LUND UNIVERSITY

Faculties of Humanities and Theology

ÄFYD13, Physics 3: Basic Quantum Mechanics, and Mathematical Methods for Vibrations, Waves and Diffusion for Teachers, 15 credits

Fysik 3: Grundläggande kvantmekanik och matematiska metoder för svängningar, vågor och diffusion för lärare, 15 högskolepoäng

First Cycle / Grundnivå

Details of approval

The syllabus was approved by Study programmes board, Faculty of Science on 2020-06-11 to be valid from 2020-06-11, spring semester 2021.

General Information

The course is a component of the teacher education programme at Lund University.

Language of instruction: Swedish

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 general aim of the course is that, on completion of the course, students will have acquired the knowledge and skills in basic quantum mechanics that are required for continued studies in quantum physics and in mathematical methods for oscillations, waves and diffusion.

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. formulate, and qualitatively justify the Schrödinger equation
3. explain and provide examples of how operators in quantum mechanics are used to represent observable physical quantities

4. formulate expressions for the measurement of a quantum particle and explain key concepts such as probability, outcome, expected value and uncertainty
5. explain the driven harmonic oscillator in detail
6. describe the basic equations for heat conduction and diffusion
7. relate phase and group velocity to the concept of dispersion
8. explain and use different general and partial differential equations that occur in physics.

Competence and skills

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

9. solve the Schrödinger equation for an infinite potential well in one dimension as well as describe the main features of the solution and its properties for a finite well
10. calculate the probability and describe the qualitative properties of transmission through simple potential structures in one dimension
11. derive basic operator relations and perform simple calculations using operators
12. carry out simple approximate calculations of energies based on pertubation theory and variational method
13. formulate the Schrödinger equation for the harmonic oscillator in one dimension in terms of ladder operators, as well as calculate and describe the key properties of wave functions and eigen energies
14. in a small group, carry out experimental laboratory sessions in the subject and present the work in a written laboratory report
15. use numerical methods to solve quantum mechanical problems
16. based on a probability distribution, determine different expected values of individual statistical variables and the sum of several independent variables
17. use the complex Fourier transform in time and space
18. analyse electric circuits with a spectrum analyser
19. analyse vibrating systems as eigenvalue problems.
20. use numerical methods to solve simple differential equations
21. in writing, discuss their understanding of physical problems
22. summarise and collect information from different sources of relevance to the course content.

Judgement and approach

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

23. assess in which situations a quantum mechanical approach is required
24. evaluate the importance of static uncertainty in quantum mechanics
25. explain and provide examples of the role of quantum mechanics in social development
26. decide and evaluate the use of complex numbers to solve linear differential equations
27. critically discuss magnitude estimation to analyse physical problems
28. identify and discuss the impact of different gases on the greenhouse effect
29. based on the course learning outcomes and their own goals, reflect on their progress with regard to knowledge and skills.

Course content

Module 1: Basic Quantum Mechanics, 7.5 credits

Module 1 covers basic quantum mechanics. Specific topics covered:

- wave-particle duality, superposition and wave function
- the Schrödinger equation
- bound states in one dimension
- scattering in one-dimensional potentials
- operators, observables and operator relations
- measurements, expected values and uncertainty
- harmonic oscillator
- approximate methods for the calculation of energies

Module 2: Mathematical Methods for Vibrations, Waves and Diffusion, 7.5 credits

Module 2 covers mathematical and numerical methods for primarily classical physics. Specific topics covered:

- the driven harmonic oscillator with Q factor, phase and line width
- complex Fourier transform
- brief introduction to non-linear oscillations
- sound and water waves
- mathematical description of wave packets with phase and group velocity
- vibration modes in molecules, strings and drums.
- diffusion and heat conduction

Course design

The teaching consists of lectures, calculation exercises, laboratory and numerical projects with written reports and written assignments. Participation in the projects, submission of reports and some written assignments are compulsory.

Assessment

The assessment is based on:

Module 1 Basic Quantum Mechanics, 7.5 credits:

- one written or oral examination at the end of the course corresponding to 5.5 credits that primarily assesses intended learning outcomes 1-4, 9-13, 15-16 and 23-25
- compulsory laboratory and numerical projects and approved reports corresponding to 2 credits that primarily assess intended learning outcomes 14-15
- compulsory self-reflection that primarily assesses intended learning outcome 29.

