Lund University

Faculties of Humanities and Theology

ÄFYD14, Physics 4: Modern Physics and Physics Education, 30 credits

Fysik 4: Modern fysik med fysikdidaktik, 30 högskolepoäng

First Cycle / Grundnivå

Details of approval

The syllabus was approved by Study programmes board, Faculty of Science on 2021-01-20 and was last revised on 2023-06-08. The revised syllabus applies from 2023-06-08, spring semester 2024.

General Information

The course is a component of the teacher education programme at Lund University.

Language of instruction: Swedish
The module in didactics is taught in Swedish and the modules in physics are taught in English.

Main field of studies	*Depth of study relative to the degree requirements*
Physics	G2F, First cycle, has at least 60 credits in first-cycle course/s as entry requirements

Learning outcomes

The course consists of four modules:

1. Atomic and Molecular Physics, 7.5 credits
2. Nuclear Physics, 7.5 credits
3. Particle Physics, Cosmology and Accelerators, 7.5 credits
4. Didactics of Physics, 7.5 credits

Knowledge and understanding

On completion of the course, the students shall be able to:

1. explain the quantum mechanical and special relativistic concepts and tools needed to describe modern atom, molecule, nuclear and particle physics.

2. provide examples of and describe important experiments and experimental

methods in modern physics.

3. describe and explain energy structures and properties of atoms and molecules.

4. describe and explain properties and structures of atomic nuclei.

5. provide examples of and explain different nuclear reactions.

6. account for how electromagnetic radiation and different elementary particles interact with matter.

7. describe the structure of matter according to the standard model from quarks and leptons to atoms and molecules.

8. describe the fundamental interactions.

9. account for the development of the universe and describe how we acquire knowledge about it.

10. describe different applications of modern physics and its tools, such as accelerators, for example, in energy production, astronomy, materials science and medicine.

11. illustrate and describe current research in several areas of modern physics.

Competence and skills

On completion of the course, the students shall be able to:

12. make active choices regarding teaching content and design e.g. in connection with problem-solving and in connection with laboratory sessions and use of simulations, animations and modelling.

13. discuss and justify assessment and grading of pupils' physics knowledge based on the assessment criteria in the school's steering documents.

14. apply basic quantum mechanical and special relativistic concepts and methods in modern physics.

15. plan, execute, analyse and present experiments in modern physics.

16. carry out numerical calculations and use computer simulations in the different parts of the course.

17. independently or in small groups, acquire knowledge in modern physics and present these in in speech and in writing.

18. independently plan and, based on an understanding of physics and didactic research, justify teaching elements in the areas covered in the course, and be able to critically review their proposals on teaching elements and those of others.

Judgement and approach

On completion of the course, the students shall be able to:

19. assess experimental results

20. assess the applicability and limitations of physical models.

21. demonstrate an understanding of the role of modern physics in society.

22. reflect on, discuss and problematise an application of modern physics and its potential effects in a specific social sector.

23. evaluate the image science has of the structure and development of the universe based on observations, modeling and theories.

24. based on the intended learning outcomes for the course as well as their own goals, summarise and reflect on their own progress regarding knowledge and skills.

25. work on the teaching of source-critical review and controversial society issues as a way to invoke the pupils' interest and to demonstrate the relevance of physics.

Course content

Module 1: Atomic and Molecular Physics, 7.5 credits

Module 1 focuses on atomic and molecular physics. Specific topics covered:

