 CP/ 480 h (180 h in-class, 300 h self-study)
Learning targets	Modern measuring techniques at selected examples of electronics, photonics, microscopy, spectroscopy, vacuum engineering, radiation measuring technique and material physics. Specific analysis of the methods with regard to measuring quality, measuring limitations and errors Basic principles of electronic measuring and control technology through practical application of instrumentation hardware and software Imaging methods. Safe and reliable application of laser, optical and fiber-optical elements, vacuum apparatus, radiation sources and detectors.
Contents	<u>Electronics</u>: analysis of components of analog and digital electronics (diode, transistor, operation amplifier, gate, flip-flops, shift register); cooperation of the components in computer-aided measuring techniques <u>Laser and optical measuring techniques</u>: properties of laser radiation (coherence, mode structure); analysis of chosen problems of interferometry, holography and speckle measurement technology <u>Microscopy</u>: modern methods of microscopy: high-resolution (transmission) electron microscopy, scanning force microscopy, scanning tunnelling microscopy <u>Spectroscopy</u>: modern methods of electron, laser and ion spectroscopy <u>Vacuum techniques</u>: introduction to pumps and pump systems; methods of vacuum measurement technology <u>Radiation techniques</u>: physics of ionising radiation, detectors, methods of radioactive dating, medical applications, basics of radiation protection <u>Techniques of material physics</u>: X-ray/neutron diffractometry, X-ray spectroscopy, atom probe tomography, calorimetry, thin-film deposition method, ion beam-assisted preparation techniques in electron microscopy
Requirements to meet	Successful participation in each module part
Exam	The module grade is based on the overall evaluation of the documentation of the experimental work performed in the six module parts

Module	**Geophysics (elective)**
Semester	1st semester or later, WS and SS
Person in charge	Prof. Dr. M. Lange, Prof. Dr. U. Hansen
Components (course, duration, CP, term)	Introduction to geophysics (lecture, 2 h/w, 2 CP, WS) Exercises for introduction to geophysics (1 h/w, 2 CP, WS) Geophysical basics I (lecture, 2 h/w, 2 CP, SS) Exercises for geophysical basics I (1 h/w, 2 CP, SS) Geophysical basics II (lecture, 2 h/w, 2 CP,WS) Exercises for geophysical basics II (1 h/w, 2 CP, WS) International field course (5 h/w, 6 CP)
Credit points/ Work load	18 CP / 540 h (210 h in-class, 330 h self-study)
Learning targets	Overview of geophysical functions and the most important methods including simple practical demonstrations and exercises. International field course: application and knowledge of selected methods of applied geophysics (seismic, geoelectrics, electromagnetics, magnetics, gravimetry) and first steps of data evaluation and data interpretation.
Contents	Important components of the Earth's system, development, present properties, and significant processes Seismology and seismological methods for investigations of the inner structure of the Earth; basic principles of the seismic investigation methods Gravitational field and gravimetry, magnetic field and magnetics as well as electric and electromagnetic methods for investigations of the Earth
Requirements to meet	Active participation and work on exercises
Exam	1. two hour exam at the end of "Introduction to geophysics" (condition: 50% right solutions of the exercises) 2. three hour exam at the end of "geophysical basics II" (content of I and II) (condition: 50% right solutions of the exercises) 3. excursions report at the end of the field course The module grade is calculated from the two exam marks and the mark for the excursion report. The exams to "geophysical basics I and II" will be given double weight.

