Faculty of Science

FYSN37, Physics: Quantum Many-particle Physics in Solids, 7.5 credits

Fysik: Kvantmångpartikelfysik i fasta ämnen , 7,5 högskolepoäng

Second Cycle / Avancerad nivå

Details of approval

The syllabus was approved by The Education Board of Faculty of Science on 2024-12-04. The syllabus comes into effect 2024-12-04 and is valid from the autumn semester 2025.

General information

The course is an elective course at advanced level for a Master's or Bachelor's degree in physics. It can also be taken as a stand-alone course.

Language of instruction: English

Main field of study	*Specialisation*
Physics	A1F, Second cycle, has second-cycle course/s as entry requirements

Learning outcomes

The overall goal of the course is that upon completion, the student should have acquired knowledge of how the electrical, magnetic and optical properties of solid materials depend on the electron distribution. The quantum mechanical treatment is based on the interaction of electrons both with the crystal lattice and with other electrons. The course introduces the most common approximations for this complex multi-particle problem and shows how they are practically applied.

Knowledge and understanding

After completing the course the student shall be able to:

- explain the concepts of exchange and correlation energy
- describe the basic concepts behind density functional theory
- explain the idea behind Green's functions in quantum many-body theory

- explain practical applications of the theoretical methods and models used for a quantitative description of the electronic structure of crystalline materials.

Competence and skills

After completing the course the student shall be able to:

- apply learnt methods to the specific research problems addressed in the course.

Judgement and approach

After completing the course the student shall be able to:

- discuss the main content of original scientific papers in the subject area of the course.

Course content

The course consists of the following elements:

1. Review of many-particle theory with the occupation number representation.
2. Mean field theory: Hartee-Fock theory
3. Explanation of the relevance of single-particle equations and of the concepts of exchange and correlation.
4. The main concepts of density functional theory for ground state properties of molecules and solids. Description of the simplest approximations and their quality.
5. The concepts of quasiparticles and their self-energies are reviewed and used to describe photoemission. Simple approximations for self-energies are presented and we discuss the accuracy of the approximations.
6. Different methods for solving single-particle equations are used, such as:

- Bloch's theorem, reciprocal space.
- Plane waves and pseudopotentials.
- Linear methods for the band problem, mainly LAPW and LMTO methods.
- Slater-Koster tight-binding method.

Course design

The teaching consists of lectures, mandatory assignments and a mandatory independent project work.

Assessment

Examination is oral in the form of an exam at the end of the course and in writing in the form of assignments and project reports during the course. The oral examination also aims to verify the independence of the written elements.

For students who do not pass the regular examination, an additional examination is offered in close connection to this.

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.

Grades

Grading scale includes the grades: Fail, Pass, Pass with distinction
A passing grade for the entire course requires a passed exam, passed assignments and a passed project report.

Maximum number of points for each examining part:
Examination = 60 points
Assignments = 20 points
Project report = 20 points

At least half of the maximum number of points for each component is required to pass. The final grade is determined by weighing the results of the components included in the examination, where at least 80 points gives a Pass with distinction.

Entry requirements

Admission to the course requires 90 credits in science including knowledge equivalent to FYSN27 Quantum Mechanics (7.5 credits, where the course must be started but not necessarily completed) and FYSC23 Solid State Physics (7.5 credits), or equivalent. General entry requirements and English 6/B.

Further information

The course replaces FYST27 Physics: Electron Structure Theory, 7.5 credits and cannot be credited in a degree together with this course.

The course is given at the Department of Physics, Lund University.