LUND UNIVERSITY

Faculty of Science

FYSB24, Physics: Atomic and Molecular Physics, 7.5 credits

Fysik: Atom- och molekylfysik, 7,5 högskolepoäng

First Cycle / Grundnivå

Details of approval

The syllabus was approved by Study programmes board, Faculty of Science on 2020-07-02 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 a 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 goals of the course is to broaden the knowledge of quantum mechanics from the earlier course FYSB22 to spherically symmetric systems. This new understanding is applied in atom and molecular physics, where the students have the opportunity to learn the basis for the structure of these system. An understanding of spectroscopic methods and how they are used in experimental studies are central in the course. The course also gives the opportunity to practise 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 and good knowledge of their all in all contents facilitate for the student to go through the course.

Intended learning outcomes in the programme syllabus refer to the programme syllabus of the Degree of Bachelor in physics at Lund University which corresponds to targets for general qualification in the Higher Education Ordinance in turn.

1-7 is interim target against intended learning outcomes 1 in the programme syllabus.
8, 11, 12 is interim target against intended learning outcomes 2 in the programme syllabus.
9, 10, 13, 15 is interim target against intended learning outcomes 3 in the programme syllabus.
9, 13 is interim target against intended learning outcomes 4 in the programme syllabus.
14, 15 is interim target against intended learning outcomes 5 in the programme syllabus.
16, 17 is interim target against intended learning outcomes 7 in the programme syllabus.
18 is interim target against intended learning outcomes 8 in the programme syllabus.

Knowledge and understanding

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

1. Interpret and apply quantum mechanical concepts and tools that are needed to describe modern atomic and molecular physics.
2. In detail explain the energy structure and the properties of atomic one-electron systems and other two-particle systems bound by Coulomb forces.
3. Explain the structure and the properties of two-electron systems.
4. Explain at a general level the structure of atomic systems with more than two electrons.
5. Give example of and describe important experimental methods in atomic and molecular physics.
6. Describe and use the theory of fundamental examples of the interaction of atoms and molecules with electromagnetic fields.
7. Develop and summarise the principle for lasers and illustrate their use.

Competence and skills

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

8. Apply basic quantum mechanical concepts and methods in the atomic and molecular physics.
9. Plan, carry out and present experiments and analyse simple atomic and molecular spectra.
10. Carry out numerical calculations on simple atomic systems.
11. Give example of and explain current research in atomic physics.
12. Explain how atomic physics can be applied in for example synchrotron light physics, astrophysics and plasma physics.
13. Independently write and defend a report about a completed experiment that contains explanation, development and use of experimental methods, estimate of errors and uncertainties and illumination of results and discussions by means of tables and figures.
14. Independently be able to acquire new knowledge and present them in oral and written form.
15. Estimate and anticipate the applicability and the limitations of physical models relevant for the course.

Judgement and approach

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

16. Discuss and give examples of the atomic and molecular physics role in society.
17. Discuss and give examples of how atomic and molecular physics can be used to supervise, understand and improve a sustainable development and human influence on his environment.
18. Summarise and reflect based on intended course learning outcomes and own aims over progress regarding knowledge and skills.

Course content

The course consists of three different themes:

Atomic physics

- 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 systems.
- 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 dipole approximation.
- 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.

Molecular physics

- 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.

Applications

- 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.

Course design

The teaching consists of lectures and calculation exercises, laboratory and numerical projects with written reports and a workshop and group reflection about climate. The introductory meeting, projects with written report as well as the workshops and group and self reflections are compulsory.

Assessment

The examination consists of:

- Compulsory written examination as written examination or take-home examination. Take-home examination also with oral discussion. Corresponded to 5 credits. and assess mainly intended learning outcomes 1-8, 11, 12, 14 and 15.
- Laboratory projects and reports correspond to 1.5 credits and mainly assess intended learning outcomes 9. 13 14 and 15.
- Numerical projects and reports correspond to 0.5 credits and mainly assess intended learning outcomes 10 13, 14 and 15.
- Workshop and grojup reflection if climate corresponds to 0.5 credits and assess mainly intended learning outcomes 14, 16 and 17.
- The self-reflection is compulsory and mainly assesses intended learning outcomes 18.

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.

Grades

Grading scale includes the grades: Fail, Pass, Pass with distinction
To pass the entire course, passed written examination projects and project reports, group reflection and self-reflection are required as well as participation in all compulsory components:

- Introduction meeting,
- Introduction to project,
- Laboratory and numerical projects,
- Workshop about climate.
- Self-reflection over learning.

Calculation of grade

- Written examination gives a percentage result that corresponds to the part achieved points, relatively the total possible number of points and the grades Fail, Pass or Pass with distinction. The limit for Pass is normally 50% and for Pass with distinction 80%.
- Laboratory and numerical projects (where implementation and reports are taken into account) give the grades passed, passed with distinction. For joining of grade, these are converted to percent results according to G=65%, VG=90%. The result for the project part is decided by a weighted mean of these percent results. The limit for Pass with distinction is 80%.
- For joining for calculation of final results and grades for the whole course, a weighted mean is calculated by percent results for examination and reports where the credits for the components are used as weight. The limit for Pass with distinction is 80%.
- Workshop and group reflection about climate and self-reflection only give grade Failed and Passed and are not used to calculate a final grade. If there are special reasons, projects can be excepted from to be assessed with percent result and include then not in the calculation of the final result.

Entry requirements

Admission to the course requires general entry requirements, 7.5 credits in physics including knowledge corresponding to:

- FYSB22 Basic Quantum Mechanics, 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 (maximum one of the courses apart from FYSB21 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 (at least followed)

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 of the medical physics program, or of the Master’s programme in computational science, physics. 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. For those who have acquired equivalent knowledge in other ways, the course can be taken as a stand-alone course.

The course may not be included in qualification together with FYSA31 Quantum Physics, 30 credits, FYSC11 Atomic and Molecular Physics, 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.