Faculty of Science

FYSB23, Physics: Basic Statistical Physics and Quantum Statistics, 7.5 credits

Fysik: Grundläggande statistisk fysik och kvantstatistik, 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 goal of the course is that after completing the course, the students must have acquired knowledge and skills in basic statistical physics and quantum statistics. 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 overall content makes it easier for the student to complete the course

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

1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13, 17, 18 are milestones towards learning objective 1 in the syllabus.

2, 4, 6, 7, 13 are milestones towards learning outcome 2 in the syllabus.

8, 9, 10, 11, 12, 14, 16 are milestones towards learning outcome 3 in the syllabus.

3, 4, 10, 13, 14, 15 are milestones towards learning objective 4 in the syllabus.

11, 12, 14 are milestones towards learning outcome 5 in the syllabus.

14 is a milestone towards learning objective 7 in the syllabus.

14, 17, 18, 19, 20 are milestones towards learning outcome 8 in the syllabus.

Knowledge and understanding

After completing the course, the student should be able to:

1. describe and explain the laws of thermodynamics and their meaning.
2. define and explain the concepts of equilibrium, entropy and statistical weight.
3. describe the approach to the equilibrium state in terms of phase space concepts, reversibility and irreversibility.
4. describe and explain the principle of equipartition and describe how quantum mechanics corrects its predictions of heat capacities.
5. describe and explain the equation for non-ideal gases (van der Waals equation).
6. define and explain the concepts of phase transition and order parameter, and give examples from the mean field treatment of ferromagnetism.
7. describe and summarize the ultraviolet catastrophe.
8. explain the negative heat capacity of self-gravitating systems and its consequences in stellar processes.
9. describe the mechanism behind the pressure in degenerate fermion gases and provide applications in astronomy.

Competence and skills

After completing the course, the student should be able to:

10. derive and use the Boltzmann factor
11. set up the partition function for simple systems and, based on the partition sum, characterize equilibrium states.
12. determine the degrees of freedom of a system and calculate from these the prediction of classical physics for its heat capacity.
13. work with the densities of states and average number density for ideal sparse gases and ideal fermion and boson gases, respectively.
14. develop, interpret and describe simple numerical experiments with statistical mechanics.
15. orally describe a phenomenon relevant to the course or results from laboratory and numerical projects in a popular scientific way.
16. use error reproduction and statistical analysis on measured data from laboratory exercises during the course.

Judgement and approach

After completing the course, the student should be able to:

17. evaluate and reflect on experimental results.
18. evaluate and reflect on the application and limitation for physical models.
19. demonstrate and understand the importance of statistical mechanics in society.
20. reflect on course objectives and own goals of progress in terms of knowledge and competence.

Course content

The course covers basic statistical physics and quantum physics, with a focus on systems in equilibrium states. Special treatment:

- the ideal gas law; van der Waals equation
- state variables, entropy, free energy
- Boltzmann factor, canonical and grand canonical ensemble
- the laws of thermodynamics
- heat capacity, equipartition principle, ultraviolet catastrophe
- identical particles, degenerated quantum gases
- mean field treatment of the para-ferromagnetic transition
- describing, carrying out, and interpreting a numerical experiment in statistical mechanics: how / if a chain of harmonic oscillators approaches equilibrium state (Fermi-Pasta-Ulam problem).
- negative heat capacity for self-gravitating systems
- degeneracy pressure in self-gravitating compact objects

Course design

The teaching consists of lectures, lessons, laboratory and numerical projects, oral exercises and presentations, calculation exercises, written and numerical assignments. Participation in the introduction meeting, the introduction to projects, the laboratory and numerical projects, as well as the self-reflection on learning are mandatory.

Assessment

The assessment is based on:

- a written examination at the end of the course corresponding to 5.5 credits and examines all learning outcomes.
- compulsory laboratory and numerical projects during the course and approved reports correspond to 2.0 credits and mainly examine learning goals 16 and 18.
- project in popular science communication during the course that examines mainly learning outcome 17.
- compulsory written assignments during the course that examine all learning outcomes.
- compulsory self-reflection at the end of the course that examines mainly learning outcome 20.

For students who have not passed the regular exam, additional examinations are offered in close proximity of the regular exam.

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, approved reports and a passed exam is required as well as participation in all compulsory parts:

- introduction meeting
- introduction to projects,
- laboratory and numerical projects
- self-reflection on learning

Calculation of grades

- Self-reflection and laboratory and numerical projects only give grade Fail and Pass and are not used to calculate a final grade.
- The examination gives a grade based on the percentage of completed credits. The limit for Pass is normally 50% and for Pass with Distinction is 80%.
- When all compulsory parts are Pass or Pass with distinction, the grade for the entire course is determined by the examination grade.

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 cannot be credited in the degree together with FYSB12, Basic Statistical Physics and Quantum Statistics, or equivalent previous courses.

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