Module	**Chemistry for Physicists (elective)**
Semester	1st (WS) and 2nd (SS) semester
Person in charge	Dean of Studies (chemistry)
Components (course, duration, CP, term)	General chemistry (lecture, 5 h/w, 5 CP, WS) Exercises for general chemistry (4 h/w, 4 CP, WS/SS) Introductory chemical laboratory for students with chemistry as a minor (in the free period, 4 h/w, 6 CP, WS/SS) Inorganic chemistry (lecture, 3 h/w, 3 CP, SS)
Credit points/ Work load	18 CP / 540 h (240 h in-class, 300 h self-study)
Prerequisites	Laboratory: the first written exam to the exercise for "inorganic chemistry" passed with at least 40%. The second exam must be written after the laboratory.
Learning targets	Fundamental terms describing important chemical substances and their reactions and quantitative treatment Relevant inorganic and organic substances and their role in engineering, biosphere and environment as well as their physical-chemical properties; Reactivity and properties of the most important basic materials in environment and ecological systems, basic competence in evaluation of quantitative chemical data (units of concentration, equilibrium constant); Risk potential of chemical substances, secure working practice in chemical laboratories, knowledge and competences to obtain chemical data and information; Ability to work autonomously on related chemical problems
Contents	<u>1. Semester</u>: atomic structure, chemical bonds (covalent, metallic and ionic bonds), symmetry relations, gases, liquids and solutions, stoichiometry and description of mass conversion in chemical reactions, thermal equilibrium, energy conversion and kinetics of chemical reactions, acids and bases, redox reaction, solubility. Construction of inorganic bonds (alkane series, alkenes, alkines, aromatics), substituent effects, homolysis and heterolysis, basic types of organic reactions (substitution, addition, elimination), organic acids and bases, carbonyl reactivity. An introduction to the chemical way of thinking: School knowledge will be reviewed and explored in more depth. <u>2. Semester</u>: elemental chemistry, emphasising relevant technical processes; relationships within the periodic table, chemical bonds and structural chemistry; molecular, solid state chemistry and material science aspects; coordination chemistry with Ligand field theory.
Requirements to meet	Regular and active participation in exercises and laboratory, successful participation in both exams
Exam	30-45 minute oral exam

Module	Basics of Programming (elective)
Semester	1st and 2nd semester or later (beginning WS)
Person in charge	Prof. Dr. A. Clausing, Prof. Dr. K. Hinrichs
Components (course, duration, CP, term)	computer science I (lecture, 4 h/w, 5 CP, WS) Exercises for “computer science I” (2 h/w, 4 CP, WS) computer science II (lecture, 4 h/w, 5 CP, SS) Exercises for “computer science II” (2 h/w, 4 CP, WS)
Credit points/ Work load	18 CP / 540 h (210 h in-class, 330 h self-study)
Learning targets	Conventional abstraction and formalization mechanisms used in computer science Development of programs in higher level computer languages Creation of algorithms and data structures; implementation and analysis (concerning the consumption of resources)
Contents	Overview of computer science, introduction to fundamental terms and ways of thinking in computer science, introduction to a functional and an object-orientated computer language, representation, structure and interpretation of calculations, systems and their descriptions, abstract data types and data structures, creation and analysis of algorithms, fundamental terms of calculability, searching and sorting, schedule structures, trees and graphs, address calculation method
Requirements to meet	Successful participation in the exercises for computer science I and II
Exam	two hour written exam

Module	**Medical Physics and Biophysics (elective)**
Semester	2nd and 3rd semester or later (beginning SS)
Person in charge	Dr. K. Dreisewerd, Dr. M. Mormann
Components (course, duration, CP, term)	Molecular biophysics of cells and tissue I (lecture, 2 h/w, 2 CP, SS) Molecular biophysics of cells and tissue II (lecture, 2 h/w, 2 CP, WS) Biophysical methods of molecular biology, cell biology and physiology (lecture, 2 h/w, 2 CP, SS) Biophysical methods of molecular biology, cell biology and physiology (laboratory, 5 h, 8 CP, SS) Selected topics of medical physics and biophysics (compact seminar, 15h, 1 CP, every semester) One of three electives 1) Biomedical analytics Basics and applications of biomedical mass spectrometry I and II (lecture, 2 h/w; 2 CP, WS and SS) Seminar basics, methods and applications of the laser and electrospray mass spectrometry (seminar, 1 h/w; 1 CP, every semester) 2) Laser microscopy Fluorescence microscopy I and II (lecture, 2 h/w, 2 CP, SS and WS) Basics, methods and cell biological appliances of the confocal microscopy (Seminar, 1 h/w; 1 CP, WS/SS) 3) Electron microscopy and microanalysis Electron and scanning probe microscopic methods for advanced students (lecture, 1 h/w and laboratory 1 h/w, every semester, 3 CP)
Credit points/ Work load	18 CP / 540 h (240 h in-class, 300 h private study)
Learning targets	Basics of medical physics and biophysic; biophysical standard methods
Contents	Molecular biophysics of cells and tissues, biophysical methods of molecular biology, cell biology and physiology 1) basics and applications of biomedical mass spectrometry (laser and electrospray mass spectrometry) 2) basics, methods and cell biological applications of confocal microscopy 3) electron and scanning probe microscopically methods for advanced students
Requirements to meet	Completion of lab reports Successful participation (including own talk/presentation) in seminar
Exam	30-45 minute oral exam

