LUND UNIVERSITY

Faculty of Science

FYSC22, Physics: Nuclear Physics, 7.5 credits

Fysik: Kärnfysik, 7,5 högskolepoäng

First Cycle / Grundnivå

Details of approval

The syllabus was approved by Study programmes board, Faculty of Science on 2021-03-15 and was last revised on 2024-10-11 by The Education Board of Faculty of Science. The revised syllabus comes into effect 2024-10-11 and is valid from the autumn semester 2025.

General information

The course is a compulsory first cycle course for a degree of Bachelor of Science in Physics and an alternative-compulsory course for a degree of Master of Science in Computational Science with specialisation in Physics.

Language of instruction: English

Main field of study	*Specialisation*
Physics	G2F, First cycle, has at least 60 credits in first-cycle course/s as entry requirements

Learning outcomes

The overall goal of the course is to develop an understanding of the atomic nucleus based on macroscopic and microscopic models. To assess the success and limitations of different models that are used to describe the many aspects of atomic nuclei; their excitations and decays are central in the course. Quantum mechanical concepts are exemplified and applied. Origin, detection and relevance of ionizing radiation in science and society are discussed, not the least supported by the laboratory work. The course also gives the opportunity to train problem-solving by means of analytical and numerical methods, and to write scientific reports.

The course is based on the knowledge described in the course syllabi for the courses: FYSA12, FYSA13, FYSA14, MATA21, MATA22, NUMA01, MATB21, FYSB21, FYSB22, FYSB23, FYSB24 and good knowledge of their combined contents facilitates the student to conduct the course.

Learning outcomes in the study plan refer to the study plan for the bachelor's degree in physics at Lund University, which in turn corresponds to degree objectives for general degrees in the Higher Education Ordinance.

1, 2, 3, 4, 6, 9 are milestone targets to achieve learning outcome 1 in the programme syllabus.

2, 5, 6, 8, 12, 14 are milestone targets to achieve learning outcome 2 in the programme syllabus.

7, 10, 11, 13 are milestone targets to achieve learning outcome 3 in the programme syllabus.

7, 8, 13 are milestone targets to achieve learning outcome 4 in the programme syllabus.

7, 10, 12, 13 are milestone targets to achieve learning outcome 5 in the programme syllabus.

3, 5, 9, 15 are milestone targets to achieve learning outcome 6 in the programme syllabus.

3, 5, 8, 15 are milestone targets to achieve learning outcome 7 in the programme syllabus.

1, 4, 5, 6, 9, 10, 11, 12, 14, 16 are milestone targets to achieve learning outcome 8 in the programme syllabus.

Knowledge and understanding

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

1. Explain properties and structure of atomic nuclei.
2. Describe different models for atomic nuclei and their limitations.
3. Describe how ionising radiation originates and how the radiation interacts with matter.
4. Exemplify and explain different nuclear reactions.
5. Exemplify the interaction between science and technology and the application of nuclear physics in society.

Competence and skills

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

6. Apply basic quantum mechanical concepts and methods in nuclear physics.
7. Plan, conduct, and present result of experiments in speech and writing.
8. Analyse simple nuclear spectra.
9. Exemplify and in general terms explain current research in nuclear physics.
10. Use numerical problem-solving in the form of computer codes on nuclear physics problems and data analysis.

Judgement and approach

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

11. Estimate and anticipate the applicability and the limitations of models of the atomic nucleus.
12. Assess experimental results
13. Present oral and written reports in the subject of nuclear physics where the student has independently acquired, assessed and used new knowledge.
14. Explain and give examples of how nuclear physics relates to other fields in physics.
15. Explain and give examples of nuclear physics and in particular the role of the nuclear power in society.
16. Summarise and reflect on own progress for knowledge and skills based on

intended course learning outcomes.

Course content

The course deals with:

- The properties of atomic nuclei and its macroscopic description (size, shape, mass, stability, collective excitation).
- Laws for radioactive decay and different decay paths 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 model - the microscopical 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 (stellar burning and the production of the elements).

Course design

Teaching consists of lectures, group teaching and supervision in connection with laboratory sessions and associated computer exercises and seminars. Participation in the introduction meeting is mandatory. The lectures are mainly devoted to an overview of the theoretical contents including subjects that are relevant for laboratory sessions, societal aspects of nuclear physics, and presentation of contemporary research. The lectures are accompanied by group teaching and compulsory individual written assignments that constitute a part of the final grade. The laboratory sessions include preparatory assignments and meetings, implementation of computer exercises, and concluding seminars for a laboratory session and written reports for the other two. All parts of the laboratory work are compulsory. The laboratory sessions in the course constitute a combined number of points and are graded separately.

