FYSC11, Physics: Atomic and Molecular Physics, 7.5 credits
Fysik: Atom- och molekylfysik, 7,5 högskolepoäng
First Cycle / Grundnivå

Main field of studies
Physics

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

Details of approval
The syllabus was approved by Study programmes board, Faculty of Science ….

General Information
Language of instruction: English

Learning outcomes

Kursen syftar till att utvida grundläggande kvantmekanik till system med sfärisk symmetri. Detta tillämpas sedan inom atom- och molekylfysik. En förståelse av den spektroskopiska principen är central i kursen. Lärandemål i utbildningsplanen hänvisar till utbildningsplanen för kandidatexamen i fysik vid Lunds universitet, vilket i sin tur motsvarar examensmålen för generell examen i högskoleförordningen, se ”övrigt”.

Kursens mål:
1-5 aims towards intended learning outcomes 1 in the programme syllabus.
6-11 aims towards intended learning outcomes 2-5 in the programme syllabus.
12-15 aims towards intended learning outcome 6 in the programme syllabus.
16 aims towards intended learning outcomes 6-7 in the programme syllabus.

Knowledge and understanding
On completion of the course, the student should be able to:
1. Explain quantum mechanical concepts needed to describe modern atomic and molecular physics
2. Describe in detail the energy structure of atoms with one or two valence electrons and qualitatively for many-electron systems
3. Describe some important experimental techniques used in atomic and molecular physics
4. Describe how atoms and molecules interact with electromagnetic radiation
5. Describe the principle for lasers and give examples of their applications

Competence and skills
On completion of the course, the student should be able to:
6. Use basic quantum mechanical concepts and apply them to the physics of atoms and molecules
7. Plan, carry out and present experiments and analyze simple atomic and molecular spectra
8. Perform numerical calculations for simple atomic systems
9. At a general level illustrate and describe current research within atomic physics
10. Describe application of atomic physics in e.g. synchrotron light physics, astrophysics or plasma physics.
11. Independently produce and defend a report on an experiment, which includes a description of the purpose, experimental techniques, uncertainty estimates and illustrations in form of tables and figures.

Judgement and approach
On completion of the course, the student should:
12. be able to evaluate experimental results
13. show an ability to assess the applicability and limitations of physical models
14. independently be able to acquire new knowledge and present these in oral or written form
15. demonstrate an understanding of the role of atomic physics in society
16. Discuss and examplify how atomic and molecular physics can be used in monitoring, improving and understanding sustainability and human impact on the environment.

Course content
The thematic content of the course:

Atomic Physics
- Recapitulation of basic quantum mechanical concepts.
- The quantum mechanical treatment of angular momentum including orbital and spin, and properties of eigenvalues and eigenfunctions. Additions of angular momenta.
- Quantum mechanical treatment of spherically symmetric potentials with applications to e.g. hydrogenic and hydrogen-like ions.
- Numerical solutions of the radial equation for simple atomic systems.
- Two-electron systems, including an introduction to correlation and exchange effects.
- Relativistic effects giving rise to the fine structure of ions.
- Many-electron system, with a discussion of the Pauli principle and the periodic system, LS-coupling and an orientation about the central field approximation. Experimental observations of effects connected to these phenomena.
- Radiative transitions, with emphasis on the electric dipole approximation.
- Interaction with external magnetic fields, including the Zeeman effect.
- Hyperfine - and isotope structure.

Molecular Physics
- Introduction to molecular physics, with a discussion of the binding of diatomic molecules. An orientation of covalent and ionic binding and the LCAO-method.
- Quantum mechanical treatment and observation of rotational and vibrational spectra.
- Short introduction to important experimental techniques in atomic physics.

Applications of Atomic and Molecular Physics
- Laser physics and its applications.
- Use of molecular spectra in monitoring climate change
- Spectroscopy of light sources and their energy efficiency.

Applications could also include
- X-ray radiation, X-ray spectra, X-ray spectroscopy, Photoelectron spectroscopy.
- Synchrotron light and its applications.
- Astrophysics and plasma physics.

Course design
The teaching consists of lectures, group work, problemsolving sessions and experimental and numerical workshops. The workshops, consisting of the preparations, actual experiment or
calculations and a written report, are compulsory. Hand-ins could be rewarded by bonus points for the final examination.

Assessment
The examination routines contain written hand-ins and a written final exam, as well as compulsory workshops.
- The final exam examines intended learning outcomes 1-6, 9-10, 13, 15 and 16
- The experimental workshops examine the learning outcomes 3-5, 7 and 9-14
- The numerical workshop examines learning outcome 1 and 8

Grades
Marking scale: Fail, Pass, Pass with distinction.

To pass the entire course requires approved examination, passed laboratory reports and participation in all compulsory parts. The final grade of the course is decided through a weighted average of the grades for the written examination and the laboratory sessions according to their individual credits. Written assignments can give bonus points for the examination.

Entry requirements
To be admitted to the course, students must meet the general entry requirements for physics and have finished 22.5 hp out of the following physics courses: FYSA12, FYSA13, FYSA14 or equivalent. 22.5 hp of finished mathematics courses out of the following courses or equivalent is also a requirement for admission to the course: MATA21, MATA22, NUMA01, MATB21, and MATB22

The course builds on knowledge defined in the syllabus of the following courses: FYSA12, FYSA13, FYSA14, MATA21, MATA22, NUMA01, MATB21, MATB22, and students are expected to know and understand this.

Further information
The course may not be included in a higher education degree together with FYSA31 Modern physics, 30 credits, or FYSC11 Atomic and Molecular Physics, 7.5 credits.

Appendix 1: Aims stated in the programme syllabus of Degree of Bachelor of Science:

Knowledge and understanding
For Degree of Bachelor, the student should:
1. show knowledge and understanding in the main field of study for the education included knowledge of the disciplinary foundation of the field, knowledge of applicable methods in the area, specialisation in some part of the field as well as orientation in current research questions.

Competence and skills
For Degree of Bachelor, the student should:
2. demonstrate the ability to search, collect, evaluate and interpret relevant information in a problem critically as well as to discuss phenomena, issues and situations critically
3. demonstrate the ability to independently identify, formulate and solve problems as well as to carry out assignments within given time frames
4. demonstrate the ability to orally and in writing account for and discuss information, problems and solutions in dialogue with different groups and
5. demonstrate the skills required to work independently in the field of the programme

**Judgement and approach**

For Degree of Bachelor, the student should:
6. demonstrate the ability to in the main field of study for the education make assessments considering relevant scientific, social and ethical aspects
7. demonstrate an understanding of the role of the knowledge in society and if the responsibility of people for how it is used and
8. identify the personal need for further knowledge and ongoing learning

**Subcourses in FYSC11, Physics: Atomic and Molecular Physics**

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
<th>Grading Scale</th>
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<tbody>
<tr>
<td>1003 Exam</td>
<td>5.0 hp</td>
<td>Fail, Pass, Pass with distinction</td>
</tr>
<tr>
<td>1004 Laboratory Exercises</td>
<td>2.5 hp</td>
<td>Fail, Pass, Pass with distinction</td>
</tr>
<tr>
<td>1001 Oral Exam</td>
<td>5.0 hp</td>
<td>Fail, Pass, Pass with distinction</td>
</tr>
<tr>
<td>1002 Laboratory Exercises and Projects</td>
<td>2.5 hp</td>
<td>Fail, Pass, Pass with distinction</td>
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