Module	**Basics of Economics (elective)**
Semester	1st and 2nd semester
Person in charge	Prof. Dr. A. Pfingsten, Prof. Dr. W. Ströbele
Components (course, duration, CP, term)	Basics of Economics (9 CP): - Introduction to Economics (lecture, 2 h/w, 3 CP, WS) - Financial Mathematics (lecture, 1 h/w, 2 CP, WS) - Investment and Finance (lecture, 3 h/w, 3 CP, WS) - Exercices (2 h/w, 1 CP, WS) Microeconomics I (9 CP): - Introduction to Political Economics (lecture, 2 h/w, 3 CP, WS) - Microeconomics (lecture with proseminar, 6 h/w, 6 CP, SS)
Credit points/ Work load	18 CP / 540 h (240 h in-class, 300 h self-study)
Learning targets	Understanding and application of fundamental economic terms, assigning problems into proper context, development of simple means of problem solving, solving problems in investment and finance. The module introduces to basics of microeconomics.
Contents	<u>Basics of economics</u>: Overview of basic questions and methods of economics as well as of managerial functions; special focus on investment and finance decisions including finance mathematical tools. <u>Microeconomics</u>: Basic questions of economic activity, markets and market failure, household and consumer economics (budget optimization, demand of goods, labour supply, insurance and insecurity), theory of the firm (theory of production, minimal costs combination, supply of goods, factor demand) Markets I: perfect competition (comparative static, Cobb-Web-theorem), theorems of welfare economics, imperfect markets, monopoly and dominant firms
Exam	Written exams in “Basics of Economics" and “Microeconomics”. Total grade of the module by arithmetic averaging.

Module	**Philosophy for Physicists (elective module)**
Term	1st and 2nd semester
Module Supervisor	Supervisors of the modules A (Argument and text) and E (knowing and being) of the two-subjects-bachelor in philosophy
Components (course, duration, CP, term)	Winter term Lecture: *Logic and theory of argumentation* (2 h/w, 1 CP, WS) Seminar/tutorial: *Logic and theory of argumentation* (2 h/w, 4 CP, WS) Lecture: *Epistemology* (2 h/w, 1 CP, WS) Seminar/tutorial: *Epistemology* (2 h/w, 4 CP, WS) Summer term Seminar/tutorial: *Logic, language and text* (2 h/w, 4 CP, SS) Seminar/tutorial: *Metaphysics* (2 h/w, 4 CP, SS)
Credit points/ Work load	18 CP / 540 h (180 h in-class, 350 h self-study)
Learning targets	After having studied the elective module 'Philosophy for Physicists' students shall be able to discern issues and problems of Theoretical Philosophy with respect to their content and formal structure. They will have learnt to analyze and classify philosophical arguments and to examine their validity and soundness. In particular, oral and written presentation skills are practiced. In order to achieve these educational objectives, basic knowledge and proficiency of formal logic and theory of argumentation will be imparted.
Contents	The contents of the elective module Philosophy for Physicists are mainly related to Theoretical Philosophy and comprise the following areas: Logic (propositional logic, predicate logic), Theory of Argumentation, Philosophy of Language, Epistemology, Philosophy of Science and Ontology. All of these are relevant for a philosophical propaedeutics within a programme of study in the natural sciences. The most important epistemological and metaphysical views as well as central positions in the philosophy of science are classified under both a systematical and an historical perspective. Moreover, contemporary questions and topics of Theoretical Philosophy are discussed. Especially epistemological issues (as, e.g., concerning the range of knowledge, the reasons for claims of knowledge, the distinction between explaining and understanding) are to be evaluated in the light of their historical development.
Requirements to meet	Regular attendance of the lectures, regular and active participation in the four seminars/tutorials
Exam	At least sufficient („4,0“) exam results (written tests or essays) in the four seminars/tutorials. Total module grade calculated as average of the four individual marks

Module	**Interdisciplinary Studies (elective)**
Semester	1^{st} to 4^{th} semester
Person in charge	Choice of student
Components (course, duration, CP, term)	In agreement with person in charge for the module and dean of the faculty of physics Lecture (1 h/w equates to 1 CP) Exercises to lecture (1 h/w equates to 2 CP) Experimental exercises/laboratory (1 h/w equates to 1,5 CP) Seminars (1 h/w equates to 1 CP) In total at least 12 h/w
Credit points/ Work load	18 CP / 540 h
Conditions	After consulting the person in charge
Learning targets	After consulting the person in charge
Contents	After consulting the person in charge
Study/Exam achievements	After consulting the person in charge At least two study achievements must be completed, one of them examinable.

