LUND UNIVERSITY

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 to be valid from 2020-07-02, spring semester 2021.

General Information

The course is a compulsory undergraduate course for a bachelor's degree in physics.

Language of instruction: English

Main field of studies	*Depth of study relative to the degree requirements*
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
- describe, carry out and interpret 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 laboratory and numerical projects is 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 and approved reports correspond to 2.0 credits and mainly examine learning goals 16 and 18.
- project in popular science communication that examines mainly learning outcome 17.
- compulsory written assignments during the course that examine all learning outcomes.
- compulsory self-reflection 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.

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 entire course, participation in all compulsory parts, approved reports and a passed exam is required:

- 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 basic eligibility and 45 ECTS physics equivalent to: FYSA12 15 credits, FYSA13 7.5 credits, FYSA14 7.5 credits, FYSB21 7.5 credits, and FYSB22 7.5 credits, and 45 credits mathematics equivalent to: MATA21 15 credits, MATA22 7.5 credits, NUMA01 7.5 credits, MATB21 7.5 credits, MATB22 7.5 credits.

Equivalent prior knowledge, acquired in other ways, also gives access to the course.

Further information

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

Subcourses in FYSB23, Physics: Basic Statistical Physics and Quantum Statistics

Applies from V21

2101 Examination, 5,5 hp
Grading scale: Fail, Pass, Pass with distinction
2102 Laboratory and numerical projects, 2,0 hp
Grading scale: Fail, Pass
2103 Self reflection, 0,0 hp
Grading scale: Fail, Pass