LUND UNIVERSITY

Faculties of Humanities and Theology

# ÄFYD04, Physics 4, 30 credits

*Fysik 4, 30 högskolepoäng*

**First Cycle / Grundnivå**

## Details of approval

The syllabus was approved by Study programmes board, Faculty of Science on 2018-10-23 to be valid from 2018-10-23, autumn semester 2018.

## General Information

The course is included in the Master's programme in Secondary Education at Lund University.

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

| *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 five modules:

1. Atomic and Molecular Physics, 6.5 credits
2. Nuclear Physics, 6.5 credits
3. Solid State Physics, 6.5 credits
4. Particle Physics, Cosmology and Accelerator Physics, 6.5 credits
5. Didactics, 4 credits

On completion of the course, the student shall be able to

### Knowledge and understanding

1. explain the concepts of quantum mechanics required to describe modern physics

2. describe some basic experiments from the history of quantum physics

3. discuss light's interaction with atoms, molecules and solids

4. describe different applications of modern physics within, for example, energy production, astronomy and material physics

5. give examples of and describe current research in certain subareas of modern physics

6. describe the structure of matter according to standard models, from quarks and leptons to lattice structures and band structure

7. describe the fundamental interactions

8. discuss the current state of research in modern physics and its limitations

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

10. describe the use of accelerators, for example in fundamental physics, materials studies and medical applications, focusing above all on CERN, MAX IV and ESS

## Competence and skills

11. plan and perform analyses and present experiments in modern physics

12. give examples of and describe current research in modern physics

13. perform calculations and use computer simulations in the different areas covered by the course

14. independently or in small groups acquire knowledge in a field of modern physics and present this in speech and writing

15. develop and critically review resources and processes of teaching modern physics in upper secondary school

## Judgement and approach

16. evaluate experimental results

17. demonstrate an understanding of the role of physics in society

18. demonstrate an ability to assess the applicability and limitations of physical models

19. independently acquire new knowledge and present it orally and in writing

20. reflect on, discuss and interrogate an application of modern physics and its potential effects in a certain sector of society

21. assess the the view in science of the structure and development of the universe based on observations, modelling and theories

## Course content

The course consists of the following five modules:

**Module 1 Atomic and Molecular Physics, 6.5 credits**

The module provides students with an introduction to concepts of quantum mechanics. It describes angular momentum, using electron spin and orbital angular momentum as examples. The module includes theoretical analysis of elementary atomic structure in the form of quantum mechanical treatment of the hydrogen atom, fine structure, the helium atom, spin wave functions, the Pauli exclusion principle, LS approximation in atoms with two valence electrons, and central field approximation. Experimental observations of effects connected to these phenomena are described. The electric dipole approximation of radiation transitions in the hydrogen atom is included, as well as a basic theoretical treatment of multiple-electron atoms. Other important concepts are X-ray radiation, spectra and spectroscopy as well as Moseley's law. The module also addresses the Auger effect and spectroscopy, light emission and absorption, interaction with external fields as well as hyperfine and isotope structures. Furthermore, it deals with dual- and polyatomic molecules using the LCAO method and molecular orbitals. Particular focus is placed on the molecules' rotation and vibration spectra. The module also covers lasers and synchrotron light and their applications. Important applications are to be found in astrophysics and plasma physics, in which distribution rules, radiation transfer and linear profiles are discussed. The module deals with the history of atomic physics, where basic experiments such as the Stern-Gerlach experiment, the Lamb-Retherford experiment that led to the discovery of the Lamb shift, and the Rydberg spectral experiment, are addressed and described.

**Module 2 Nuclear Physics, 6.5 credits**

The module describes the properties of atomic nuclei in general and the two-nucleon system in detail. The excitation and decay of nuclei are discussed with reference to beta decay through weak interaction, electromagnetic transitions and alfa decay. Different models of nuclear structures are addressed, e.g. the scale model of spherical and deformed systems and collective models. Nuclear reactions are described in the form of cross-sections and reaction mechanisms, and reactions through strong and electromagnetic interaction, fission and fusion. Experiments in nuclear physics and accelerators and detectors are discussed. Moreover, the module deals with applied nuclear physics, including reactor physics, especially fission reactors of different kinds, together with their structures and fields of use. Reactors as sources of energy, from environment and societal perspectives, are discussed.

**Module 3 Solid State Physics, 6.5 credits**

The module deals with crystal structure, diffraction and reciprocal lattice, crystal binding and phonons. Furthermore, it addresses lattice vibrations and thermal properties, free electron gas, electronic band structure, semiconductors, Fermi surfaces and metals. It also deals with superconductivity, magnetism, dielectricity, ferroelectricity, surface structures and nanostructures.