Module	Autonomous Learning (elective)
Semester	6th Semester, WS and SS
Person in charge	Dean of Studies
Components (course, duration, CP, term)	according to agreement with the person in charge, 5 - 10 CP
Credit Points/ Work load	5 - 10 CP / 150 - 300 h (private study)
Learning targets	This module must be taken if parts of the studies were completed at a university other than the Westfälische Wilhelms-Universität Münster and the student has less than 180 CP. Learning targets, competences and content will be defined by the Study Advisory Service.
Exam	Generally 30 – 45 minute oral exam

Description of Modules for the Study Course

Physics

(Master of Science)

Department of Physics
University of Münster

Recommended Study Organisation

<table>
<tr><th>Semester</th><th colspan="4">Module</th></tr>
<tr><td>1. (WS)</td><td rowspan="2">Laboratory Course for Advanced Students

15 CP (PM)</td><td rowspan="2">Physical Specialisation I
12 - 18 CP (WPM)</td><td rowspan="2">Physical Specialisation II
12 - 18 CP (WPM)</td><td rowspan="2">Interdisciplinary Studies
12 - 15 CP (WPM)</td></tr>
<tr><td>2. (SS)</td></tr>
<tr><td>3. (WS)</td><td colspan="2">Professional Specialisation
15 CP (WPM)</td><td colspan="2">Methodology und Project Planning
15 CP (WPM)</td></tr>
<tr><td>4. (SS)</td><td colspan="4">Master Thesis
30 LP (WPM)</td></tr>
</table>

WS: Winter Term   SS: Summer Term   PM: Mandatory Module   WPM: Elective Module

The total credit of the three modules “Physical Specialisation I and II“ and “Interdisciplinary Studies” must amount to at least 45 CP.

Module Descriptions

Module	Laboratory Course for Advanced Students (mandatory)
Semester	1st and 2nd semester
Person in charge	Dean of Studies
Components (course, duration, CP, term)	1) Exercises in the “Physics Institute” (2,5 h/w, 3,75 CP, WS SS) 2) Exercises in the “Institute of Applied Physics” (2,5 h/w, 3,75 CP, WS, SS) 3) Exercises in the “Institute of Nuclear Physics” (2,5 h/w, 3,75 CP, WS, SS) 4) Exercises in the “Institute of Material Physics” (2,5 h/w, 3,75 CP, WS, SS)
Credit points/ Work load	15 CP/ 450 h (150 h in-class, 300 h self-study)
Prerequisites	Desirable: Laboratory experience during undergraduate studies in the amount of 25 CP
Learning targets	Professional use of analog and digital metrological standard methods and the analysis of data using computers, acquisition of practical skills in operation of ambitious experimental set-ups in different topics of experimental physics Advanced knowledge of atomic and solid state physics, devices and measuring methods of the atomic and solid state physics Basic knowledge of electronics, optoelectronics, control technique and information technology Advanced knowledge of nuclear and particle physics, nuclear-physical devices and measuring methods Mechanisms of functional materials, devices and measuring methods of material physics
Contents	Selected experiments to acquire advanced knowledge in measuring techniques and experimental and theoretical aspects of different areas of physics
Requirements to meet	Successful completion of the experiments requested in module parts 1) - 4)
Exam	Preparation, implementation and written lab report of each experiment will be graded. Each module part (1-4) will assign an individual grade. Overall module grade by arithmetic averaging.

Module	Functional Nanosystems (elective)
Semester	1st and 2nd semester
Person in charge	Prof. Dr. H. Fuchs, Prof. Dr. H. Arlinghaus
Components (course, duration, CP, term)	12 – 18 CP, according to agreement with the person in charge, consisting of: - laboratory course in nanophysics (6 CP) - at least 2 advanced lectures in nanophysics (4 CP) - at least 1 seminar (2 CP)
Credit points/ Work load	12 – 18 CP / 360 – 540 h (ca. 1/3 in-class, 2/3 self-study)
Learning targets	Advanced knowledge in modern analytical methods for the characterisation of nanostructures and their functionalities
Contents	Basics of nanophysics (fundamental atomic and molecular interactions, nanomaterials, nanofabrication, functional properties) with an emphasis on modern analytical tools
Requirements to meet	Successful participation (including talk/presentation) in a seminar in nanophysics Successful completion of a laboratory course
Exam	30 – 45 minute oral-exam

