UNIVERSITY OF GOTHENBURG

DEPARTMENT OF PHYSICS

FYM290 Quantum mechanics, 4.5 credits

Kvantmekanik, 4,5 högskolepoäng

Second Cycle

Confirmation

This course syllabus was confirmed by Department of Physics on 2019-03-11 and was last revised on 2023-05-08 to be valid from 2024-01-15, spring semester of 2024.

Field of education: Science 100%
Department: Department of Physics

Position in the educational system

The course is part of the master program in physics.

The course can be part of the following programmes: 1) Complex Adaptive Systems, Master's Programme (N2CAS) and 2) Physics, Master's Programme (N2PHY)

Main field of studies	*Specialization*
Physics	A1N, Second cycle, has only first-cycle course/s as entry requirements

Entry requirements

A Bachelor's degree in Physics or equivalent, including 30 credits mathematics (including linear algebra and analysis) as well as electromagnetism and quantum mechanics.

Applicants must prove their knowledge of English: English 6/English B from Swedish Upper Secondary School or the equivalent level of an internationally recognized test, for example TOEFL, IELTS.

Learning outcomes

As a continuation of the introductory quantum mechanics courses, this course aims at providing the students with a firm, deeper knowledge of nonrelativistic quantum

mechanics, at demonstrating the power of quantum mechanics to describe microscopic phenomena, and at introducing the students to contemporary applications. The course will start with a brief review of the foundations of quantum mechanics and will then continue with powerful techniques to study the behaviour of single-particle or few-particle quantum systems. The course will gradually move towards more complex systems, eventually leading to second quantization and a description of spontaneous and stimulated emission of light. These concepts will be illustrated by examples from modern technology, including a guest lecture on quantum information and quantum computing. In this way, the course will help preparing the students for courses in, for example, condensed matter physics, quantum field theory, or spectroscopy.

On successful completion of the course the student will be able to:

- Explain the basic principles of quantum mechanics;
- Describe the dynamics of quantum-mechanical systems in the Schrödinger, Heisenberg, and interaction pictures;
- Explain the correspondence principle and how classical mechanics relates to quantum mechanics;
- Use the WKB approximation;
- Apply scattering theory to calculate the cross section of quantum particles interacting with a potential, another particle, or a crystal;
- Describe how to model particles in a magnetic field and use this to explain the Zeeman and the Aharonov-Bohm effect;
- Understand the concept of the density operator and apply it to describe ensembles and open systems;
- Describe and explain second quantization and apply it to lattice vibrations (phonons) and the electromagnetic field (photons);
- Use the concepts developed in the course to describe the phenomena of spontaneous and stimulated emission;
- Discuss the basic principles of quantum information and quantum computing;
- Read scientific literature on the above topics.

Course content

- Brief review of Dirac notation; noncommuting observables; representations
- Quantum dynamics: the Schrödinger, Heisenberg, and interaction pictures
- Correspondence principle, Ehrenfest's theorem; hidden variables, Bell inequalities
- WKB approximation
- Scattering theory
- Charged particles in a magnetic field, Zeeman effect, Aharonov-Bohm effect
- Density operator, pure and mixed states, ensembles and open systems
- Second quantization
- Radiative transitions; spontaneous and stimulated emission; Rabi oscillations

- Quantum information; entanglement; no-clone theorem; quantum computing

Form of teaching

The course will consist of lectures, problem-solving sessions, and guest lectures. Attendance at the guest lectures is compulsory.

Language of instruction: English

Assessment

Students will be examined by way of compulsory assignments to be handed in during the course and a compulsory oral exam at the end of the course.

If a student, who has failed the same examined element on two occasions, wishes to change examiner before the next examination session, such a request is to be submitted to the department in writing and granted unless there are special reasons to the contrary (Chapter 6, Section 22 of Higher Education Ordinance).

In the event that a course has ceased or undergone major changes, students are to be guaranteed at least three examination sessions (including the ordinary examination session) over a period of at least one year, though at most two years after the course has ceased/been changed. The same applies to work experience and VFU, although this is restricted to just one additional examination session.

Grades

The grading scale comprises: Pass with Distinction (VG), Pass (G) and Fail (U). Grade VG requires VG on both on assignments and exam.

Course evaluation

The results of and possible changes to the course will be shared with students who participated in the evaluation and students who are starting the course.