Module 2 Mathematical Methods for Vibrations, Waves and Diffusion, 7.5 credits:

- one written examination at the end of the course corresponding to 4 credits that primarily assesses intended learning outcomes 5-8, 17, 19 and 26
- compulsory laboratory and numerical projects and approved reports corresponding to 3 credits that primarily assess intended learning outcomes 18, 20-22 and 27
- compulsory written assignments corresponding to 0.5 credits that primarily assess intended learning outcomes 5, 19 and 28

- compulsory self-reflection that primarily assesses intended learning outcome 29.

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.
Grades awarded for Modules 1 and 2:

For a Pass on the whole module, students must have been awarded a Pass on all reports and the examination and have participated in all compulsory components:

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

Calculation of Grades for Modules 1 and 2:

The self-reflection is awarded the grade of Pass or Fail and is not used to calculate the final grade on the module.
The examination is awarded a percentage grade corresponding to the proportion of points achieved, relative to the total number of possible points. The minimum required for a Pass is normally 50% while the minimum for a Pass with Distinction is 80%.
Laboratory and numerical projects (for which the execution and reports are taken into account) and the compulsory written assignments are awarded the grade of Fail, Pass or Pass with Distinction. For the final calculation of results, these are converted to percentage grades for which a Pass=65% and a Pass with Distinction=90%. A weighted mean of these percentage grades is used to calculate the grade for the project component. The minimum required for a Pass with Distinction is 80%.

The final results and grade for the whole module are calculated as a weighted mean of the percentage grades awarded for the examination and reports, according to the credits awarded for each component. The minimum grade for a Pass with Distinction is 80%.

Grades for the course:

The grades awarded for the course are Fail, Pass and Pass with Distinction.

To be awarded a Pass on the course, students must be awarded a Pass on Modules 1 and 2.

For the final results and grade for the whole course, a mean is calculated from the percentage grades awarded for the two modules, 1 and 2. The minimum grade for a Pass with Distinction is 80%.

Entry requirements

To be admitted to the course, students must fulfill the general entry requirements and have physics knowledge equivalent to the courses ÄFYD11, 30 credits, ÄFYD12, 15 credits or the courses FYSA12, 15 credits, FYSA13, 7.5 credits, FYSA14, 7.5 credits as well as mathematics knowledge equivalent to the courses ÄMAD01, 30 credits, ÄMAD02, 15 credits or the courses MATA21, 15 credits, MATA22, 7.5 credits, NUMA01, 7.5 credits, MATB21, 7.5 credits, MATB22, 7.5 credits.

Students who have obtained the equivalent knowledge by other means may also be admitted to the course.

Further information

The course is coordinated with the courses FYSB22 Basic Quantum Mechanics, 7.5 credits and FYSB21 Mathematical Methods for Vibrations, Waves and Diffusion, 7.5 credits. The course cannot be included in a degree together with these courses, nor with ÄFYD03, Physics 3: Basic Quantum Mechanics, Statistical Mechanics and Quantum Statistics for teachers, 15 credits, FYTA12 Fundamental 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 ÄFYD13, Physics 3: Basic Quantum Mechanics, and Mathematical Methods for Vibrations, Waves and Diffusion for Teachers

Applies from V21

2101 Exam in basic quantum mechanics, 5,5 hp
Grading scale: Fail, Pass, Pass with distinction
2102 Laboratory exercises and projects in basic quantum mechanics, 2,0 hp
Grading scale: Fail, Pass, Pass with distinction
2103 Self-reflection - basic quantum mechanics, 0,0 hp
Grading scale: Fail, Pass
2104 Exam in mathematical methods, 4,0 hp
Grading scale: Fail, Pass, Pass with distinction
2105 Laboratory exercises and projects in mathematical methods, 3,0 hp
Grading scale: Fail, Pass, Pass with distinction
2107 Hand-in assignments in mathematical methods, 0,5 hp
Grading scale: Fail, Pass, Pass with distinction
2109 Self-reflection - mathematical methods, 0,0 hp
Grading scale: Fail, Pass