Assessment

Examination takes place in the form of practical components during the course through exercises, written assignments, laboratory sessions and written reports, and through a concluding oral exam at the end of the course. Entry to this oral examination requires passed written assignments and submission of laboratory reports during the course. A compulsory component is also a written self-reflection on one's own learning.

Compulsory written assignments that include numerical projects correspond to 1.0 credits and mainly assess intended learning outcomes 1-4, 6, 8, 10, and 12.

Three laboratory projects, two with associated reports, correspond to 2.5 credits; 1x 0.5 credits and 2x 1.0 credits with written report. They mainly assess intended learning outcomes 3, 7, 8, 10, 12, and 13.

Compulsory examination corresponds to 4.0 credits and assesses mainly intended learning outcomes 2, 3, 5, 6, 9, 11, and 13-15.

The self-reflection is compulsory and mainly assesses intended learning outcome 16.

For students who have not passed the regular exam, an additional exam opportunity is offered 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.

Grades

Grading scale includes the grades: Fail, Pass, Pass with distinction
To pass the whole course it is required to, pass the written assignments, the examination, the laboratory sessions, the self-reflection as well as participation in all compulsory parts:

- Introductory meeting.
- Written assignments.
- Laboratory parts.
- Self-reflection on learning.

Calculation of grade

- Assignments give a per-cent result that corresponds to the part of completed credits relative to the total number of possible points. 50%, which corresponds to grade Pass, are required for entry to the final examination. The limit for Pass with distinction is 80%.
- Three laboratory sessions, two with written report, each one gets a result in per-cent. Preparatory assignments, implementation, data analysis, and report are taken into account. 50%, which corresponds to grade Pass, are required for all three laboratory projects to obtain a result for the whole laboratory part. The result is based on a weighted mean of these three results in per-cent. The credits for the parts are used as weight. The limit for Pass with distinction is 80%. Submitted report for completed laboratory sessions are required for entry to final examination. Reports submitted late are approved with maximum 50%.
- The final examination gets a result in per-cent. The limit for Pass is 50% and for Pass with distinction 80%.
- To calculate a combined final result and grade for the whole course, a weighted mean is derived by using the per-cent results for written assignments, laboratory part, and examination. The credits for the parts are used as weight. The limit for Pass with distinction is 80%.

Entry requirements

Admission to the course requires general entry requirements, 22.5 credits in physics including knowledge corresponding to:

- FYSB22 Basic Quantum Mechanics, 7.5 credits (at least followed)

- FYSB23 Basic statistical Physics and quantum statistics, 7.5 credits (at least followed), and
- FYSB24 Atomic and Molecular Physics, 7.5 credits (at least followed),

and 45 credits in mathematics (maximum one of the courses incomplete, but at least followed), including knowledge corresponding to:

- MATA21 Analysis in One Variable, 15 credits,
- MATA22 Linear Algebra 1, 7.5 credits,
- NUMA01 Computational Programming with Python, 7.5 credits,
- MATB21 Analysis in Several Variables 1, 7.5 credits and
- MATB22 Linear Algebra 2, 7.5 credits

as well as either 37.5 credits in physics (and if any of the courses FYSB22–24 is completed, a maximum of one of these courses may be incomplete, but at least followed), including knowledge corresponding to:

- FYSA12 Introduction to University Physics, with Mechanics and Electricity, 15 credits
- FYSA13 Introduction to University Physics, with Optics, Waves and Quantum Physics, 7.5 credits
- FYSA14 Introduction to University Physics, with Thermodynamics, Climate and Experimental Methodology, 7.5 credits and
- FYSB21 Mathematical Methods for Vibrations, Waves and Diffusion, 7.5 credits

or an additional 37.5 credits in mathematics (and if all 45 credits of mathematics above are completed, a maximum of one of these courses can be unfinished, but at least followed), including knowledge corresponding to:

- MATB23 Analysis in Several Variables 2, 7.5 credits and
- MATB24 Linear Analysis, 7.5 credits.

Students who have obtained the corresponding knowledge by other means may also be admitted to the course.

Further information

The course is part of the Bachelor's programme in physics, theoretical physics, astrophysics or of the medical physics program. The teaching is based on the assumption that the student follows the program and has assimilated the knowledge in the previous courses, and takes other program courses in parallel. The course is also elective in the Master’s programme in computational science. For those who have acquired equivalent knowledge in other ways, the course can be taken as a stand-alone course.

The course can not be credited towards a degree together with FYSC12 Physics: Nuclear Physics and reactors, 7.5 credits or the equivalent earlier courses as well as ÄFYD14, Modern Physics and Physics Education, 30 credits.

The course is given by the Department of Physics, Lund University.