The English version of the curriculum for the „Master of Science Programme in Physics“ unfolds no legal effects and is for information purposes only. The legal basis is regulated in the curriculum published in the University of Innsbruck Bulletin on 24 April 2007, issue 34, No. 198 and 15 April 2008, issue 2, No. 13 and 18 April 2012, issue 21, No. 245.

Decision of the Curriculum Committee of the Faculty of Mathematics, Computer Science and Physics on 9 January 2007, approved by Senate Decree on 29 March 2007:

On the basis of § 25 para. 1 no. 10 University Organisation Act 2002, BGBl. I (Federal Law Gazette) No. 120, most recently amended by Federal Law BGBl. I (Federal Law Gazette) No. 134/2008 and § 32 Section "Regulations of Study Law", republished in the University of Innsbruck Bulletin of 3 February 2006, Issue 16, No. 90, most recently amended by the University of Innsbruck Bulletin of 30 September 2009, Issue 113, No. 438, the following is decreed:

Curriculum for the

# Master of Science Programme in Physics

at the Faculty of Mathematics, Computer Science and Physics
of the University of Innsbruck

## § 1 Qualification Profile

The Master's degree follows the Bachelor's degree in physics and teaches the advanced knowledge and skills necessary for highly qualified, independent and innovative research plus development work in physics related technical professions. Furthermore, physics students in the course are taught strategies for solving problems that will make them attractive graduates for many other industrial and economic sectors. This is achieved by an in-depth study of selected frontline fields of physics together with integration into modern research.

Typical fields of activities for graduates, in addition to university-related research, include the implementation and support of research and development projects in physics and technology related industries and service sectors. Physicists find attractive employment opportunities in areas such as measurement and medical technology, information and telecommunications companies, as well as consulting firms and the financial sector.

Graduates should be able to use their knowledge to solve problems in science, technology, medicine and business. Therefore, the Masters study deepens the knowledge of both the foundations and methods of physics. Research based teaching in connection with the University's research strengths is included to promote creative thinking and also to prepare students for proceeding to the Doctoral program.

## § 2 Classification

The Master’s program is part of the Physics Section of studies in Natural Sciences.

## § 3 Length and Scope

The Master's degree in Physics consists of 120 ECTS credits (denoted below as ECTS-AP).

There are four compulsory modules worth a combined total of 17.5 ECTS-AP (9 semester hours) plus elective modules chosen by the students with requirement that students attain a minimum of 70 ECTS-AP. This corresponds to 4 semesters study period. The Master's thesis is assigned 32.5 ECTS-AP and the final oral exam counts for 2.5 ECTS-AP.

**§ 4 Admission**

(1) The prerequisite for admission to the Physics Master's program is the conclusion of a Bachelor's degree in Physics or other equivalent program at a recognized Austrian or foreign post-secondary educational institution.
(2) Successful completion of the Bachelor's degree or Teachers training course in physics at the University of Innsbruck counts as a prerequisite under paragraph (1).

**§ 5 Types of courses and maximum number of participants**

(1) Lecture (VO)
Lecture courses in didactic form covering the concepts, results and methods of the subject area.
Aim: To stimulate interest and convey in a relatively short period of time well-structured knowledge and understanding of the subject area.

(2) Proseminar (PS)
These introductory seminars are usually in close connection with the content of a lecture course. Students are given exercises and their solutions are discussed in the Seminar. When the Seminar is connected with a lecture, the lecture contents are repeated with practical examples.
Aim: To practice solving problems, learn the methods of the field and practice presenting technical and scientific content of well learned content.
Continuous assessment. The number of students in each class: 25

(3) Laboratory classes (PR)
Promote the acquisition of skills through guided but independent work and the practical discussion of scientific content.
Continuous assessment. The number of students in each class is limited to 25.

