Faculty of Science

FYST87, Physics: Computational Atomic Physics with Applications in Astrophysics, 10 credits

Fysik: Beräkningsatomfysik med astrofysikaliska tillämpningar, 10 högskolepoäng

Second Cycle / Avancerad nivå

Details of approval

The syllabus was approved by Study programmes board, Faculty of Science on 2022-06-14 to be valid from 2022-06-14, spring semester 2023.

General Information

The course is an elective course for second cycle studies for a scientific candidate - or Master's degree (120 credits) in physics.

Language of instruction: English

Main field of studies	*Depth of study relative to the degree requirements*
Physics	A1N, Second cycle, has only first-cycle course/s as entry requirements

Learning outcomes

The overarching aim of the course is an introduction to computational atomic physics. The course covers methods and utilises codes developed for calculations in current research. Applications are chosen in different fields, such as astrophysics, plasma physics and fusion research.

Knowledge and understanding

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

1. describe how modelling of atomic systems is carried out with modern computational methods,

2. give an account of theoretical concepts as electron correlation radiative transitions, resonanses in photoionisation and collision cross-section,

3. explain how atomic data are applied in plasma modelling.

Competence and skills

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

4. carry out calculations especially of interest in for example plasma modelling of atomic eigenstates, radiation and collision processes,

5. in writing and orally present and provide arguments for calculated results in a systematic and scientifically correct way.

Judgement and approach

On completion of the course, students shall be able to

6. interpret, discuss and analyse data from atomic calculations,

7. reflect on the role of atomic physics for the analysis of astro-physical plasma.

Course content

The course consists of two modules:

Module 1: Introduction to computational atomic physics with applications, 7 credits.

In this part, the bases of theoretical atomic physics is treated, with a review and repetition of atomic structure in the form of the central field approximation, electron correlation and relativistic effects. It also treats atomic processes, such as excitation and ionisation processes related to electromagnetic radiation and electron collisions. Especially, resonanses in these processes are discussed.

Several different methods are introduced and used in this part of the course:

- Hartree and Dirac-Fock-methods for calculation of non-relativistic and relativistic atomic structure,
- configuration interaction and self-consistent multiconfiguration methods to include electron correlation,
- Z dependent pertubation theory to estimate how different atomic properties varies with the nuclear charge,
- R matrix methods for calculation of continuum processes, as for instance ionisation at electron and photon collisions.

Applications of atomic physics treats, how atomic data are used in studies of astro-physical plasma. Basic plasma modelling in and out of equilibrium is also included.

Module 2: Final project in calculation atomic physics with applications, 3 credits.

In this part of the course the students perform, individual or in small groups, a project where the methods that have been introduced in module 1 are applied on a realistic problem in atomic physics or its applications. If the project is carried out in groups, it should appear clearly in the report what each student has contributed with.

Course design

The teaching consists of lectures, computer exercises in groups and a final project. Participation in computer exercises and final project are compulsory. The course is carried out at distance, that is online. The course is offered as a distance learning course using an online learning platform and digital tools. It is assumed that the student participates under these conditions and has access to a computer with Internet connection and capacity for the calculations that should be carried out.

Assessment

Examination in module 1 is arranged through oral and written presentation of computer exercises during the course.
Examination in module 2 is arranged through oral and written presentation of the final project at the end of the course.

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.

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.
To pass the whole course, passed oral and written presentation is required of computer exercises and the final project. The grading scale for oral and written presentations of computer exercises is Failed, passed. The grading scale for oral and written presentation of the final project is Failed, passed, Passed with distinction.

The final grade are decided through grade on the project assignment.

Entry requirements

Admission to the course requires 120 credits scientific studies in which 75 credits in physics and 45 credits in mathematics is included, or a Degree of Bachelor in physics - in both cases including knowledge equivalent to FYSB24 Atomic and Molecular Physics, 7.5 credits, FYSB22 Basic quantum mechanics, 7.5 credits, and NUMA01 Beräkningsprogrammering with Python, 7.5 credits, and English 6/B.

Further information

This course replaces the course FYST47 Intensive course in calculation atomic physics, 7.5 credits and cannot be included in a degree together with this course.

Knowledge equivalent to FYSN17 Quantum Mechanics, 7.5 credits, is recommended but is not a requirement.

The course is offered at the Department of Physics, Lund University.

Subcourses in FYST87, Physics: Computational Atomic Physics with Applications in Astrophysics

Applies from V23

2301 Computer exercises 1-4 Introduction, 2,0 hp
Grading scale: Fail, Pass
Module 1

2302 Computer exercises 5-8 Correlation and relativistic effects, 2,5 hp
Grading scale: Fail, Pass
Module 1

2303 Computer exercises 9-12 Continuum and applications, 2,5 hp
Grading scale: Fail, Pass
Module 1

2304 Finishing project, 3,0 hp
Grading scale: Fail, Pass, Pass with distinction
Module 2