Master study programme

The Master's degree programme in Physics is offered as a mono or major programme, each with 90 ECTS credits. In the second option, a minor of 30 ECTS credits must be completed in addition to the major in physics of 90 ECTS credits.

At the beginning of the Master's programme, students discuss their individual curriculum with the director of the study programme, which is then written down in a learning agreement.

Before beginning the Master's thesis, this learning agreement is finalised with the director of the study programme and/or the supervisor of the Master's thesis. Subsequent changes to the agreement require the agreement of the director of the study programme.

Master's theses are offered in two different lengths. Longer theses of 50 ECTS take about 10 months with full-time employment (including preparation for the examination, as well as the possibility of holidays in consultation with the supervisor). Independent research is strongly emphasised in such theses.

Shorter theses amounting to 30 ECTS take about 6 months with full-time employment (including preparation for the examination and the possibility of holidays in consultation with the supervisor). It is possible to attend a wider range of advanced lectures for such theses.

Work in the physics groups at UZH can be divided into the following overall research areas:

- Condensed matter: the study of materials whose properties are characterised by the interaction of many quantum states. The work is mainly experimental, in the groups Aegerter, Chang, Natterer, Nordlander, Janoschek, Latychevskaia and Schilling, as well as theoretical in the groups Neupert and Bzdušek.

- Elementary particle physics: the study of the fundamental building blocks of matter and their interactions. The work is carried out experimentally in the Baudis, Canelli, Kilminster, Serra, Steinkamp and Caminada groups, and theoretically in the Gehrmann, Grazzini, Isidori, Pozzorini, Signer, Stoffer, Zoller and Crivellin groups.

- Astro(particle) physics and cosmology: the study of the properties of galaxies and the universe as a whole. This includes in particular the search for dark matter. The work is carried out theoretically in the Helled, Jetzer, Mayer, Moore, Saha, Feldmann, Schneider and Yoo groups and experimentally in the Baudis, Kilminster, Penning and Soares-Santos groups.

- Biological and medical physics: The use of physical examination methods and imaging techniques to understand biological systems or for medical applications, e.g. in radiotherapy. The work takes place in the Aegerter, Kozerke, Latychevskaia, Schneider, Schuler and Unkelbach groups.

An overview of current research work can be found in the annual reports at http://www.physik.uzh.ch/en/research/reports.html and on the websites of the individual research groups: http://www.physik.uzh.ch/en/research/research.html

Master's theses can be carried out in the groups of the Institute of Physics and associated research groups. For research areas that are not covered by these groups, it is also possible to carry out a Master's thesis in an external research group. For this purpose, a written application with a work plan must be submitted to a UZH physics lecturer who must be prepared to take responsibility for co-supervision of the thesis. The choice of lectures to be attended will then be agreed on with this lecturer.

However, only topics relating to physics are generally considered for such thesis projects. A Master's thesis in an external research group is subject to the requirements of the Master's degree

programme in physics at UZH in terms of duration, quality, supervision and grading. The corresponding credit points therefore count as credit points earned at UZH.

Successful graduates are awarded the degree of ‘Master of Science UZH in Physics’. To obtain the Master's degree, 90 ECTS credits are required.

The Master's programme is taught in English.

Admission to the Master's degree programme with a major in Physics

A Bachelor of Science UZH in Physics or a Bachelor's degree in Physics from another Swiss university automatically entitles the holder to be admitted to the Master's degree programme in Physics.

All compulsory and compulsory elective modules of the Bachelor's degree programme (incl. Bachelor's thesis) must be completed when registering for the Master's degree programme.

A maximum of 30 ECTS credits acquired during the Bachelor's degree programme can be credited towards the Master's degree programme. The Master's thesis may only be started after completion of the Bachelor's degree programme.

Bachelor's degrees from foreign universities are assessed individually by the faculty. The relevant documents must be submitted together with the application for enrolment to the Registrar's Office or to the Admissions Office for students with foreign qualifications. Depending on previous education, additional coursework may be required during the Master's programme.