- Repetition of basic quantum mechanics.
- Quantum mechanical treatment of angular momentum, both in the orbital and spin form, including their eigenvalues and eigenfunctions. Addition of angular momentum.
- Quantum mechanical description of spherical symmetric systems with applications on hydrogen-like and hydrogenic examples.
- Numerical solutions of the radial equation for simple atomic systems.
- Two-electron systems with an introduction to correlation and exchange effekter.
- Relativistic effects that give rise to the fine structure of ions.
- Many-electron systems with a discussion of the Pauli exclusion principle and the periodic system, LS-coupling and the central field approximation.
- Description of radiative transitions, especially according to the electric dipoleapproximation.
- Interaction with relatively weak magnetic fields and the Zeeman effect.
- Hyperfine structure and isotope shift.
- Experimental observations of the theoretical phenomena treated in the course.
- Introduction to molecular physics with a discussion of binding in diatomic molecules. An introduction about covalent and ionic bondings, and the LCAO-method (Linear Combination of Atomic Orbital).
- Quantum mechanical treatment of rotational, vibrational and roto-vibrational spectra.
- Introduction to experimental methods in molecular physics.
- Laser Physics, with applications in for example cooling.
- Molecular physics and supervision of climate changes.
- Spectroscopy for sources of light and their energy efficiency.
- Additional applications in for example X-ray and photoelectron spectroscopy, astrophysics and plasma physics.

Module 2: Nuclear Physics, 7.5 credits

Module 2 focuses on nuclear physics. Specific topics covered:

- The properties of atomic nuclei and their macroscopic description.
- Radioactive decay law and different decay pathways for atomic nuclei: fission, alpha decay, beta decay, electromagnetic transitions etc.
- Interaction between ionising radiation and matter.
- Biological effects of ionising radiation, radiation safety and applications.
- Radiation detectors in research and society.
- Basic properties of the interaction between nucleons: nucleon-nucleon-scattering and the deuteron.
- Introduction to the shell modell - the microscopic approach.
- Nuclear reactions: cross sections, resonance, reaction mechanisms.
- Neutrons, neutron scattering, neutron detectors and applications.
- Fission reactors: electricity production, environment and society.
- Nuclear fusion.
- Introduction to nuclear astrophysics: the energy production of stars and creation of the elements.

Module 3: Particle physics, Cosmology and Accelerators, 7.5 credits

Module 3 covers particle physics and cosmology as well as accelerators and their application. Specific topics covered:

- Special relativity.
- An overview of elementary particles and their interactions: leptons, quarks and composite particles are discussed, as well as the electromagnetic, weak and strong force and its mediators.
- Reactions and decay represented by Feynman diagrams.
- The particle physics standard model with the electroweak interactions and quantum chromodynamics.
- The Higgs mechanism and its discovery.
- Possible theories beyond the standard model together with an orientation of the research frontier in high energy physics.
- The expansion, components and development of the universe as well as the relation between cosmology and particle physics.
- The most important unanswered questions in particle physics and cosmology, such as dark matter and dark energy as well as the asymmetry between matter and antimatter.
- Methods to determine identity and momentum of particles in high energy physics experiments.
- The principles of acceleration, in mainly synchrotron and linear accelerators and storage of particle beams.
- Examples from the front line of subatomic physics: LHC at CERN and the studies relevant MAX IV and ESS in Lund.
- Generation of secondary beams of photons and neutrons for different applications, for example at MAX IV and ESS in Lund.

Module 4 Didactics of Physics, 7.5 credits

Module 4 covers didactics of physics issues relating to the learning and teaching of modern physics. Specific topics covered:

- Current physics education research on the teaching and learning of modern physics with a special focus on conceptual challenges with regard to the size and scale of particles and bodies in space and time, linked to different learning theories.
- Pupils' ideas on modern physics
- How simulations, animations and modelling are used in the teaching of physics to represent aspects of the physics content of the course.
- School experiments in modern physics.
- Analysis of the role of modern physics in the curriculum and course syllabi for primary and secondary schools.

Course design

Modules 1-3

The teaching consists of lectures, exercises, group tuition, supervision in connection with laboratory sessions and computer exercises, seminars and study visits.

Laboratory sessions are an important part of the course and are supplemented by simulations and computer exercises. Laboratory sessions include preparatory assignments and meetings, implementation and final seminars or written reports. Presentations in connection with laboratory sessions and simulations form an important part of the course. All components associated with laboratory and simulation work are compulsory. Module 1 includes a workshop on climate that is also compulsory.

Student presentations of assignments to the group are an essential component of the course.

Participation in study visits is compulsory but can be replaced by a written project. Study visits can lead to a small cost for the student.

Module 4

The teaching in the didactics of physics module consists of lectures, seminars, the design and implementation of experiments that can be carried out in upper-secondary schools and supervision of project work.