(4) Seminar (SE)
Scientific examination of content and methods of a subject through presentations, written assignments and discussion sessions. The students learn to present scientific results through written reports and oral (seminar talk) presentations.
Continuous assessment. The number of students in each class: 15

**§ 6 Name, type, extent and content of teaching modules and short description of the courses**

(1) The Master´s program is divided into 4 areas of research focus
1. Quantum Physics (Q) with specialization in
   a. Experimental Physics ($Q_{EXP}$)
   b. Theoretical Physics ($Q_{TH}$)
2. Ion, Plasma- & Applied Physics (I) with specialization in
   a. Experimental Physics ($I_{EXP}$)
   b. Theoretical Physics ($I_{TH}$)
3. Astro- & Particle Physics (AT) with specialization in
   a. Astrophysics ($AT_A$)

   b. Particle Physics ($AT_T$)
4. Computational Physics (CP)

**(2) Compulsory modules**

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| 1. *Basic Concepts in Research: Quantum Physics* | 5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop the basic concepts of quantum physics by themselves. Furthermore, they should acquire a basic understanding of research oriented approaches to quantum physics. | |
| Basic Concepts of Quantum Physics, VO3<br>*Contents*<br>Introductory understanding of research related topics in atomic physics, molecular physics, quantum optics, and quantum information: light-matter interactions, coherent effects, interferometry, entanglement, matter waves, quantum gases, precision measurements, macroscopic quantum phenomena. | 5 ECTS-AP |

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| 2. *Basic Concepts in Research: Ion, Plasma & Applied Physics* | 5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop the basic concepts of Ion, Plasma and Applied Physics by themselves. Furthermore, they should acquire a basic understanding of research oriented approaches to Ion, Plasma and Applied Physics. | |
| Basic Concepts of Ion, Plasma and Applied Physics, VO3<br>*Contents*<br>Introductory understanding of research related topics in Ion, Plasma and Applied Physics: Electron-Matter and Ion-Matter Interactions, Plasmas in nature and technological applications, behavior of Plasmas, concepts of Nuclear Fusion and Energy Physics, Molecular Physics, Mass Spectrometry and Analysis, Cluster Physics and Nanotechnology, Nonlinear Dynamics, fundamentals of Electrical Engineering. | 5 ECTS-AP |

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| 3. *Basic Concepts in Research: Astrophysics and Particle Physics* | 5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop the basic concepts of Astrophysics and Particle Physics by themselves. Furthermore, they should acquire a basic understanding of research oriented approaches to Astrophysics and Particle Physics. | |

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| Basic Concepts of Astrophysics and Particle Physics, VO3<br>*Contents*<br>Galaxies, Cosmology, Structure Formation and Structural Evolution, Dark Matter and Dark Energy, Gamma and X-ray Astrophysics. Relativistic Kinematics, Electromagnetic, Strong and Weak Elementary Processes, | 5 ECTS-AP |

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| Feynman Diagrams, Hadron Systematics, Quarks and Quantum Chromodynamics, Electroweak Unification. | |

| *4. Defense of the Master's thesis* | 2.5 ECTS-AP |
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| Concluding Defense of the Master's thesis.<br>*Prerequisite:* the successful completion of all other compulsory and elective modules as well as the positive assessment of the thesis. | |

**(3) Elective Modules**

| 1. *Quantum Physics II* | 10 ECTS-AP |
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| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to work on further concepts and methods of Quantum Physics by themselves. Furthermore, they should acquire a deeper understanding of Quantum Physics. | |
| Quantum Physics II, VO4<br>*Contents*<br>Scattering Theory, Relativistic Quantum Mechanics, Quantization of Linear Field Equations, Locality, Spin-Statistics-Theorem, Elements of Quantum Electrodynamics.<br><br>Quantum Physics II, PS2<br>*Contents*<br>Discussion, getting a deeper knowledge and practice with the contents of the lecture course; getting exercise in scientific argumentation and in the presentation of Mathematical and Physical Contents. | 6 ECTS-AP<br><br><br><br><br>4 ECTS-AP |