**Module 4 Particle Physics, Cosmology and Accelerator Physics, 6.5 credits**

The module provides students with an overview of elementary particles and their interaction. Leptons, quarks and composite particles are discussed, as well as the electromagnetic, weak and strong force and its exchange particles. Reactions and decay are represented with Feynman diagrams. In particular, the module introduces the standard model of particle physics including electroweak interaction and quantum chromodynamics. The Higgs mechanism is introduced and possible theories beyond the standard model are discussed together with an overview of the research front in high-energy physics. The expansion and development of the Universe and the relation between cosmology and particle physics is discussed. The most important unanswered questions of cosmology, such as dark matter and the asymmetry between matter and antimatter are highlighted. Accelerator physics and methods to determine the identity and linear momentum of particles are presented as well as the principle for experiments in high-energy physics. Experimental studies of subatomic systems require particle beams with high energy. Particle accelerators are now used also in wider society, e g for medical applications and for materials studies in physics, pharmacology, biology, chemistry etc. The principles of acceleration, mainly synchrotron and linear accelerators and storing of particle rays, are presented. Examples are taken from the front line of subatomic physics, e.g. LHC at CERN, and MAX IV and ESS in Lund with regard to current materials studies. In this contexts, attention is paid to the creation of secondary beams of photons and neutrons for different applications.

**Module 5 Didactics, 4 credits**

The module deals with the teaching of current physics research in school, pupils' notions of the areas covered in the course, the nature, simulation and modelling of science in physics teaching and school experiments.

## Course design

**Modules 1-4:**

The teaching consists of lessons, group tuition, supervision in connection with laboratory sessions, computer exercises and seminars, and study visits. The lessons are mainly devoted to study of sections of the theory course and problem-solving. Research communication, which is an important element of the course, is also included in the lessons, often in connection with a demonstration of the current activities. Laboratory sessions are an important part of the course and are supplemented by simulations and computer exercises. 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. The components in the course are assigned a total number of points and performance is graded. Student presentations to the group are an essential element of the course. Participation in study visits is compulsory. Study visits can be associated with costs for the student but can be replaced by an independent study assignment.

The course includes seminars in which the physics content is discussed with a focus on the student's qualitative understanding, the historical development of concepts and models covered in the course, and their present-day significance.

**Module 5:**

The teaching of the didactics component consists of lessons, seminars, design and implementation of experiments that can be carried out in upper secondary school, and supervision of project work. The project work addresses a current research area and includes interviews with one or more researchers, composition of a text that can be suitable for upper secondary school and planning of a teaching sequence (including a modelling or simulation exercise). Furthermore, an accompanying teaching manual will be designed, including relevant perspectives on the nature of science, research about the learning processes of pupils in the area, and proposals of study and discussion assignments.

## Assessment

**Module 1-4**

The assessment is based on written assignments as well as oral and written exams. Normally, three opportunities for assessment are offered per academic year and module. Additional assessment opportunities can be offered subject to an agreement with the course director and director of studies.

Module 1 Atomic and Molecular Physics is assessed through written assignments and laboratory reports during the first study period, and a written exam at the end of the first study period.
Module 2 Nuclear Physics is assessed through written assignments and laboratory reports during the first study period as well as an oral exam at the end of the first study period.
Module 3 Solid State Physics is assessed through written assignments and laboratory reports during the second study period as well as a written exam at the end of the second period.
Module 4 Particle Physics is assessed through written assignments and a laboratory report during the second study period, as well as an oral exam and study visit at the end of the second study period.

**Module 5**

The assessment of the module Didactics is based on an oral and written presentation of a project and the execution and presentation of a school experiment.

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.

*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.
For a grade of Pass on the whole course, students must have passed the exam, the written assignments, the laboratory sessions and simulations including a report, and participated in all the compulsory components of all the modules. The final grade is determined by an aggregate of the assessed components.

## Entry requirements

FYD01 Physics 1: Physics and Physics Education, 30 credits, ÄFYD02 Physics II, 15 credits, ÄFYD03 Basic Quantum Mechanics, Statistical Mechanics and Quantum Statistics, 15 credits, or the equivalent.

## Further information

The course may not be included in a degree together with any of the courses FYSC11 Atomic and Molecular Physics, 7.5 credits, FYSC12 Nuclear Physics and Reactors, 7.5 credits, FYSC13 Solid State Physics, 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.

## Subcourses in ÄFYD04, Physics 4

Applies from H18

1801 Atomic and Molecular Physics - written exam, 5,0 hp
Grading scale: Fail, Pass, Pass with distinction
1802 Atomic and Molecular Physics - labs, 1,5 hp
Grading scale: Fail, Pass, Pass with distinction
1803 Nuclear Physics - oral exam, 5,0 hp
Grading scale: Fail, Pass, Pass with distinction
1804 Nuclear Physics - labs, 1,5 hp
Grading scale: Fail, Pass, Pass with distinction
1805 Solid State Physics - written exam, 5,0 hp
Grading scale: Fail, Pass, Pass with distinction
1806 Solid State Physics - labs, 1,5 hp
Grading scale: Fail, Pass, Pass with distinction
1807 Particle Physics and Cosmology - oral exam, 5,0 hp
Grading scale: Fail, Pass, Pass with distinction
1808 Particle Physics - lab and study visit, 1,5 hp
Grading scale: Fail, Pass, Pass with distinction
1809 Didactics of Quantum Physics, 4,0 hp
Grading scale: Fail, Pass, Pass with distinction