The project work includes the study of a current area of research of relevance to the course content, for which one or more researchers are interviewed, a text is written on the area of research that is appropriate for upper-secondary schools and a teaching session is planned (including a modelling or simulation exercise). An associated teacher's guide is produced including relevant perspectives on the nature of the subject, research on the learning of pupils in the subject, a proposal on pupil tasks with assessment criteria and discussion assignments.

Assessment

The assessment of Module 1 Atomic and Molecular Physics is based on:

- A written examination (in the case of a take-home examination, this is supplemented by an oral report component). Corresponding to 5.0 credits.
- Laboratory projects and reports, corresponding to 1.5 credits.
- Numerical projects and reports, corresponding to 0.5 credits.
- Workshop and group reflection on climate, corresponding to 0.5 credits.
- A compulsory written self-reflection, corresponding to 0.0 credits.

The assessment of Module 2 Nuclear Physics is based on:

- An oral examination, corresponding to 4.0 credits.
- Laboratory projects and reports, corresponding to 2.5 credits.
- Written assignments, including numerical projects, corresponding to 1.0 credits.

The assessment of Module 3 Particle Physics, Cosmology and Accelerators is based on:

- Take-home examinations during the course and an oral examination at the end of the course, altogether corresponding to 6.0 credits.
- Laboratory projects and reports, corresponding to 1.5 credits.
- Study visit at an experimental facility, corresponding to 0.0 credits.

The assessment of Module 4 Didactics of Physics is based on:

- Compulsory seminars, corresponding to 1.0 credits.
- Written and oral presentation of project work, corresponding to 5.0 credits.
- Execution and oral presentation of school experiments, corresponding to 1.5 credits.

Students who do not pass an assessment will be offered another opportunity for assessment soon thereafter.

The examiner, in consultation with Disability Support Services, may deviate from the regular form of examination in order to provide a permanently disabled student with a form of examination equivalent to that of a student without a disability.

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Subcourses that are part of this course can be found in an appendix at the end of this document.

Grades

Marking scale: Fail, Pass, Pass with distinction.

- The final grade for the whole course is based on a combined evaluation of all assessed components using a weighted mean of the percentage grades, in which the credits for each component are taken into consideration. For a Pass with Distinction, students must be awarded at least 80 %.
- For a Pass on the whole course, students must have passed all examinations, written assignments, laboratory sessions, numerical projects, seminars and presentations and have participated in all compulsory components for all modules.
- The workshop and group reflection on climate, and the self-reflection in Module 1, the study visits in Module 3, and the seminars and school experiments in Module 4 are only awarded a Pass or Fail and are not used to calculate the final grade.

Entry requirements

To be admitted to the course, students must have successfully completed at least 105 credits in previous higher education studies, of which 60 credits must be in physics and didactics of physics equivalent to: ÄFYD11, Physics 1: Introductory Physics and Physics Education, 30 credits, ÄFYD12, Physics 2: Environmental Physics and Energy Processes with Didactics of Physics, 15 credits, ÄFYD13, Physics 3: Basic Quantum Mechanics, and Mathematical Methods for Vibrations, Waves and Diffusion for Teachers, 15 credits, as well as 45 credits in mathematics equivalent to: MATA21, Mathematics: Analysis in One Variable, 15 credits, MATA22, Mathematics: Linear Algebra 1, 7.5 credits, NUMA01, Numerical analysis: Computational Programming with Python, 7.5 credits, MATB21, Mathematics: Analysis in Several Variables 1, 7.5 credits and MATB22, Mathematics: Linear Algebra 2, 7.5 credits.

Further information

The course cannot be included in a degree together with any of the following courses: ÄFYD04, Physics 4, 30.0 credits, FYSB24, Physics: Atomic and Molecular Physics, 7.5 credits, FYSC12, Nuclear Physics and Reactors, 7.5 credits, FYSC14, Particle Physics, Cosmology and Accelerators, 7.5 credits, EXTF85, Particle Physics, Cosmology and Accelerators, 7.5 credits or FKFN20, Nuclear Physics, Advanced Course, 7.5 credits or previous equivalent courses.