| 2. *Laser Physics, Laser Spektroscopy & Photonics* | 7.5 ECTS-AP |
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| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop the concepts and methods of Laser Physics, Laser Spectroscopy and Photonics by themselves. Furthermore, they should acquire a basic understanding of Laser Physics, Laser Spectroscopy and Photonics. | |
| Laser Physics, Laser Spectroscopy & Photonics, VO4<br>*Contents*<br>Optical Amplification, Gauß's Beam Optic and Optical Resonators, types of Lasers, Continous and Pulsed Lasers, Ultrashort Pulses, Coherence and Statistical Properties of Light, Doppler Confined and Unconfined Methods of Spectroscopy, Spectroscopy with Short Pulses, Coherent Spectroscopy, Atomic Clocks, Acusto- and Electrooptics, Linear and Nonlinear Optics, Conversion of Frequencies, Light Guides, Optical Communication Technology. | 7.5 ECTS-AP |

| 3. *Seminar (Q)* | 5 ECTS-AP |
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| *Objectives*<br>Graduates of this module are expected to reflect the problems of quantum physics in a creative and methodical manner and to present the results clearly | |

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| through written reports and/or oral presentation. | |
| Seminar Quantum Physics, SE2<br>*Contents*<br>Discussion of actual topics in Atomic Physics, Molecular Physics, Quantum Optics and Quantum Information. | 5 ECTS-AP |

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| 4. *Advanced Laboratory Class 2* | 10 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand the problems of the technical details of Experimental Physics by performing advanced experiments. They should have acquired the ability to conduct the experiments by themselves. Furthermore, they should have acquired a deeper understanding of experimental techniques in Physics. | |
| Advanced Laboratory Class 2, PR4<br>*Contents*<br>The practical accomplishment of the following experiments should make clear the experimental working in Physics; Examples: Counter Experiments, Semiconductor Spectroscopy, Nonlinear Optics, Diode Lasers, Amplitude and Phase Modulation, Laser Spectroscopy, Electron Absorption and Creation of Negative Ions, Ion-Molecule-Reactions. | 10 ECTS-AP |

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| 5. *Advanced Laboratory Class 3* | 7.5 ECTS-AP |
| *Objectives*<br>Graduates of this module are prepared by the practical accomplishment to the experimentally oriented master thesis. They should have acquired the ability to conduct the experiments by themselves. Furthermore, they should have acquired a deeper understanding of experimental techniques in Physics. | |
| Advanced Laboratory Class 3, PR3<br>*Contents*<br>The practical accomplishment of experiments is a preparation for the master thesis. In general the experiments are conducted with state-of-the-art research technology. Examples: Electronic Stabilizer, Stabilization by Lasers, Interaction of Electrons with Free Biomolecules, Analytic Mass Spectroscopy, Scanning Tunneling Microscope/Nanolitography. | 7.5 ECTS-AP |

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| 6. *Research Class in Experimental Quantum Physics* | 12.5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to conduct actual research by guided accomplishment of projects in Quantum Physics. They should have acquired the ability to conduct innovative experiments by themselves (attended by tutors). Furthermore, they should have acquired a deeper understanding of experimental techniques in Quantum Physics. | |
| Research Class in Experimental Quantum Physics, PR8<br>*Contents*<br>Introduction to experimental scientific research in the field of Atomic Physics, Molecular Physics, Quantum Optics and Quantum Information; guided work in current research. | 12.5 ECTS-AP |

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| 7. *Particle Traps & Laser Cooling* | 5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand and explain the content | |

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| of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop the contents and methods of Particle Traps and Laser Cooling by themselves. Furthermore, they should acquire a basic understanding of Particle Traps and Laser Cooling. | |
| Particle Traps & Laser Cooling, VO3<br>*Contents*<br>Magnetic Traps, Dipol Traps, Ion Traps, Doppler and Sub-Doppler Cooling, selected applications for Quantum Gases, Interferometry and Quantum Information. | 5 ECTS-AP |

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| 8. *Mathematical Methods 3* | 5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop the basic concepts in Mathematical Methods by themselves. Furthermore, they should acquire a deeper understanding of Mathematical Methods in Physics. | |
| Mathematical Methods of Physics 3, VO2<br>*Contents*<br>Group Theory, Stochastic Processes or Mathematical Software Packages used in Physics. | 5 ECTS-AP |