Admission to the consecutive Master’s programme from the BSc180/BSc150 mono or major study programme in Physics

With a BSc degree in the mono study programme in Physics 180 or in the major study programme in Physics 150 ECTS Credits, it is possible to transfer to the consecutive Master's programme without any conditions.

Admission to the consecutive Master’s programme from the major study programme Physics 120

With a BSc degree in the major study programme Physics 120 ECTS Credits, admission to the consecutive Master's programme requires the following modules.

- Solid State Physics (PHY210)
- Nuclear and Particle Physics I (PHY211)
- Quantum Mechanics I (PHY 331)
- Thermodynamics and Statistical Mechanics (PHY341)

Modules from this list that were not completed as a core elective in the 3rd year of the Bachelor's programme must be completed during the Master's programme, these can be counted as part of the electives of the Master's programme.

Compulsory modules

Master's thesis and associated module examination (30 or 50 ECTS)

The Master's thesis forms a central part of the Master's degree programme, especially if the longer version of 50 ECTS is chosen. The Master's thesis consists of an independent research project within one of the physics research groups at our university or by arrangement in an external research group.

The Master's thesis is reported in a written report, which is graded.

If you work full-time, a 50 ECTS Master's thesis takes approximately 10 months, including preparation for the module examination and writing the report. Holidays of up to four weeks are also possible in consultation with the supervisor within this time frame. In the case of part-time employment and more or fewer holidays, the duration changes accordingly.

A Master's thesis worth 30 ECTS corresponds to a duration of approximately 6 months, whereby the same conditions apply. This duration includes holidays of up to two weeks.

The module examination for the Master's thesis consists of two parts, each lasting around 30 minutes, and is also graded. The Master's thesis is first presented in a public seminar. In a second, non-public part, at least two lecturers will conduct an oral examination on physical concepts related to the Master's thesis.

The overall grade for the Master's thesis is calculated from the weighted average of the grades for the written report (2/3) and the module examination (1/3). Both the Master's thesis and the module examination must be graded as sufficient, i.e. at least 4.0.

The dates for the Master's thesis and the associated module examination are set directly with the supervisor. Registration takes place using the forms on the website

https://www.physik.uzh.ch/en/study/Counselling-and-forms/formulare.html

Research seminar

Research seminars must be attended as part of the Master's degree programme. These can be chosen from all the research seminars on offer, as well as the joint colloquium in physics with ETH. A total of 20 seminar lectures must be attended during 2 semesters, whereby attendance must be confirmed by the organiser of the seminar or a participating lecturer. Forms can be found on the website

https://www.physik.uzh.ch/en/study/Counselling-and-forms/formulare.html

Minor subject

90 ECTS Credits are required to obtain the Master's degree in Physics. A minor subject can be taken voluntarily for an additional 30 ECTS Credits.

Master's grade

The Master's grade is calculated from the credit-weighted average of all graded modules in the Master's degree programme.**Selection of further lecture modules**

In addition to the research seminar and the Master's thesis, a total of 16 ECTS must be selected from a block of core elective modules, listed below. Depending on the area of the Master's thesis, various combinations of core electives are recommended to ensure optimal preparation for the

thesis. However, especially with a shorter Master's thesis totalling 30 ECTS credits, it is possible to attend a broader range of advanced lectures.

The elective area remaining after the core elective lectures can also be filled with other core elective modules.

Master's modules in physics from all areas of physics offered by ETH and UZH are also permitted.