The course is offered at the department of Physics, Lund University.

Subcourses in ÄFYD14, Physics 4: Modern Physics and Physics Education

Applies from V24

2401 Module 1: Atomic and Molecular Physics – Exam, 5,0 hp
Grading scale: Fail, Pass, Pass with distinction
2402 Module 1: Atomic and Molecular Physics – Laboratory Projects, 1,5 hp
Grading scale: Fail, Pass, Pass with distinction
2403 Module 1: Atomic and Molecular Physics – Numerical Projects, 0,5 hp
Grading scale: Fail, Pass, Pass with distinction
2404 Module 1: Atomic and Molecular Physics – Workshop, 0,5 hp
Grading scale: Fail, Pass
2405 Module 1: Atomic and Molecular Physics – Self-reflection, 0,0 hp
Grading scale: Fail, Pass
2406 Module 2: Nuclear Physics – Exam, 4,0 hp
Grading scale: Fail, Pass, Pass with distinction
2407 Module 2: Nuclear Physics – Laboratory Projects, 2,5 hp
Grading scale: Fail, Pass, Pass with distinction
2408 Module 2: Nuclear Physics – Assignments, 1,0 hp
Grading scale: Fail, Pass, Pass with distinction
2410 Module 3: Particle Physics – Exam, 6,0 hp
Grading scale: Fail, Pass, Pass with distinction
2411 Module 3: Particle Physics – Laboratory Projects, 1,5 hp
Grading scale: Fail, Pass, Pass with distinction
2412 Module 3: Particle Physics – Excursion, 0,0 hp
Grading scale: Fail, Pass
2413 Module 4: Didactics of Physics – Seminars, 1,0 hp
Grading scale: Fail, Pass
2415 Module 4: Didactics of Physics – Project Work, 5,0 hp
Grading scale: Fail, Pass, Pass with distinction
2416 Module 4: Didactics of Physics – School Experiments, 1,5 hp
Grading scale: Fail, Pass

Applies from H21

2101 Module 1: Atomic and Molecular Physics – Exam, 5,0 hp
Grading scale: Fail, Pass, Pass with distinction
2102 Module 1: Atomic and Molecular Physics – Laboratory Projects, 1,5 hp
Grading scale: Fail, Pass, Pass with distinction
2103 Module 1: Atomic and Molecular Physics – Numerical Projects, 0,5 hp
Grading scale: Fail, Pass, Pass with distinction
2104 Module 1: Atomic and Molecular Physics – Workshop, 0,5 hp
Grading scale: Fail, Pass
2105 Module 1: Atomic and Molecular Physics – Self-reflection, 0,0 hp
Grading scale: Fail, Pass
2106 Module 2: Nuclear Physics – Exam, 4,0 hp
Grading scale: Fail, Pass, Pass with distinction
2107 Module 2: Nuclear Physics – Laboratory Projects, 2,5 hp
Grading scale: Fail, Pass, Pass with distinction
2108 Module 2: Nuclear Physics – Assignments, 1,0 hp
Grading scale: Fail, Pass, Pass with distinction
2109 Module 2: Nuclear Physics – Self-reflection, 0,0 hp
Grading scale: Fail, Pass
2110 Module 3: Particle Physics – Exam, 5,0 hp

Grading scale: Fail, Pass, Pass with distinction
2111 Module 3: Particle Physics – Laboratory Exercises & Projects, 2,5 hp
Grading scale: Fail, Pass, Pass with distinction
2112 Module 3: Particle Physics – Excursion, 0,0 hp
Grading scale: Fail, Pass
2113 Module 4: Didactics of Physics – Seminars, 2,0 hp
Grading scale: Fail, Pass
2114 Module 4: Didactics of Physics – Excursion, 0,5 hp
Grading scale: Fail, Pass
2115 Module 4: Didactics of Physics – Project Work, 4,0 hp
Grading scale: Fail, Pass, Pass with distinction
2116 Module 4: Didactics of Physics – School Experiments, 1,0 hp
Grading scale: Fail, Pass