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| 9. *Relativity* | 5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop topics in Relativity by themselves. Furthermore, they should acquire a basic understanding of Relativity. | |
| Relativity, VO3<br>*Contents*<br>Minkowski Geometry, Pseudo-Riemannian Geometrie, Einstein Equations, Solution by Schwarzschild – Kruskal, Cosmology (Solution by Robertson-Walker) | 5 ECTS-AP |

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| 10. *Theoretical Quantum Optics* | 7.5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop topics in Theoretical Quantum Optics and Quantum Information by themselves. Furthermore, they should acquire a basic understanding of Theoretical Quantum Optics and Quantum Information. | |
| Theoretical Quantum Optics, VO3<br>*Contents*<br>Production and Detection of Photons, Jaynes-Cummings Modell, Cavity Quantum Electrodynamics, Laser Cooling, Theory of Ultracold Atomic Gases, implementation of Quantum Computers and Quantum Communication by Quantum Optical Methods.<br><br>Theoretical Quantum Optics and Information, PS1<br>*Contents* | 4.5 ECTS-AP<br><br><br><br><br><br>3 ECTS-AP |

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| Discussion, getting a deeper knowledge and practice with the contents of the lecture course; getting acquainted with scientific argumentation and presentation of theoretical contents in Physics. | |

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| 11. *Research Class in Theoretical Quantum Physics* | 7.5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand the problems of the technical details of Quantum Physics by conducting practical work in research projects in Quantum Physics. They should have acquired the ability to conduct simple innovative projects by themselves. Furthermore, they should have acquired a deeper understanding of projects in Theoretical Physics by studying the scientific literature. | |
| Research Class in Theoretical Quantum Physics, PR6<br>*Contents*<br>Introduction to scientific research in Theoretical Physics in the fields of Atomic Physics, Molecular Physics, Quantum Optics and Quantum Information; guided work on scientific projects. | 7.5 ECTS-AP |

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| 12. *Theoretical Quantum Information* | 5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop topics in Theoretical Quantum Information by themselves. Furthermore, they should acquire a deeper understanding of Theoretical Quantum Information. | |
| Theoretical Quantum Information (Q), VO2<br>*Contents*<br>Fundamentals of Classical Information Theory, protocols of Quantum Cryptography and Quantum Communication, theory of Entangled States, Quantum error correction, Quantum Computers and Quantum Simulators, Algorithms in Quantum Information. | 5 ECTS-AP |

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| 13. *Theory of Condensed Matter* | 5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop topics in Condensed Matter Physics by themselves. Furthermore, they should acquire a basic understanding of the theory of Condensed Matter. | |
| Theory of Condensed Matter, VO3<br>*Contents*<br>Quantum theory of Condensed Matter, BCS model of Superconductivity, Superfluidity, Bose-Einstein Condensation, modern topics in the theory of Solid State Physics, Nanostructures. | 5 ECTS-AP |

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| 14. *Ion and Plasma Physics (Introduction)* | 7.5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop topics in Ion and Plasma Physics. Furthermore, they should acquire a basic understanding of Ion and Plasma | |

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| Physics. | |
| Ion and Plasma Physics (Introduction), VO4<br>*Contents*<br>Production of charge carriers, production and properties of Plasma, gas discharge, interactions of Ions with neutral and other charged particles, surfaces and light, analysis of Ions and Plasma, magnetic confinement of Plasma, dynamics of Plasma and instabilities, layers of space charge, modelling of Individual Molecules, Clusters, Nanoparticles and Plasma. | 7.5 ECTS-AP |

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| 15. *Data Acquisition and Analysis* | 2.5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop topics in Data Acquisition and Data Analysis by themselves. Furthermore, they should acquire a basic understanding of Data Acquisition and Data Analysis. | |
| Data Acquisition and Analysis, VO2<br>*Contents*<br>Basics of processing of discrete signal, discrete Fourier transform (DFT), LTI-systems, convolution theorem, scanning theorem, digital filters (IIR, FIR), computer assisted acquisition of data with LABVIEW, analog-to-digital conversion (ADC), digital-to-analog conversion (DAC). | 2.5 ECTS-AP |

