Faculty of Science

FYSB12, 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 the Study programs board, Faculty of Science, on 2015-10-15 and was last revised on 2015-10-15. The revised syllabus applies from 2016-01-01, spring semester 2016.

General Information
The course is an elective component of the Bachelor’s programs in science, and a compulsory component of a Bachelor of Science degree in Physics and of the Master of Science program in Medical Physics.

Language of instruction: English

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

Learning outcomes

The objective is that the students, on completion of the course, shall have acquired knowledge and skills within basic statistical physics and quantum statistics. The learning outcomes listed below relate to the general outcomes in the Higher Education Ordinance (1993:100).

Knowledge and understanding
On completion of the course, the students shall be able to

1. account for the laws of thermodynamics and explain their implications [1]
2. understand and explain for the concepts of equilibrium, entropy and statistical weight [1,2]
3. illustrate the approach to equilibrium in terms of phase space concepts, reversibility, and irreversibility. [1,4]
4. account for the equipartition principle and describe how quantum mechanics corrects its predictions of heat capacities [1,2,4]

5. account for the equation of state of imperfect gases (van der Waals equation) [1]
6. account for the concept of phase transition and order parameter, with examples from mean filed treatment of ferromagnetism [1,2,8]
7. account for the ultraviolet catastrophe [1,2]
8. explain the negative heat capacity of self-gravitating systems and its consequences in stellar processes. [1,3]
9. account for the mechanism behind the pressure in degenerate fermion gases and provide examples in astronomy where this is significant. [1,3]

Competence and skills
On completion of the course, the students shall be able to
10. from a probability distribution perspective, evaluate various expectation values of individual statistical variables and the sum of several independent variables. Should this go?
11. develop and use the Boltzmann factor [3,4]
12. develop and use the partition function for simple systems and characterize equilibrium in terms of the partition function [3,5]
13. decide a system’s degrees of freedom and use this as a basis for calculating a classical physics prediction for its heat capacity[1,3,5]
15. account for densities of states and average number density for ideal sparse gases, and ideal fermion and boson gases [1,2,4]
16. develop, interpret and describe simple statistical mechanics numerical experiments [3,4,5,7,8]
17. orally describe a phenomenon that is relevant to the course using a popular science approach or results from lab sessions or numerical activities [4]
18. Apply error propagation, and statistical analysis of measured data from lab sessions in the course [3]

Judgement and approach
On completion of the course, the students shall be able to
19. estimate and reflect on experimental results [1,8]
20. evaluate and reflect on the applicability and limitations of physical models [1,8]

Course content
The course covers basic statistical physics and quantum statistics, with a primary focus on systems in equilibrium. In particular:
- basic statistics for several, independent variables
  - the ideal gas law; the van der Waals equation
  - state variables, entropy, free energy
  - the Boltzmann factor, canonical and grand canonical ensemble
  - the laws of thermodynamics
  - heat capacities, equipartition principle, the ultraviolet catastrophe
  - identical particles, degenerate quantum gases
  - mean field treatment of the para-ferromagnetic transition
  - describe, conduct, and interpret a numerical experiment in statistical mechanics: how/if a chains of an/harmonic oscillators approaches equilibrium (Fermi-Pasta-Ulam problem).
  - negative heat capacity of self-gravitating systems
• degeneracy pressure in self-gravitating compact objects

**Course design**
The teaching consists of laboratory sessions, short oral presentation by the students, lectures, calculation exercises and written and numerical assignments (approach to equilibrium for the Fermi-Pasta-Ulam problem, i.e. a chain of nonlinear oscillators). Compulsory participation is required in laboratory sessions and associated elements.

**Assessment**
The assessment is based on:
- compulsory laboratory sessions – assessment of learning outcomes 16 and 18 in particular
- project on popular science communication – assessment of learning outcome 17 in particular
- compulsory written assignments during the course – assessment of all learning outcomes
- a written exam at the end of the course – assessment of all learning outcomes.

*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.
For a grade of Pass on the whole course, the students must have passed the reports and presentations of compulsory components and the exam.

**Entry requirements**
To be admitted to the course, students must meet the general entry requirements for physics and have finished the following physics courses: FYSA12, FYSA13, FYSA14 or equivalent. 30 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, FYSB10 (Andreas course proposal), and FYSB11 and students are expected to know and understand this.

**Applies from ????

1501 Exam, 5,5 hp
Grading scale: Fail, Pass, Pass with distinction

1502 Laboratory exercises and Projects, 2,0 hp
Grading scale: Fail, Pass