PhD COMPREHENSIVE EXAMINATION
CONDENSED MATTER PHYSICS SYLLABUS

1. Electrons in solids

Bloch theorem, electronic band structure, metals and semiconductors. Wave packet, quasiclassical dynamics, effective mass.

Ballistic transport, quantized conductance. Mesoscopic transport, Landauer formalism. Macroscopic transport: Boltzmann equation, relaxation time approximation.

2. Semiconductors

Bond structure and band structure of semiconductor crystals. Doping, impurity levels. Transport in pure and doped semiconductors.

Band gaps, band engineering. Two-dimensional electron gas. Quantum Hall effect. Level structure of quantum dots, single-electron transistor.

Modern semiconductor devices: MOSFET, Flash memory, semiconductor laser.

3. Magnetism

Landau levels, magnetic oscillations, experimental determination of the Fermi surface. Magnetic susceptibility of conduction electrons, Stoner enhancement.

Hund’s rules, interaction of magnetic moments in crystal structures, lattice models of magnetism, magnetic ordering. Heisenberg model, ferromagnetism.

Interpretation of ferromagnetism in the band picture, spin-polarized electronic states, spintronics. Magnetic resonance: NMR, ESR.

4. Superconductivity

Phenomenological description of type-I and type-II superconductors. Cooper pairs, BCS theory, macroscopic quantum state. Flux quantization, Josephson effect, SQUID.

Superconducting vortices, Ginzburg–Landau theory of type-II superconductors. High-temperature superconductors, applications of superconductivity.

5. Material characterization methods

Structural characterization by diffraction methods. Electron microscopy (TEM, SEM, electron-beam lithography).

Scanning probe methods (AFM, STM).

Optical investigation of the electronic structure and vibrational modes (Raman and optical spectroscopy, angle-resolved photoemission spectroscopy). Surface analytical methods (SIMS, XPS, AES).