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| 16. *Seminar (I)* | 5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to reflect the problems of Ion and Applied Physics in a creative and methodical manner and to present the results clearly in a written reports and/or oral presentation. | |
| Seminar (I), SE2<br>*Contents*<br>Independent work on a talk on a specific topic. The content of the talk should expand the acquired knowledge and address the current state of the research in the field. | 5 ECTS-AP |

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| 17. *Research Management* | 5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop topics in Research Management by themselves. Furthermore, they should acquire a basic understanding of Research Management. | |
| Research Management, VO2<br>*Contents*<br>Project management, Quality Control (TÜV, approval of technical instruments), Patent Law. | 5 ECTS-AP |

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| 18. *Measurement and Basic Experimental Techniques.* | 7.5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop topics in Measurement Techniques and | |

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| basic Experimental Techniques by themselves. Furthermore, they should acquire a basic understanding of the theory and practice of Measurement. | |
| Measurement and Basic Experimental Techniques, VO4<br>*Contents*<br>Foundations of Electrical Engineering, Resonance, Oscillations, Phase and Group Velocity, Amplifier, Method of Coincidence, Lock-in Amplifier, General Measurement Techniques, Vacuum Technique, Leak Detection, Mass Spectroscopy and Methods of Analysis of Scientific and Ordinary Samples. | 7.5 ECTS-AP |

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| 19. *Research Class in Experimental Ion and Plasma Physics* | 12.5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to conduct actual research by guided accomplishment of projects in Ion and Plasma Physics. They should have acquired the ability to conduct innovative experiments by themselves (attended by tutors). Furthermore, they should have acquired a deeper understanding of Experimental Techniques in Ion and Plasma Physics. | |
| Research Class in Experimental Ion and Plasma Physics, PR8<br>*Contents*<br>Introduction to scientific experimental research in the fields of Ion Physics, Plasma Physics and Applied Physics. Attended work on projects in the context of ongoing research projects. | 12.5 ECTS-AP |

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| 20. *Theory of Molecules* | 2.5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop topics in the Theory of Molecules by themselves. Furthermore, they should acquire a basic understanding of the Theory of Molecules. | |
| Theory of Molecules, VO2<br>*Contents*<br>Theoretical Chemistry, Quantum Chemistry and Molecular Dynamics. | 2.5 ECTS-AP |

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| 21. *Mechanics of Continua and Theoretical Plasma Physics* | 7.5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop topics in Mechanics of Continua and Plasma Physics by themselves. Furthermore, they should acquire a basic understanding of the Mechanics of Continua and Theoretical Plasma Physics. | |
| Mechanics of Continua and Theoretical Plasma Physics, VO3<br>*Contents*<br>Kinetic Theory, Mechanics of Continua, Magneto-Hydrodynamics, Plasma Physics and Nuclear Fusion, Nonlinear Dynamics of Plasma and Fluids (turbulence and creation of structures)<br><br>Mechanics of Continua and Theoretical Plasma Physics, PS1<br>*Contents*<br>Discussion, getting a deeper knowledge and practice with the contents of the lecture course; getting acquainted with scientific argumentation and | 4.5 ECTS-AP<br><br><br><br><br><br>3 ECTS-AP |

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| presentation of theoretical contents in Physics. | |

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| 22. *Research Class in Theoretical Ion, Plasma and Energy Physics* | 7.5 ECTS-AP |
| *Objectives*<br>Graduates of this module are integrated with the ongoing research projects in the field of Theoretical Ion, Plasma, and Energy Physics by contributing to the analytical and numerical solutions. In this process they will acquire a fundamental understanding of ongoing projects in Plasma and Energy and furthermore an ability to conduct new projects either in collaboration or by themselves. | |
| Research Class in Theoretical Ion, Plasma and Energy Physics, PR6<br>*Contents*<br>Introduction to scientific research in the field of Theoretical Ion, Plasma and Energy Physics. Guided participation in ongoing Research Projects. | 7.5 ECTS-AP |