Core elective modules

Module	ECTS
PHY 411 Solid state theory	10
PHY 401 Condensed Matter	10
PHY 452 Elementary Particle Theory	10
PHY 451 Elementary Particle Physics	8
PHY 471 Physics and Mathematics of Radiotherapy planning	6
PHY 361 Physics against cancer	6
PHY475 Computational problems in medical physics and radiation oncology	6
PHY431 Biological Physics	4
PHY425 Modern Optics and Microscopy	4
PHY352 Continuum Mechanics	8
AST511 General Relativity	10
AST513 Physical Cosmology	10
AST512 Theoretical Astrophysics	10
AST 514 Planetary Formation	10
PHY473 Introduction to Astroparticle Physics and Cosmology	6

The core electives and the elective modules are discussed in the learning agreement with the director of the study programme (Prof. Christof Aegerter) at the beginning of the study programme and fixed with the supervisor of the Master's thesis or the director of the Master's study programme before the start of the Master's thesis. Suitable combinations for the different areas (and sub-areas thereof) as well as possible elective modules are listed below.

Condensed matter:

For a Master's thesis in the area of condensed matter, the core elective modules PHY401 and PHY411 are recommended.

Elective modules focusing on condensed matter (offered by UZH):

- PHY 212 Festkörperphysik II
- PHY 420 Electronspectroscopy
- PHY 425 Modern Optics and Microscopy
- PHY 426 Laser Matter Interaction
- PHY 427 Electron microscopy lectures
- PHY 432 Physics with Muons: From Atomic Physics to Solid State Physics
- PHY 434 Nanomagnetism and Spintronics
- PHY 435 Introducing Photons, Neutrons and Muons for Materials Characterisation
- PHY 522 Computational Quantum Physics
- PHY 523 Unconventional Superconductivity
- PHY 541 Introduction to Disordered and Random Systems
- PHY 585 Principles of X-ray and Neutron Scattering
- CHE 437 Surface and Interface Science,
- PHY 542 Geometry and Topology in Condensed Matter Physics
- PHY 576 Topological condensed matter physics

Elementary Particle Physics:

For a Master's thesis in the area of particle physics, the core elective modules PHY451 and PHY452 are recommended.

Elective modules focusing on particle physics (offered by UZH):

- PHY 213 Kern- und Teilchenphysik II
- PHY 551 Quantenfeldtheorie I
- PHY 552 Quantum Field Theory II
- PHY 563 The Standard Model and Beyond
- PHY 462 Particle physics experiment at PSI
- PHY 432 Physics with Muons: From Atomic Physics to Solid State Physics
- PHY 585 Principles of X-ray and Neutron Scattering
- PHY 579 Special Topics in Particle Theory
- PHY 578 Effective Field Theories for Particle Physics
- PHY 461 Experimentelle Methoden und Instrumente der Teilchenphysik
- PHY 564 QCD and Scattering Amplitudes

Astrophysics

For a Master's thesis in the area of astrophysics, the core elective modules AST512 and AST514 are recommended.

Elective modules focusing on astrophysics (offered by UZH):

- AST 511 General Relativity
- AST 513 Physical Cosmology
- PHY 473 Introduction to Astroparticle Physics and Cosmology
- ESC 204 Computational Methods for Radiative Transfer
- PHY 519 Applications of General Relativity in Astrophysics and Cosmology

- ESC 411 Computational Science I
- PHY 551 Quantum Field Theory I
- ESS 427 Planetary Geochemistry

Cosmology

For a Master's thesis in the area of cosmology, the core elective modules AST511 and AST513 are recommended.

Elective modules focusing on cosmology (offered by UZH):
- AST 512 Theoretical Astrophysics
- AST 514 Planetary Formation
- PHY 473 Introduction to Astroparticle Physics and Cosmology
- ESC 204 Computational Methods for Radiative Transfer
- PHY 519 Applications of General Relativity in Astrophysics and Cosmology
- ESC 411 Computational Science I
- PHY 551 Quantum Field Theory I
- ESS 427 Planetary Geochemistry

Astroparticle Physics

For a Master's thesis in the area of experimental astroparticle physics, the core elective modules PHY451 und PHY473 are recommended.

Elective modules focusing on astroparticle physics (offered by UZH):
- AST 511 General Relativity
- AST 512 Theoretical Astrophysics
- AST 513 Physical Cosmology
- PHY 519 Applications of General Relativity in Astrophysics and Cosmology
- PHY 461 Experimentelle Methoden und Instrumente der Teilchenphysik
- PHY 585 Principles of X-ray and Neutron Scattering
- PHY 563 The Standard Model and Beyond

Biological Physics

For a Master's thesis in the area of biological physics, the core elective modules PHY352, PHY425 und PHY431 are recommended.