Module	**Nuclear and Particle Physics (elective)**
Semester	1st and 2nd semester
Person in charge	Prof. Dr. G. Münster
Components (course, duration, CP, term)	In agreement with the person in charge: - Laboratory course in the field of choice (5 CP) - At least two advanced lectures in nuclear and particle physics (at least 6 CP) - at least one seminar in nuclear and particle physics (at least 2 CP)
Credit points/ Work load	13 – 18 CP / 390 – 450 h (approx. 1/3 in-class, 2/3 self-study)
Learning targets	Advanced knowledge and methods of nuclear and particle physics
Contents	Experimental techniques of nuclear and particle physics Advanced knowledge about the fundamental constituents of matter and their interactions Aspects of the Standard Model of elementary particle physics
Requirements to meet	Successful completion of the laboratory course Successful participation (including talk/presentation) in a seminar in nuclear and particle physics Possibly: successful completion of marked written exercises or exams.
Exam	30 – 45 minute oral-exam

Module	**Material Physics (elective)**
Semester	1st and 2nd semester
Person in charge	Prof. Dr. G. Schmitz
Components (course, duration, CP, term)	**Obligatory parts:** - Lecture with exercises: ‘Material Physics I’ (4 CP) - Lecture with exercises: ‘Material Physics II’ (4 CP) - Laboratory course: ‘Practical exercises in Material Physics’ (5 CP) **Alternative parts:** In agreement with person in charge: Advanced lectures or seminars in the area of material physics, or experimental and theoretical solid state physics with a total amount of up to 5 CP
Credit points/ Work load	13-18 CP / 390-540 h (about 1/3 in-class, 2/3 self-study)
Learning targets	The module teaches profound knowledge of physical concepts and methods in material science. Courses should enable students to perform active research in current problems of material physics.
Contents	Laboratory course: Experimental methods and basic physical properties of materials Material Physics I and II: Structure and lattice defects, thermodynamics and constitution, diffusion and atomic transport, phase transformations and reaction kinetics, mechanical properties, functional materials. Advanced lectures may include: ‘Atomic transport’, ‘Physics of soft matter and biological materials’, ‘Polymer physics’, ‘Semi-conductor physics’, ‘Mechanics of materials’, ‘Nano-structured materials’, ‘Simulation methods in material science’
Requirements to meet	- Successful completion of the laboratory course - Successful participation in validated courses
Exam	30 – 45 minute oral-exam

Module	Nonlinear Physics (elective)
Semester	1st and 2nd semester
Person in charge	Prof. Dr. Cornelia Denz Prof. Dr. S. Linz
Components (course, duration, CP, term)	In agreement with the person in charge: - Basic and advanced lectures in suitable combination (at least 6 CP) - at least one seminar in nonlinear physics (at least 2 LP) - Experimental exercises in nonlinear physics or numerical techniques for nonlinear physics or - Additional seminar and advanced lectures (at least 6 CP)
Credit points/ Work load	14 - 18 CP/ 420 - 540 h (approx. 1/3 in-class, 2/3 self-study)
Learning targets	Basic concepts of nonlinear physics, the role of nonlinearities in different physical, chemical or biological systems, relevant methods for theoretical and/or experimental analysis of nonlinear systems, application of a higher computer language to problems in theoretical or experimental physics.
Contents	The module offers theoretical and experimental contents. Possibility to focus either on the theoretical or the experimental part. Each combination includes basic principles of nonlinear physics, such as signatures of complex systems, emergence, self-organisation, stability, bifurcations, attractors, and pattern formation as well as specific examples of nonlinear systems. Use of typical nonlinear model equations (i.e. Swift-Hohenberg-equation, complex Ginzburg-Landau-equation, nonlinear Schrödinger-equation) and discussion of their generic characteristics and applications to concrete systems.
Requirements to meet	Successful participation in a one-hour-exercise Successful participation (including talk/presentation) in a seminar Solving experimental and theoretical problems, including documentation of the solutions
Exam	30 – 45 minute oral exam

