Faculties of Humanities and Theology

ÄFYC01, Fysik 3: Quantum Physics with Didactics, 30 credits

Fysik 3: Kvantfysik med didaktik, 30 högskolepoäng

First Cycle / Grundnivå

Details of approval

The syllabus was approved by Study programmes board, Faculty of Science on 2016-08-11 to be valid from 2016-08-11, spring semester 2016.

General Information

The course is included in the Master?s programme in Secondary Education offered jointly by Lund and Kristianstad universities.

Language of instruction: Swedish and 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 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 students shall be able to

Knowledge and understanding

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

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

3.discuss the interaction of light with atoms, molecules and solid objects

4. describe different applications of modern physics, e.g in energy production, astronomy and material physics

5. illustrate and describe current research in some areas of modern physics

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

7. describe the fundamental interactions

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

9. account for the development of the Universe and describe how we obtain knowledge about 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. illustrate and describe current research in modern physics

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

14. independently or in small groups obtain knowledge in an area of modern physics and present it in speech and writing

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

Judgement and approach

16. assess experimental results

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

18. assess the applicability and limitations of physical models

19. independently obtain new knowledge and present it in speech and 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 scientific view of the structure and development of the Universe based on observations, modeling and theories

Course content

Module 1

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 consists of a theoretical approach to elementary atomic structure in the form of a quantum mechanics approach to the hydrogen atom, fine structure, the helium atom, spin wave functions, the Pauli exclusion principle, least squares approximation of 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 addressed are X-ray radiation, spectra and spectroscopy, and Moseley's law. The module also deals with the Auger effect and

Auger spectroscopy, light emission and absorption, interaction with external fields and hyperfine and isotope structure. Moreover, bi- and multi-atom molecules are covered, using the LCAO method and molecular orbital models. Special attention is paid to the rotation and vibration spectra of molecules. 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. Finally, the module includes the history of atomic physics, introducing and describing fundamental experiments such as the Stern-Gerlach experiment, the Lamb and Rutherford experiment that led to the discovery of the Lamb shift, and Rydberg's spectral experiment.

Module 2

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

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

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

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 5

The assessment of Physics Didactics is based on oral and written presentation of the project and the execution and report of the school experiment.

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

ÄFYA11, ÄFYA22, FYSB11 and FYSB12, or the equivalent.

Further information

The course may not be included in a degree together with one 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 ÄFYC01, Fysik 3: Quantum Physics with Didactics

Applies from V16

1601 Atomic and Molecular Physics, exam, 4,5 hp
Grading scale: Fail, Pass, Pass with distinction
1602 Atomic and Molecular Physics, labs, 2,0 hp
Grading scale: Fail, Pass, Pass with distinction
1603 Nuclear Physics and reactors, exam, 4,5 hp
Grading scale: Fail, Pass, Pass with distinction
1604 Nuclear Physics and reactors, labs, 2,0 hp
Grading scale: Fail, Pass, Pass with distinction
1605 Solid state physics, exam, 4,5 hp
Grading scale: Fail, Pass, Pass with distinction
1606 Solid state physics, labs, 2,0 hp
Grading scale: Fail, Pass, Pass with distinction
1607 Particle Physics, cosmology and accelerators, exam, 4,5 hp
Grading scale: Fail, Pass, Pass with distinction
1608 Particle Physics and accelerators, labs and study visit, 2,0 hp
Grading scale: Fail, Pass, Pass with distinction
1609 Didactics, 4,0 hp
Grading scale: Fail, Pass, Pass with distinction