Elective modules focusing on biological physics (offered by UZH):
- BIO 330 Modelling in Biology
- PHY 474 Advanced Topics in Medical Imaging
- ESC 204 Computational Methods for Radiative Transfer
- PHY 426 Laser Matter Interaction
- PHY 427 Electron microscopy lectures
- PHY 252 Computergestütztes Experimentieren
- PHY 253 Computergestütztes Experimentieren II

Medical Physics

For a Master's thesis in the area of medical physics, the core elective modules PHY361, PHY475 und PHY471 are recommended.

Elective modules focusing on medical physics (offered by UZH):

- PHY425 Modern Optics and Microscopy
- PHY 474 Advanced Topics in Medical Imaging
- ESC 204 Computational Methods for Radiative Transfer
- PHY 426 Laser Matter Interaction
- PHY 427 Electron microscopy lectures

Theoretical Physics

For a Master's thesis in the area of theoretical physics, the core elective modules PHY411, PHY452 und AST511 are recommended.

Elective modules focusing on theoretical physics (offered by UZH):

- PHY 351 Quantenmechanik II
- PHY 522 Computational Quantum Physics
- PHY 523 Unconventional Superconductivity
- PHY 541 Introduction to Disordered and Random Systems
- PHY 542 Geometry and Topology in Condensed Matter Physics
- PHY 576 Topological condensed matter physics
- PHY 551 Quantum Field Theory I
- PHY 552 Quantum Field Theory II
- PHY 563 The Standard Model and Beyond
- PHY 564 QCD and Scattering Amplitudes
- PHY 579 Special Topics in Particle Theory
- PHY 578 Effective Field Theories for Particle Physics
- AST 512 Theoretical Astrophysics
- AST 513 Physical Cosmology
- PHY 519 Applications of General Relativity in Astrophysics and Cosmology

Course contents for compulsory and core elective modules

PHY401 Condensed Matter

Phenomenology of

- energy bands and fermi areas
- optical properties
- supra-conduction
- di-electrics and ferro-electrics
- magnetic properties
- surface effects
- electron optics and applications of focussed electron radiation
- production of structures at the micro- and nanometer scale
- lithographic structuring methods
- mesoscopic physics

PHY411: Theory of Condensed Matter

- electrons and phonons
- spectra, band theory
- application of group theory
- second quantization
- Many-body-theory
- electron-phonon interactions
- supra-conduction
- magnetism

PHY451 Elementary particle physics

- Beginning of particle physics
- Detectors Accelerators
- QCD physics
- Electroweak physics
- Flavor and neutrino physics
- Dark matter
- Beyond-Standard Model physics
- Future facilities

PHY452 Elementary Particle Theory

- Elements of Quantum Field Theory
- Quantum Electrodynamics
- Nonabelian Gauge Theories
- Quantum Chromodynamics (Strong Interactions)
- Electroweak Standard Model and Higgs Mechanism
- Quark Masses and Mixing
- Neutrinos

PHY551 Quantum Field Theory

- Relativistic wave functions
- Quantification of free fields
- Re-normalization
- Perturbation theory
-

PHY461 Experimental Methods and Instruments in Particle Physics

- Physics and structure of particle accelerators
- Foundations and concepts in particle detectors
- Trace and vortex detectors, calorimetry, particle identification
- Special applications such as Cerenkov detectors, air showers, direct detection of dark matter, emulsions
- Simulations methods, selection electronics, trigger and data measurement
- Examples and key experiments

PHY463 Research internship

This internship lasts for 4 to 6 weeks, during which students construct, conduct and evaluate an experiment using a particle radiation at CERN or PSI or some other research lab. For instance, you might do an internship at PSI, where you work in a group for three weeks planning and constructing an experiment that uses the PSI's secondary laser and conducting it jointly during shifts. Then you must evaluate your data and complete a report.

