Linnæus University

Jnr: 2021/4610-3.1.1.3

Programme syllabus

Faculty of Technology

Fysik, masterprogram, 120 högskolepoäng
Physics, Master Programme, 120 credits

Level
Second Level

Date of Ratification
Approved 2010-12-17
Revised 2021-12-10 by the Faculty Board within the Faculty of Technology
The programme syllabus is valid from autumn semester 2022

Prerequisites
General entry requirements for second-cycle studies and specific entry requirements:

- Bachelor Degree in Physics of which at least 30 credits are in modern physics or the equivalent.
- English 6 or the equivalent.

Description of Programme

The Master programme in physics aims at a thorough knowledge of modern physics. During the study programme students will meet and work together with instructors and researchers who are engaged in projects in the forefront of research.

The program provides knowledge and skills that can be applied in analytical work and development projects in industry and in the public sector, while providing a solid foundation for Ph.D. studies in physics.

Objectives

Knowledge and understanding
For a Degree of Master (Two years) students must

- demonstrate knowledge and understanding in their main field of study, including both broad knowledge in the field and substantially deeper knowledge of certain parts of the field, together with deeper insight into current research and development work; and
- demonstrate deeper methodological knowledge in their main field of study.

Skills and abilities
For a Degree of Master (Two years) students must

- demonstrate an ability to critically and systematically integrate knowledge and to analyse, assess and deal with complex phenomena, issues and situations, even when limited information is available;

- demonstrate an ability to critically, independently and creatively identify and formulate issues, and to plan and, using appropriate methods, carry out advanced tasks within specified time limits, so as to contribute to the development of knowledge, and to be able to evaluate this work;
- demonstrate an ability to present and discuss clearly their conclusions and the knowledge and arguments behind them, in dialogue with different groups, orally and in writing, in national and international contexts; and
- demonstrate the skill required to participate in research and development work or to work independently in other advanced contexts.

Judgement and approach
For a Degree of Master (Two years) students must

- demonstrate an ability to make assessments in their main field of study, taking into account relevant scientific, social and ethical aspects, and demonstrate awareness of ethical aspects of research and development work;
- demonstrate insight into the potential and limitations of science, its role in society and people's responsibility for how it is used; and
- demonstrate an ability to identify their need of further knowledge and to take responsibility for developing their own knowledge.

Programme specific objectives
Knowledge and understanding
Within the framework of the objectives stated in the University regulations, students in the programme area will be able to

- demonstrate thorough knowledge and understanding of physics concepts and models together with their limitations, and on their own initiative be able to expand their knowledge area.

Skills and abilities

- initiate independently, take responsibility for and lead inquiries and investigations of complex conditions in a scientific manner;
- independently plan and carry out calculations, simulations, trials, experiments and scientific observations in physics;
- use physics terminology to present independently pictures of the state of knowledge and be able to explain and discuss scientific problems.

Judgement and approach

- collaborate in a group and carry out a group project, and independently be able to lead development work.
- follow the knowledge development and evaluate new findings through critical use of technology and physics literature and databases.
- give a correct and well-balanced picture of methods, results, conclusions and future application possibilities.

Content
Programme Overview
The programme consists of 120 credits in total, 2 years full-time study. The main area of physics makes up the majority of credits and is complemented with i) computation methods, ii) mathematics courses, and iii) a course in scientific theory.

The courses contain 30 credits chosen among a restricted group of general courses, giving a common physics background, 60 credits of elective courses and one degree project (Master thesis) covering 30 credits. Alternatively the degree project can cover 60 credits, and the elective courses then make up 30 credits. An overview is provided below. The elective courses are chosen in consultation with the program director.

During the study programme, student performance is followed in individual courses as well as in the education as a whole, and the progress is evaluated and tracked according to the set goals for learning outcomes.

Programme courses
Year 1
First semester
General courses (30 credits, chosen in the list below)
Second semester
Elective courses (30 credits, see below)

Year 2
During the second year, the student carries out a degree project. In consultation with the program coordinator, the student chooses one of three different options regarding the scope and complexity of the degree project (30 credits, 45 credits, 60 credits)

Alternative 1.
Elective courses (30 credits, see below)
Degree project (30 credits, A2E,*) - After a short introduction on "Research Methodology and Scientific Writing" the student independently formulates a problem, collects data, analyzes findings and draws conclusions. During the work the student has the continuous guidance of the supervisor.

Alternative 2
Elective courses (15 credits, see below)
Degree project (45 credits, A2E,*) - After a short introduction on "Research Methodology and Scientific Writing" the student independently formulates a problem, collects data, analyzes findings and draws conclusions. Students deepen their knowledge of a research field. During the work the student has the continuous guidance of the supervisor.