Module	**Photonics and applied physics of waves (elective)**
Semester	Recommended for 1st and 2nd semester
Person in charge	Prof. Dr. C. Denz
Components (course, duration, CP, term)	In agreement with person in charge: - At least two advanced lectures in photonics and applied physics of waves (at least 4 CP) - Experimental exercises in photonics and applied physics of waves (6 CP) - At least one seminar in photonics and applied physics of waves (at least 2 CP) or - Adaptation, documentation and presentation of a research project to an applied problem (“MiniResearch”) in the physics department (at least 160 h duration, 8 LP) or - adaptation, documentation and presentation of a technical physics project in terms of an internship in the industry or an outside or foreign research institute with scientific supervision by a professor at the department of physics (at least 4 weeks = 160 h , 8 LP)
Credit points/ Work load	12 - 18 CP/ 360 - 540 h (approx. 1/3 in-class, 2/3 self-study)
Learning targets	Transmission of physics knowledge to non-physical fields at the example of photonics; advanced knowledge in optics, photonics and the application of waves; Importance of factors (e.g. economic and social) outside of physics
Contents	Applied problems on the basis of certain examples; Systematic and advanced treatment of a problem either in optics, photonics or the application of waves.
Requirements to meet	Successful completion of exercises for any course in the modulus Successful participation (including talk/presentation) in a seminar in photonics and applied physics of waves Successful completion of an applied problem, including a documentation of the solution for “Experimental exercises on photonics and applied physics of waves” or in one of the above-mentioned projects.
Exam	30 – 45 minute oral-exam

Module	**Physics of low-dimensional solids (elective)**
Semester	1st and 2nd semester
Person in charge	Prof. Dr. J. Pollmann, Prof. Dr. T. Kuhn Prof. Dr. M. Donath, Prof. Dr. H. Kohl
Components (course, duration, CP, term)	In agreement with the person in charge - Lecture "Introduction to solid state theory" with exercises (3+2 CP) - At least one advanced lecture in the field of modern experimental solid state physics (at least 2 CP) - At least one seminar related to current problems in experimental or theoretical solid state physics (2 CP) - Experimental exercises in solid state spectroscopy (5 CP) or advanced lecture in solid state theory with exercises (3+2 CP) - Optionally additional advanced courses in experimental or theoretical solid state physics
Credit points/ Work load	14 - 18 CP / 420 - 540 h (approx. 1/3 in-class, 2/3 self-study)
Learning targets	Advanced knowledge of physical phenomena in low-dimensional solid state systems Application of experimental and theoretical techniques for analysis and description Understanding of qualitatively new effects resulting from spatial confinement and of their relevance for applications
Contents	Selected phenomena in solid state physics, in particular regarding low-dimensional systems
Requirements to meet	Successful participation in the exercises for „Introduction to solid state theory" Successful participation (including talk/presentation) in a seminar related to current problems in experimental or theoretical solid state physics Successful participation in the "Experimental Exercises for solid state spectroscopy" or a successful participation in the exercises for an advanced lecture in solid state theory
Exam	30 – 45 minute oral-exam

Module	Professional Specialisation
Semester	3^{rd} semester
Person in charge	Master thesis supervisor
Components (course, duration, CP, term)	- Advanced lectures (1 h/w corresponds to 1 CP) - Exercises for advanced lectures (1 h/w corresponds to 2 CP) - Laboratory course / internship (1 h/w corresponds to 1,5 CP) - Seminars (1 h/w corresponds to 1 CP) Approximately 5 h/w in total. - Self-studies
Credit points/ Work load	15 CP / 450 h
Learning targets	Basics of independent academic work taught through advanced research oriented courses. This module integrates the student with a working group to encourage teamwork and optimal use of information.
Contents	Independently gathering information and background knowledge and gaining familiarization with the topic of the master thesis
Exam	30 to 45 minute oral exam

Module	**Methodology und Project Planning**
Semester	3rd semester
Person in charge	Master thesis supervisor
Components (course, duration, CP, term)	In agreement with the person in charge: - laboratory course (1 h/w corresponds to 1,5 CP) - Computational physics course - Research and group seminars (1 h/w corresponds to 1 CP) - Self-studies
Credit points/ Work load	15 CP / 450 h
Learning targets	Technical and mathematical knowledge required for the master thesis
Contents	Introduction to academic work and to scientific and methodical basics required for master thesis This module integrates the student with a working group to encourage teamwork and optimal use of information
Exam	30 to 45 minute oral exam

Module	**Master Thesis**
Semester	4th semester
Person in charge	Master thesis supervisor
Components (course, duration, CP, term)	Independent work on master thesis (30 CP)
Credit points/ Work load	30 CP / 900 h
Prerequisites	At least 60 CP obtained in master studies
Learning targets	The master thesis completes scientific education. It demonstrates that the student is capable of independent research work applying state of the art methodology. The goal to perform a research project in a current field of physical research under guidance of the scientific supervisor.
Contents	Every student has to work on a current scientific problem in the field of her/his choice under guidance of the supervisor.
Exam	30 minute concluding presentation of the master thesis (second examiner must attend) The thesis grade determines the module grade. The grade conforms with § 15 Abs. 2.