Faculties of Humanities and Theology

ÄFYD03, Physics 3: Basic Quantum Mechanics, Statistical Mechanics and Quantum Statistics for teachers, 15 credits

Fysik 3: Grundläggande kvantmekanik, statistisk mekanik och kvantstatistik för lärare, 15 högskolepoäng

First Cycle / Grundnivå

Details of approval

The syllabus was approved by Study programmes board, Faculty of Science on 2018-10-09 to be valid from 2018-10-09, spring semester 2018.

General Information

The course is included in the Master's programme in Secondary Education at Lund University.

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 aim of the course is for students to acquire the knowledge and skills in basic quantum mechanics they need to pursue further studies in quantum physics as well as statistical physics and quantum statistics.

Knowledge and understanding

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

1. describe the basic properties of quantum particles as well as explain key concepts such as wave-particle duality, wave function and superposition
2. set up and qualitatively justify the Schrödinger equation
3. explain and give examples of how operators in quantum mechanics are used to represent observable physical quantities

4. formulate expressions for and explain key concepts such as probability, outcome, expected value and uncertainty, for a measurement of a quantum particle
5. derive the radial part of the Schrödinger equation for a spherical symmetric potential
6. account for the laws of thermodynamics and explain their implications
7. relate the concepts of equilibrium, entropy and statistical weight
8. describe different processes, particularly circuit processes, and applications such as engines, refrigerators, heat pumps, etc.
9. account for the principle of equal distribution and describe how quantum mechanics corrects its predictions of thermal capacities
10. provide a general description of the ultraviolet catastrophe
11. account for the underlying mechanism of the pressure in turbid fermion gases and give an example of some field of physics or astronomy in which this is important

Competence and skills

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

12. solve the Schrödinger equation for an infinite potential well in a dimension as well as describe the main features of the solution and its properties for a finite well
13. calculate the probability and describe the qualitative properties of transmission through simple potential structures in a dimension
14. derive basic operator relations and perform simple calculations using operators
15. formulate the Schrödinger equation for the harmonic oscillator in a dimension in terms of ladder operators, as well as calculate and describe the key properties of wave functions and eigen energies
16. use numerical methods to solve problems of quantum mechanics
17. based on a probability distribution, determine different expected values of individual statistical variables and the sum of several independent variables
18. derive and apply the Boltzmann factor
19. set up the partition function for simple systems and characterise equilibrium based on the partition function
20. determine the degree of freedom of a system and, on this basis, calculate the prediction of classical physics for its thermal capacity
21. calculate the efficiency in simple circuit processes and determine whether a process is reversible or not
22. work with state densities and average occupancies for ideal sparse gases and ideal fermion and boson gases
23. perform, interpret and describe in writing experiments with e.g. vacuum systems or circuit processes
24. describe in writing a phenomenon linked to the course in a conceptual way with a target group in youth education
25. orally describe a phenomenon of relevance for the course in a popular science way

Judgement and approach

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

26. assess which situations require an approach based on quantum mechanics
27. assess experimental results
28. assess the applicability and limitations of physical models

Course content

Module 1: Basic Quantum Mechanics, 7.5 credits

Module 1 deals with:

- wave-particle duality, superposition and wave function
- the Schrödinger equation
- fixed states in a dimension
- scattering against potential structure in a dimension
- operators, observables and operator relations
- measurements, expected values and uncertainty
- harmonic oscillator
- spherical symmetric systems

Module 2: Basic Statistical Mechanics and Statistical Quantum Physics, 7.5 credits, focusing on systems in equilibrium without phase transitions.

Module 2 deals with:

- the basic statistics of several independent variables
- the general state of ideal gases
- state variables, entropy, free energy
- the Boltzmann factor, canonical and large canonical ensembles
- circuit processes, the laws of thermodynamics
- thermal capacities, the principle of equal distribution, the ultraviolet catastrophe
- identical particles, degenerated quantum gases
- diffusion
- applications in astronomy, meteorology or other relevant areas of physics

Course design

The teaching consists of laboratory exercises, computer exercises, lectures, calculation exercises and written assignments. Participation in laboratory exercises, computer exercises and associated components is compulsory.

Assessment

The assessment of the course consists of:

- compulsory written assignments- assessment of all learning outcomes except for learning outcome 25
- compulsory computer exercises- assessment of learning outcome 16 in particular
- compulsory laboratory reports- assessment of learning outcomes 23 and 27 in particular

- project in popular science communication- assessment of learning outcome 25 in particular
- project in conceptual description of quantum physics- assessment of learning outcome 24 in particular
- a written or oral exam at the end of the course- assessment of all learning outcomes

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.
For a grade of Pass on the whole course, the student must have been awarded this grade on all compulsory components and on the exam for each module. The final grade is determined by the aggregated results of the assessed components in proportion to their extent (see appendix).

Entry requirements

To be admitted to the course, the student must meet the general entry requirements and have knowledge in physics and physics education equivalent to ÄFYD01 Physics and Physics Education, 30 credits, as well as 37.5 credits in mathematics including courses that correspond to NUMA01 Computational Programming with Python, 7.5 credits and MATB22 Linear Algebra 2, 7.5 credits.

Further information

The course is coordinated with FYSB11 Basic Quantum Mechanics, 7.5 credits, and FYSB12 Basic Statistical Physics and Quantum Statistics, 7.5 credits. The course cannot be included in a degree together with these courses, and not together with FYTA12 Basic Theoretical Physics, 30 credits, FYSB01 Introduction to Quantum Mechanics, 7.5 credits, FYSB02 Quantum Mechanics and Computations, 15 credits, or FYSA21 Tools in Science, 30 credits.

Subcourses in ÄFYD03, Physics 3: Basic Quantum Mechanics, Statistical Mechanics and Quantum Statistics for teachers

Applies from V18

1801 Basic quantum mechanics - written exam, 5,5 hp
Grading scale: Fail, Pass, Pass with distinction
1802 Basic quantum mechanics - laboratory work and projects, 2,0 hp
Grading scale: Fail, Pass
1803 Basic statistical mechanics - written exam, 5,5 hp
Grading scale: Fail, Pass, Pass with distinction
1804 Basic statistical mechanics - laboratory work and projects, 2,0 hp
Grading scale: Fail, Pass