Alternative 3
Degree project (60 credits, A2E,*) - After a more thorough foundation in "Research Methodology" the student independently formulates a more complex problem, collects data, analyzes findings and draws several conclusions. The project work is carried out with the advantage of being a small project in a research group and the work prepares the student for further research at a more advanced level. During the work the student has the continuous guidance of the supervisor.

General courses
Mathematical methods for physics (7.5 credits, A1N,*): The course aims at helping the students to acquire the mathematics that they need for advanced undergraduate and beginning graduate study in physical sciences, and to develop a strong background in the mathematics of theoretical physics. Topics to be covered include the solutions and general properties of the most important differential equations in theoretical physics, the eigenvalue problem and the spectral theorem for self-adjoint operators, a study of special functions in mathematical physics, the theory of Fourier series and the integral transforms.

Quantum mechanics II (7.5 credits, A1N,*): The course offers the possibility of a deeper study of fundamental concepts in quantum mechanics. Among the topics covered are semiclassical approximations, quantum mechanics with path integrals, general theory of angular momentum, time-dependent perturbation theory, the adiabatic approximation and the Berry's phase, scattering theory.

Computational physics I (7.5 credits, G2F,*): The aim of this course is to give the students a theoretical and practical introduction to computational methods and tools used in physics. Content of the course includes: use of Matlab and Mathematica to solve common numerical problems (linear algebra, numerical integration) and to make interface with C and/or Fortran codes. Finite element and finite difference methods to solve partial differential equations. Montecarlo methods for simple physical systems with many degrees of freedom and statistical mechanics problems. Molecular dynamics.

Classical electrodynamics (7.5 credits, A1N,*): The course provides a central knowledge of advanced electrodynamics. Focus is on the use of advanced mathematical physics tools to solve complex electrodynamics problems relevant for several fields in physics. Content: Maxwell's equations, conservation laws and electromagnetic potentials. Wave propagation in media. Simple radiating systems of moving charges. Selected advanced topics, such as relativistic formulation, radiation by moving charges, radiation damping, quantum optics.

Statistical physics I (7.5 credits, A1N,*): The course presents an introduction of the foundations of statistical mechanics with focus on phase transitions. Content includes: review of thermodynamics, Canonical and grand canonical ensembles. Thermodynamic description of phase transitions. Maxwell construction. Landau theory of phase transitions. Elements of ergodic theory. Classical and quantum fluids. Existence of thermodynamics limit. Fermi-Dirac distributions and degenerate Fermi gas. Bose-Einstein distribution and Bose Einstein condensation.

Examples of elective courses
Physics

Statistical physics II (7.5 hp, A1N,*)
The course is a continuation of Statistical Physics I and covers a variety of topics of interest in modern statistical mechanics, focusing primarily on critical phenomena and the renormalization group. The precise choice of topics will depend partly on the particular interest of the class. Possible topics include: diffusion, random walks, Langevin equation, noise and fluctuations, polymers and self avoiding random walks. Spin glasses. Phase transition in two dimensions. Topological classification of defects. Kosterlitz-Thouless transition. Order parameters, broken symmetry, Goldstone's theorem and the Anderson's Higgs mechanism.
The renormalization group and the e-expansion. Universality classes, fixed points and scaling, critical exponents.

Quantum theory of many-particle systems (7.5 credits, A1F,*): The course gives a general introduction of quantum many-body physics and the use of Green's functions with emphasis on topics in advanced condensed matter theory. Second quantization and quantum field theory. Diagrammatic techniques. Applications of Green's functions techniques: the electron gas. Imaginary-time finite-temperature field theory.

Solid state physics II (7.5 credits, A1N,*): Course content: Crystal structures, X-ray diffraction and reciprocal lattice, Brilloui zones, crystal binding, van der Waals, ionic, covalent, and metallic binding, lattice vibrations and phonons, phonons and thermal properties of solids, free-electron model, electrical conductivity and Ohm's law, periodic potential and the Bloch theorem, energy bands and semiconductors.

Solid state physics III (7.5 credits, A1F,*): The goal of the course is to study a few of the most remarkable and far-reaching phenomena in solid state physics, whose foundations were laid in the introductory solid state physics courses of the bachelor program. Among the topics covered are electron-electron interactions in metals, introduction to magnetism, superconductivity, optical properties of solids.

Physics of low-dimensional structures (7.5 credits, A1N,*): The main purpose of the course is to introduce the student to the most important and basic examples of nanostructures and show how their reduced dimensionality strongly affect their physical properties. An appropriate theoretical background, complementing required pre-requisites, will be provided. However, emphasis of the course will be on experimental labs. In these labs the student will be trained in applying knowledge from physics, chemistry and biology in performing and interpreting experiments on nanostructures such as quantum dots, nanowires and quantum wells. Furthermore, the student shall be oriented about applications of nanostructures e.g. in the life sciences and electronics.