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| 23. *Introduction to Scientific Research in Ion, Plasma and Energy Physics* | 5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop topics in the field of Ion, Plasma and Energy Physics by themselves. Furthermore, they should acquire a basic understanding for scientific research in those fields. | |
| Introduction to Scientific Research in Ion, Plasma, and Energy Physics, VO2<br>*Contents*<br>Accompanying lecture to the research class in Theoretical Ion, Plasma and Energy Physics: special methods and procedures in the field of Ion, Plasma and Energy Physics. | 5 ECTS-AP |

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| 24. *Numerical Mathematics* | 5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop topics in Numerical Mathematics by themselves. Furthermore, they should acquire a basic understanding of Numerical Mathematics. | |
| Numerical Mathematics, VO2<br>*Contents*<br>Numerical solution of initial value problems of ordinary Differential Equations (one and many step Algorithms, variation of step size); boundary value problems in ordinary Differential Equations (theory, method of differences, variational methods). Partial Differential Equations of Hydrodynamics and Magneto-Hydrodynamics with and without external forces. Discontinuities in Numerical Calculations (Godunov Scheme). | 5 ECTS-AP |

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| 25. *Astroparticle Physics* | 2.5 ECTS-AP |
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to work on further contents in Astroparticle Physics by themselves. Furthermore, they should acquire a basic understanding of Astroparticle Physics. | |

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| Astroparticle Physics, VO2<br>*Contents*<br>Nucleosynthesis in Astrophysics, large structures in the Universe, interstellar matter; the standard model of Particle Physics formulated as a Gauge Theory, Radiative Corrections, Experimental Tests; Cosmic Rays, Neutrinos. | 2.5 ECTS-AP |

| 26. *Statistics and Data Analysis* | 5 ECTS-AP |
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| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to work on further topics in Statistics and Data Analysis by themselves. Furthermore, they should acquire a basic understanding of Statistics and Data Analysis. | |
| Statistics and Data Analysis, VO2<br>*Contents*<br>Fundamentals of Statistics in Data Acquisition, Test methods concerning small test samples, Statistics using Detectors, ideal and real Detectors in Astrophysics and Particle Physics (CCD, Multiplier, Counter…), defects and non linear properties of Detectors, Error Correction, Analysis of time ordered data.<br><br>Statistics and Data Analysis, PS1<br>*Contents*<br>Discussion, getting a deeper knowledge and practice with the contents of the lecture course; computer aided Analysis of Data. | 2.5 ECTS-AP<br><br><br><br><br><br><br><br>2.5 ECTS-AP |

| 27. *Seminar (AT)* | 5 ECTS-AP |
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| *Objectives*<br>Graduates of this module are expected to reflect the problems of Astrophysics and Particle Physics in a creative and methodical correct manner and to present the results clearly in written reports and/or oral presentation. | |
| Seminar (AT), SE2<br>*Contents*<br>Independent work on a talk on a specific topic. The content of the talk should expand the acquired knowledge and address the current state of the research in the field. | 5 ECTS-AP |

| 28. *Special Course 1 (AT)* | 5 ECTS-AP |
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| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop the basic concepts of Astroparticle Physics by themselves. Furthermore, they should acquire a deeper understanding of selected topics in Astroparticle Physics. | |
| Special Course 1 (AT), VO3<br>*Contents*<br>Selected topics in Astroparticle Physics. | 5 ECTS-AP |

| 29. *Special Course 2 (AT)* | 5 ECTS-AP |
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| *Objectives* | |

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| Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to develop further concepts of Astroparticle Physics by themselves. Furthermore, they should acquire a deeper understanding of selected topics in Astroparticle Physics. | |
| Special Course 2 (AT), VO2<br>*Contents*<br>Selected topics in Astroparticle Physics. | 5 ECTS-AP |

| 30. *Laboratory Class at the Telescope* | 10 ECTS-AP |
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| *Objectives*<br>Graduates of this module are expected to understand the experimental methods and techniques in Astrophysics by attendance of this laboratory class. They should acquire the ability to accomplish observations on the telescope by themselves. Furthermore, they should acquire a basic understanding of the experimental research methods in Astrophysics. | |
| Advanced Laboratory Class at the Telescope, PR4<br>Contents<br>Management of Observations, CCD Direct Imaging, Stellar Spectroscopy, Data Analysis, writing a scientific report. The lecture course will be blocked (depending on the wheater) and takes place only during the winter term. | 10 ECTS-AP |

