DEPARTMENT OF PHYSICS

FYP330 Solid State Physics, 7.5 credits

Fasta tillståndets fysik, 7,5 högskolepoäng

First Cycle

Confirmation

This course syllabus was confirmed by Department of Physics on 2017-08-08 and was last revised on 2023-06-07 to be valid from 2023-08-28, autumn semester of 2023.

Field of education: Science 100%

Department: Department of Physics

Position in the educational system

The course is included in the Bachelor of Science in Physics and is also given as a freestanding course.

Advanced course in the main subject physics.

The course can be part of the following programme: 1) Bachelor of Science in Physics (N1FYS)

Main field of studies	*Specialization*
Physics	G2F, First cycle, has at least 60 credits in first-cycle course/s as entry requirements

Entry requirements

For admission to the course, completed courses are required from the first four semesters of Bachelor of Science in Physics, or that the equivalent knowledge has been acquired in a different way.

Learning outcomes

After having gone through the course Solid State Physics the student is expected to be able to:

Knowledge and understanding

- describe and explain the concepts of crystal structures and their unit cells, reciprocal lattices, Brillouin zones, and other relevant parameters and also how they can be determined experimentally;
- explain the principle difference between x-ray, neutron, and electron diffraction;
- explain the vibrational modes in crystals in terms of the simple spring-ball model, their quantisation and also how they contribute to the heat capacity;
- be able to explain the difference between acoustic and optical phonons;
- describe the basic aspects of the free electron gas and in a weak periodic potential, the band structure of crystals, boundary conditions for semiconductors and related aspects such as electrons/holes and their effective mass;
- explain the concepts Fermi sphere, Fermi surface, Fermi wave vector, Fermi energy, and Fermi temperature;
- describe how the Fermi surface is related to the band structure;
- describe the effect of electromagnetic fields through the Drude model for the complex conductivity and how this is related to the DC conductivity, reflectivity, refractive index, and plasma oscillations;
- be able to give a simple explanation for the color of different metals;
- describe the basic difference between metals and semiconductors / insulators using the band structure;
- explain the meaning of the Bloch theorem for electrons in a periodic potential, and the term crystal momentum;
- describe the basic physics of a semiconductor, with direct or indirect band gap, intrinsic or doped;
- explain the concepts of conduction and valence bands, and the description of the electrons in the valence band in terms of holes, effective mass of bands, mobility concept, as well as the exponential temperature dependence of conductivity;
- describe the Hall effect and how this is related to the type of charge carriers;
- give a brief overview of different experimental methods for material characterisation, which the students will use during the practical lab sessions;

Competence and skills

- mathematically describe and define a unit cell, a primitive unit cell and the Wigner-Seitz cell in different crystal structures;
- define planes in crystal structures and their corresponding Miller indices;
- determine and calculate lattice parameters of crystal structures, and also describe how they can be determined by diffraction;
- calculate the reciprocal lattice of a crystal;
- calculate the structure factor for different types of structures;
- calculate the vibrational modes in crystals in the simple spring-ball model;
- calculate the basic properties of the free electron gas as given by the Fermi-Dirac

distribution of a particle in a box or with periodic boundary conditions;
- calculate the density of states depending on energy spectra and dimensionality;
- derive the band structure in a weak periodic potential from the empty lattice model, and using the tight-binding model for simple lattices;
- calculate the chemical potential and the electron / hole density for intrinsic or doped semiconductors;
- use the equation of motion of a Bloch electron and how this is related to the concept of effective mass;
- qualitatively derive the Fermi surface of a weak periodic potential;

Judgement and approach
- have obtained an insight in how similar types of simplified models and concepts can be applied to seemingly different phenomena (electrons, holes, bandstructures, phonons, elementary excitations, quasiparticles,...);
- have a realized the usefulness and need for a complementary description of phenomena wave vector space.

Course content

The course provides an overview of the physical properties of solids, experimental methods used to explore them and how properties are explained on the basis of theoretical models at a microscopic level.

The course begins by describing how atoms are arranged in crystalline substances and how the order can be determined by diffraction of incident radiation (x-rays, electrons, neutrons) or via direct imaging methods. In the description of diffraction the reciprocal lattice is introduced, as an essential concept for the understanding of many of the properties of crystalline substances.

Next, vibrational waves and thermal properties derived from these are treated.

The course then continues to discuss electronic properties (conductivity, optical reflectivity, plasma oscillations, Landau levels, the Hall voltage), starting first from the free electron model and thereafter, starting from a description of an electron in a periodic potential (band structure, optical excitations, effective mass, holes). An important application is intrinsic and doped semiconductors.

Different aspects of the contents are treated in three sub-courses.

Sub-courses

1. **Solid State Physics** *(Fasta tillståndets fysik),* 4.5 credits
   Grading scale: Pass with Distinction (VG), Pass (G) and Fail (U)
2. **Laboratory sessions** *(Laborationer),* 1.5 credits
   Grading scale: Pass (G) and Fail (U)

3. **Project** *(Projekt),* 1.5 credits
   Grading scale: Pass (G) and Fail (U)

Form of teaching

Sub-course 1 includes lectures, exercises, OpenTA tasks, a "dugga" and a written exam. The lectures highlight the most important aspects of solid state physics and include examples of how the knowledge is applied in different contexts. The exercises provide further examples. The Open TA tasks support the work with continuous learning during the course, and the "dugga" provides a check about halfway through the course. The excercises of the "dugga" are representative of those of the part the final written exam covering the first half of the course.

Sub-course 2 comprises four compulsory laboratory sessions providing practical experience of analytical methods for determining material structure and properties.

Sub-course 3 consists of a project.

Language of instruction: Swedish

Assessment

Sub-course 1 has a written exam, consisting of problem solving and descriptive tasks. The course includes a voluntary "dugga" and online home problems that give bonus points for the exam (grading scale: U, G, VG).

Sub-course 2: A pass grade requires active participation in all laboratory sessions. Active participation is assessed on an individual basis by the responsible teacher present during the laboratory session (grading scale: U,G).

Sub-course 3: written and/or oral project presentation (grading scale: U,G).

Grades

The grading scale comprises: Pass with Distinction (VG), Pass (G) and Fail (U).
Pass (G) on the entire course requires Pass (G) grades on sub-course 1, sub-course 2 and sub-course 3. Pass with Distinction (VG) on the entire course requires Pass with distinction on sub-course 1 and Pass (G) grades on sub-courses 2 and 3.

Course evaluation

A course evaluation should be arranged after the course has ended where all participating students are given the possibility to provide anonymous feedback via a course survey. The course responsible should, together with student representatives, discuss and assess the completed survey. Meeting notes should afterwards be made available via the university learning platform.