Quantum transport in nanostructures (7.5 credits, A1F,*): The course introduces basic concepts of transport theory in meso- and nanostructures in different physical regimes. The main topics are semiclassical Boltzmann equation and quantum corrections. Anderson localization. Transport in Coulomb blockade regime with quantum master equations. Phase coherent transport within Landauer formulation and formulation in terms of non-equilibrium Green's functions. Applications to the study of transport in quantum dots, nanoparticles and nanowires.

Quantum theory of magnetism (7.5 hp, A1F,*)
The course offers an introduction of the different microscopic mechanisms responsible for magnetism in metals, insulators and semiconductors. Topics of the course: Atomic magnetism, diamagnetism and paramagnetism. Microscopic mechanisms of magnetic interactions and interacting spins. Mean field approximation. Spin Waves. Magnetic anisotropy. Green's Function methods. Itinerant magnetism. Magnetism in metals. Electronic structure, spin density functional theory and magnetism. Local moments and indirect exchange. New magnetic materials – dilute magnetic semiconductors and magnetism in low-dimensional systems.

Nanomagnetism and spintronics (7.5 hp, A1F,*)
This course provides an introduction to the physics of quantum magnetism, with focus on nanostructures and their integration in spin electronic devices. Topics covered: Quantum theories of magnetism. Normal and ferromagnetic metals. Itinerant ferromagnetism. Spin-polarized electronic structure. Giant Magnetoresistance, spin-valve effect, spin-torque. Spin- dependent tunnelling. Molecular nanomagnets and magnetic nanoparticles.

Geometric phases in quantum systems (7.5 credits, A1F,*): This course provides an introduction to the concept of geometric phases in quantum mechanics, with applications in molecular physics, condensed matter physics and quantum field theory. Berry adiabatic phase, the topological phase and the Aharonov-Bohm effect. Geometric phases for general cyclic evolution. Appropriate mathematical concepts and tools of differential geometry, which constitute the theoretical basis of the geometric phases, will be developed during the course.

Nuclear and particle physics (7.5 credits, A1N,*):The course deals with the elementary particles and the fundamental forces in Nature according to the standard model. The course also deals with the structure of nuclei, instability, decays and reactions. Experimental methods in nuclear and high energy physics are also treated.

Particle physics and quantum field theory(7.5 credits, A1N,*) The fundamental structure and forces in Nature are described in the language of quantum field theory. Canonical quantization of scalar, Dirac and gauge fields (QED) is treated. The course also deals with weak and strong interaction and super symmetry.

Cosmology with theory of relativity (7.5 credits, A1N,*): The evolution and structure of the universe is treated according to the Big-Bang model. Special focus is set on the early universe. The course deals also with the foundations of general relativity, the Einstein field equation and its solutions applicable in cosmology such as the Robertson-Walker- and Schwarzchild metric and gravitational waves.

Analytical mechanics (7.5 credits, G2F,*): This course covers standard topics in Lagrangian and Hamiltonian mechanics. Generalized coordinates. Variational calculus. Hamilton principle and Lagrange equation. Legendre transformation and Hamilton's equations. Symmetry properties, cyclic coordinates, and conservation theorems. Poisson brackets and Hamilton-Jacobi theory.

Artificial atoms and quantum dots (7.5 credits, G2F,*): The study of semiconductor quantum dots and metal nanoparticles, known also as artificial atoms, is an important research area in Nanoscience. The purpose of the course is to learn about the discrete quantum-energy spectra of these zero-dimensional nanostructures on the basis of their analogy with atomic and molecular physics. Content: the two-electron and the many-electron atoms. Fabrication and physical properties of semiconductor quantum dots and metal nanoparticles. Addition spectra, shell structure and dependence on magnetic fields. Quantum spin properties of quantum dots. Double-quantum dot molecules.

Bionanoscience (7.5 credits, G2F,*): The course will give theoretical knowledge and practical skills in nanobiotechnology, biosensors and molecular diagnostics. Content: Bio-compatibility. Lab-on-a-chip. Flow in micro- and nanochannels, Microcontact printing of proteins. Use of electron beam lithography and nanoimprint lithography in bionanotechnology. Different nanostructures for control of biological macromolecules and cells in vitro. Interactions between cells, particularly nerve cells, and nanostructures. Artificial nanopores and their applications. Microbiologically produced nanoparticles and macromolecules with relevance in nanobiotechnology. Non-biological organic polymers in nanobiotechnology. Biomolecular motors. Nanostructures consisting of DNA-protein conjugates. "Microarrays" in proteomics and genomics. Exploitation of DNA in nanoelectronics, nanomechanics and biocomputation. Biomimetic ferritins. Nanoparticles and nanowires in bionanoscience. DNA-gold nanoparticle conjugates. Luminescent quantum dots. Nanoparticles as non-viral transfection systems. Nanoparticles for labeling of biomolecules.