PHY552 Quantum Field Theory II

Advanced topics such as:

- Re-normalization groups
- Abel and non-Abel Eicht theories

- Standard model, Higgs mechanism
- Path integrals
- PHY568 Flavour Physics
- B-Penomenology
- Neutrino masses and oscillations
- CP violations in B^0_s

AST511 General Relativity

- repetition of special relativity
- principle of equivalence
- motion in the gravitational field, gravitational red-shift
- tensors in Riemann-Space
- covariant derivative, parallel transport
- Riemann tensor, Bianchi-Identities
- Einstein's field equations
- Schwarzschild-solution
- precession of the perihelion, deflection of light
- geodesic precession
- gravitational waves
- black holes
- Friedman-Robertson-Walker universe

AST513 Physical Cosmology

- big bang and early universe
- nucleosynthesis
- inflation
- relativistic perturbation theory and growth of structure
- cosmic microwave background and large scale structure
- dark matter and dark energy

AST512 Theoretical Astrophysics

- radiative processes in the interstellar medium
- Star structure

- Star development
- Supernovae
- White dwarfs
- Neutron stars
- Black holes
- Planet formation

227-0385-10L Biomedical Imaging

(is being offered by the Institute for Biomedical Engineering)

- Physikalische und technische Grundlagen der medizinischen Bildgebung
- Bildrekonstruktion
- Röntgenbildgebung
- Computertomographie (CT)
- Single Photon Emission Tomography (SPECT)
- Positron Emission Tomography (PET)
- Magnetresonanztomographie (MR)
- Ultraschall

PHY471 Physics and Mathematics of Radiotherapy planning

- Wechselwirkung von Strahlung im Gewebe
- Dosisberechnungsalgorithmen
- Bestrahlungsplanung
- Intensitätsmodulierte Strahlentherapie (IMRT)
- Mathematische Optimierungsmethoden in der IMRT Planung
- Bildregistrierung
- Grundlagen der klinischen Radioonkologie, Zielvolumendefinition, Fraktionierung

PHY361 Physics against cancer: The physics of imaging and treating cancer

- Radiation Physics
- Imaging for radiotherapy
- Imaging with protons and ions
- Radiotherapy with photons, electrons, protons and heavy ions
- Basics of radiobiology and bio-physical modelling for radiotherapy

- Organ motion management
- Special radiotherapy techniques

STA404 Clinical biostatistics

- Confidence intervals for proportions,
- Analysis of diagnostic studies,
- Analysis of agreement,
- Randomized controlled trials,
- Hypothesis tests and sample size calculation,
- Randomization and blinding,
- Analysis of continuous and binary outcomes,
- Multiplicity,
- Subgroup analysis,
- Protocol deviations,
- Some special designs (crossover, equivalence, and clusters),
- Analysis of prognostic studies,
- Development and assessment of clinical prediction models.

ESC411 Computational Science I

- Ordinary differential equations
- Partial differential equations
- Monte-Carlo
- Inverse problems
- Signal-processing
- Optimization
- Visualization
- Combinatorial problems

PHY233 Numerical Methods I

- Floating point representation
- Solving systems of linear equations
- Matrix diagonalization algorithms
- Eigenvalue calculations

- Function interpolation and extrapolation
- Solving the differential equations with numerical methods

BIO330 Modelling in Biology

- Deterministic Reaction-Diffusion models
- Stochastic Reaction-Diffusion models
- Finite-element modelling
- Cell-based tissue models
- Image analysis

BIO253 Experimental Techniques in Physical Biology

- Biomechanics of tissue
- Force measurements
- Modern microscopy
- Scattering methods
- Nuclear magnetic resonance

PHY431 Biology for Physicists

- Constituents of Biomatter, DANN, RNA, Proteins
- Heredity and evolution
- Allometric scaling laws
- Morphogenesis
- Transcription of genes
- Neural Networks