| 31. *Astrophysics 2* | 7.5 ECTS-AP |
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| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop topics in Astrophysics by themselves. Furthermore, they should acquire a deeper understanding in the field of Astrophysics. | |
| Astrophysics 2, VO3<br>*Contents*<br>The Planet System, Hydrodynamics of the Composition of a star, Evolution of stars and details of Nuclear Fusion, Formation and Dynamics of Galaxies, Galaxies in a global context, interstellar matter.<br>Astrophysics 2, PS2<br>*Contents*<br>Discussion, getting a deeper knowledge and practice with the contents of the lecture course; getting acquainted with scientific argumentation and presentation of Mathematical Contents. | 4 ECTS-AP<br><br><br><br><br>3.5 ECTS-AP |

| 32. *Research Class in Astrophysics* | 12.5 ECTS-AP |
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| *Objectives*<br>Graduates of this module are expected to conduct actual research by guided accomplishment of projects in Astrophysics. They should have acquired the ability to conduct innovative experiments by themselves (attended by tutors). Furthermore, they should have acquired a deeper understanding of experimental work on projects in Astrophysics. | |
| Research Class in Astrophysics, PR8<br>*Contents*<br>Introduction to experimental scientific research in the field of Astrophysics. Attended work on projects in the context of ongoing Research Projects. | 12.5 ECTS-AP |

| 33. *Laboratory Class in Particle Physics* | 5 ECTS-AP |
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| *Objectives*<br>Graduates of this module are expected to conduct actual research by guided participation in projects in Particle Physics. They should have acquired the ability to conduct innovative experiments by themselves (attended by tutors). Furthermore, they should have acquired a deeper understanding of experimental techniques in Particle Physics. | |
| Laboratory Class in Particle Physics, PR3<br>*Contents*<br>Introduction to the methods in experimental Particle Physics by analysing six aspects of experiments performed at CERN:<br>- Calculation of the decay of neutral Kaons (simulated data)<br>- Simulation of the decay of a Kaon in a detector<br>- Annihilation of Electrons and Positrons on the Z-peak<br>- Analysis of Real Data<br>- Determination of the branching ratio R (hadrons/leptons)<br>- Determination of the parameters of the Z-resonance | 5 ECTS-AP |

| 34. *Research Class in Particle Physics* | 12.5 ECTS-AP |
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| *Objectives*<br>Graduates of this module are expected to conduct actual research by participation in projects in Particle Physics. They should have acquired the ability to conduct innovative experiments by themselves (attended by tutors). Furthermore, they should have acquired a deeper understanding of experimental techniques in Particle Physics. | |
| Research Class in Particle Physics, PR8<br>*Contents*<br>Introduction to scientific research in Experimental Particle Physics. Guided work on projects in current Research. | 12.5 ECTS-AP |

| *35. Advanced Courses in Mathematics* | 15 ECTS-AP |
|---|---|
| *Objectives*<br>In the major field of study „Computational Physics“ students have to acquire advanced knowlegde in Mathematics. | |
| Every student has to supply lecture courses with 15 ECTS-AP out of the Bachelor or Master Programme in Technical Mathematics; those courses must not be contained in the compulsory courses in the Bachelor or Master Programme in Physics. | 15 ECTS-AP |

| 36. *Numerical Solution of Partial Differential Equations* | 10 ECTS-AP |
|---|---|
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop topics in Numerical Solution of Partial Differential Equations by themselves. Furthermore, they should acquire a deeper understanding of this field. | |
| Numerical Solution of Partial Differential Equations, VO3<br>*Contents*<br>Numerical Algorithms for the solution of systems of Partial Differential Equations, especially the method of Finite Elements and Finite Differences; Analysis of stability of solutions; error estimates. | 6 ECTS-AP |

| | |
|---|---|
| Numerical Solution of Partial Differential Equations, PS2<br>*Contents*<br>Discussion, getting a deeper knowledge and practice with the contents of the lecture course; acquiring exercise in scientific argumentation and in the presentation of Mathematical and Physical Contents. | 4 ECTS-AP |