Computational physics II (7.5 credits, A1N,*): This course offers a theoretical and practical introduction to advanced computational methods and techniques used in research in condensed matter physics and particle physics. The choice of the topics will depend on the interest of the class. Topics relevant for condensed matter theory are density-functional theory for electronic structure calculations. Tight-binding methods. Exact numerical diagonalizations for interacting quantum many-particle systems. Topics in particle physics include: Montecarlo simulations of particle interactions and detectors in high-energy physics.

Applied Quantum Mechanics (7,5 hp, G2F,*)
Experimental course with aim on nuclear, atomic and surface physics.

Cosmic rays and High Energy Astrophysics (7.5 credits A1N,*)
The purpose of the course is to give the students the necessary knowledge on the problem of the origin and acceleration of cosmic rays from an observational point of view. The problem of cosmic rays plays a central role in astrophysics. The key topics of the course are the different astrophysical processes involved in the production and the acceleration of energetic particles through the Cosmos and their interactions with matter and fields. After an overview of all the astrophysical accelerators which operate at very different scales, the focus will be put on the experimental aspects related to the detection of cosmic rays, gamma-rays and neutrinos.

Introduction to High Energy Astrophysics (7.5 credits A1N,*)
High-energy astrophysics and astroparticle physics are at the boundaries of astrophysics and particle physics. Their aim is to study particle physics and the fundamental interactions, through the observation of phenomena in the Universe, rather than in a laboratory on Earth. Through the tools and methods developed for high-energy physics and used for astrophysical observations, a whole new aspect of the Universe is available for the study of violent phenomena (collapses and explosions of stars, ejection of relativistic matter etc.), extreme states of matter (neutron stars and black holes) or particle acceleration and cosmic radiation. The course highlights the importance of the multi-wavelength approach in the field and discusses the acceleration sites and radiation of high-energy particles in the Universe such as pulsars, binaries, Supernova Remnants and Active Galactic Nuclei.

Experimental methods in Particle and Astroparticle Physics, (7.5 credits A1N,*)
The aim of this course is to provide students with up-to-date information on the most advanced and specialized particle detectors for colliders and astrophysics in terms of operative principles and performance related to their use in present and future experiments in nuclear, subnuclear and astroparticle physics. Some of the topics covered by the course are: experiments and techniques in current and future colliders, experimental problems, detectors, computing problems, electronics used in most recent experiments.

Mathematics
Vector analysis (7.5 credits, G2F)
Transform theory (7.5 credits, G2F)
Linear algebra (7.5 credits, G1F)
Analytical functions (7.5 credits, G2F)
Stochastic processes (7.5 credits, A1N)
Functional analysis (7.5 credits, A1N)
Finite element method (7.5 credits, G2F)

(G) = Course marked with (G) is a course at the elementary (undergraduate) level.
(A) = Course marked with (A) is a course at the advanced level (90 credits required)
(*) = Course marked with (*) is a course in the main subject area

A selection of the above elective courses is offered every year. Students decide in consultation with the program director which elective courses are included in their study plan.
Though students have freedom within certain limits to choose their courses, each student and the programme director must make sure that the individual study plan contains
a)a maximum of 25% (i.e. 30 credits) of the courses at the elementary (undergraduate) level and
b)a minimum of 50% (i.e. 60 credits) of the courses, general and elective, excluding the degree project, in the main field of study (i.e. Physics)
in order for the student to obtain the degree.

Community Contacts
Students are offered contact with industry through study visits, work projects, seminars, etc. Some guest speakers from research and industry will be invited during the programme, for example, i) researchers from the Nanometer Structure Consortium at Lund University and scientists from the Max Lab in Lund, ii) representatives of nanotechnology companies in the Oresund Region, and iii) a guest speaker from the Oskarhamn nuclear power plant.

The physics division plans to set up an advisory board for the programme.

Studies Abroad
Study abroad is possible during the last two terms. Courses are chosen in consultation with the programme director. The students are invited to take part in the range of agreements with foreign universities available at Linnaeus University.

Scope of programme
The concepts of sustainable development and gender permeate the on-going University activity. For the Master programme with a large percentage of international students, diversity and internationalization are given features in everyday activities within the programme.

Quality Development

Students are involved in both programme and course evaluations. The programme director meets regularly with all students and discusses courses, as well as helps to choose the right direction of the programme and elective courses. The programme evaluations are archived at the School of Computer Science, Physics and Mathematics.

Degree Certificate

Those students who have fulfilled the requirements of the programme obtain a Master of Science in Physics. The degree certificate is bilingual (Swedish/English) and is accompanied by a Diploma Supplement (in English).

Masterexamen
Huvudområde: Fysik

Master (120 credits)
Main field of study: Physics