Subjects of the Final Examination
BME Faculty of Natural Sciences, Physicist MSc
Nanotechnology–Materials Science specialization

Fundamentals of Solid State Physics

1. Electronic structure and electron transport

The band structure of electrons, metals and semiconductors. Drude model to describe electronic conduction phenomena. Quasi-classical dynamics of Bloch electrons, description of transport by the Boltzmann equation. Temperature dependence of resistivity in metals. Transport phenomena on the nanoscale, relevant length scales. Landauer formula, quantized conductivity. Electronic heat conduction, Seebeck effect, Peltier effect.

2. Fundamentals of semiconductor physics

Basic properties of semiconductors, band structure, thermally excited charge carriers, chemical potential, carrier density at finite temperature. Doped semiconductors, donor and acceptor states, temperature-dependent behavior.

3. Semiconductor devices

Semiconductor devices for electronics: Schottky barrier and Schottky barrier diode, p–n junction, Zener diode, Esaki diode, bipolar and field effect transistor, flash memory. Semiconductor devices for optronics: laser diode, light-emitting diode (LED), solar cell, blue LED.

4. Fundamentals and applications of magnetism

Magnetic moment of atoms, orbital and spin moment, Hund's rules. Mean field theory of ferromagnetism, exchange interaction. Spintronics: giant magnetoresistance (GMR) phenomenon, spin valve. Magnetic sensors. Spin-qubit, ESR.

Modern Methods of Material Testing and Nanofabrication

5. Modern microscopy methods

Scanning probe methods: scanning tunneling and atomic force microscopy. Electron microscopy: scanning and transmission electron microscope.

6. Nanostructures in electronics, modern nanofabrication methods

Top-down fabrication of semiconductor devices and nanostructures: electron beam, optical and soft lithography, layer growth methods. Band engineering, two-dimensional electron gas, HEMT, Moore's law, CMOS, MOSFET, 3D tri-gate transistor. Micro-electromechanical systems. Bottom-up methods, self-assembling systems.

7. Optical investigation of electron structure and vibration properties

Optical response of atoms, metals, semiconductors and insulators. Interaction of light with molecular and lattice vibrations. Design and operation of infrared and Raman spectrometers.

8. Surface and structure analysis methods

SIMS, SNMS, XPS és AES methods. Their operation principle, surface sensitivity, and the information they provide.
Techniques combined with microscopy: EDS, EBD, EELS. Structure analysis by X-ray diffraction.

The exam consists of the presentation of two subtitles, one from section *Fundamentals of Solid State Physics* and one from section *Modern Methods of Material Testing and Nanofabrication*, given by the examination committee (e.g. "*Quasi-classical dynamics of Bloch electrons, description* *of transport by Boltzmann equation*" + "*Scanning probe methods: scanning tunneling and atomic force microscopy*").

The following Physics BSc courses at BME form a good basis for section *Fundamentals of Solid State Physics*: *Introduction to Solid State Physics* (BMETE11AF05), *Applied Solid State Physics* (BMETE11AF11)/*Theoretical Solid State Physics* (BMETE11AF34). While not required for the final exam, you may earn further insight into this subject by attending the following elective Physicist MSc courses: *Physics of Semiconductors* (BMETE11MF26), *Fundamentals of Nanophysics* (BMETE11MF37) and *Theory of Magnetism* (BMETE11MF44).

Section *Modern Methods of Material Testing and Nanofabrication* is based on the Physics BSc course *Nanotechnology and Materials Science* (BMETE11MF36). While not required for the final exam, you may earn further insight into this subject by attending the following elective Physicist MSc courses: *Optical Spectroscopy in Materials Science* (BMETE11MF39) and *Microtechnology and Nanotechnology* (BMETE12AF33).

A significant part of the final examination is the defense of the diploma thesis. The defense consists of a presentation delivered by the student about her/his results covering the fundamentals of the physics of the research field, which is followed by a detailed discussion with questions targeting both the results presented and the fundamental physics on which the research is based. The aim of this is to enable the examination committee to assess the student’s general knowledge about her/his research field including its theoretical groundings, which will be reflected in the final mark.