| *37. Particle Physics* | 2.5 ECTS-AP |
|---|---|
| *Objectives*<br>Graduates of this module are expected to understand and explain the content of the course, and to be able to apply the methods of the course. They should acquire the ability to further develop topics in Particle Physics by themselves. Furthermore, they should acquire a deeper understanding of Particle Physics. | |
| Particle Physics, VO2<br>*Contents*<br>Annihilation of Electrons and Positrons on the Z-peak, experiments at CERN, Hadrons and Leptons, Z-resonance, the standard model of Particle Physics, models beyond the standard model, results from the LHC. | |

| *38. Elective Module* | 15 ECTS-AP |
|---|---|
| *Objectives*<br>Graduates should acquire further knowledge in addition to the contents of the compulsory modules (2) and the elective modules (3) out of the fields of Mathematics or Computer Science or further knowledge in one or more fields of Physics. | |
| Graduates should enroll in lecture courses of the Faculty of Mathematics, Computer Science and Physics marked by „WP“ (Wahlmodul Physik = elective module in Physics) corresponding to a workload of 15 ECTS-AP. Alternatively, they may enroll in modules of the Master Programmes in Mathematics or Computer Science, which are not part of the Master Programme in Physics. | |

(4) Combinations of optional modules to be completed are:

1. Major field of study: Quantum Physics
   a. Experimental Physics: 1, 2, 3, 4, 5, 6, 7, 38
   b. Theoretical Physics: 1, 2, 3, 8, 9, 10, 11, 12, 13, 38
2. Major field of study: Ion, Plasma and Applied Physics
   a. Experimental Physics: 4, 5, 14, 15, 16, 17, 18, 19, 38
   b. Theoretical Physics: 8, 9, 14, 15, 16, 17, 20, 21, 22, 23, 24, 38
3. Major field of study: Astrophysics and Particle Physics
   a. Astrophysics: 24, 25, 26, 27, 28, 29, 31, 32, 38 and either 8+9 or 30
   b. Particle physics: 4, 24, 25, 26, 27, 28, 29, 33, 34, 37, 38
4. Major field of study: Computational Physics: 8, 24, 26, 35, 36, 38,
   one of the modules 3, 16, 27
   plus one of the modules 6, 19, 32, 34
   or the modules 11 and 12
   or the modules 22 and 23

## § 7 Master´s Thesis

As part of the Master´s Degree in Physics, a Master´s Thesis must be written. Students are awarded 32.5 ECTS-credits for the thesis, which should be a scholarly work in a relevant field of Physics.

## § 8 Admission procedures for the admission to courses with a limited number of participants

For courses with a limited number of participants, places in courses will be awarded as follows:

1. Students who have been granted an extension to complete their studies because of missing initial background are allowed to be preferred.
2. When places are not filled according to criterion 1, the remaining places are awarded first to students for whom the course is compulsory and then to students for whom the course is an optional module.
3. When places are not filled according to criteria 1 and 2, remaining places will be raffled by ballot.

## § 9 Examination Procedure

(1) There will be an examination for each compulsory and elective lecture module. The lecturer will announce at the beginning of the course whether the examination will be held orally or via a written paper.
(2) Successful participation in seminars will be assessed through a talk presentation plus seminar paper.
(3) Any additional assessment criteria of student performance will be announced by the lecturer at the start of the course.
(4) A module is completed by the positive assessment of its course components.
(5) The Master´s Programme is completed by the final defense of the Master´s Thesis. This final exam will be assigned 2.5 ECTS-AP. The exam takes approx. 60 minutes and begins with a 20 minute public lecture presentation about the thesis followed by open discussion and questions about the talk. The exam is concluded with questions about the thesis from members of the examination board.

## § 10 Academic Degree

Graduates of the Master's Study in Physics are awarded the academic degree of "Master of Science" (abreviated as M.Sc.).

## §12 Coming into force

This curriculum comes into force on October 1 2007.

For the Curriculum-Committee
Univ.-Prof. Dr. Alexander Ostermann
Chair

For the Senate
Univ.-Prof. Dr. Ivo Hajnal
Chair