

Solid State Physics

S. Art yukhin (IIT)

Part 1. Basics of solid state theory

- Brief overview of main concepts and tools in Quantum Mechanics. Particle in a box, harmonic oscillator, hydrogen atom, dimer. Bonding and antibonding states. Symmetry and invariants. Representation theory. Perturbation theory. Semiclassical approximation. Tunneling under the barrier.
- Crystalline solids - elastic properties. Strain. Phonons, heat capacity. Dynamical matrix. Polar instability, phase transitions, ferroelectricity, piezoelectricity, LO-TO splitting. Landau theory of phase transitions. Mean-field approximation. Critical exponents. Domain structure.
- Electrons in crystals. Crystal field splitting. Band structure, weak coupling, tight-binding. Band metals and insulators. Optical properties on semiconductors, Lindhard function, excitons. Fermi Liquid, Electron-phonon interactions. Superconductivity. Fermi surface. Nesting, Pierls instability, charge density wave state. Density functional theory.

Part 2. electronic interactions and emergent phenomena

- Transition metal ions, Coulomb repulsion on narrow orbitals, Hubbard model, Hund exchange. Mott transition. Dynamical mean-field theory. Photoemission spectroscopy. Heavy fermions. Kondo effect. Stoner instability. Magnetism.
- Magnetic insulators. Heisenberg exchange. Spin-orbit coupling, weak ferromagnetism, magnetic anisotropy, anisotropic exchange. Domain structures. Magnetization switching, domain wall motion. Spin currents. Spintronics.
- Frustrated magnetism. Spiral states and skyrmions. Spin ice. Spin liquid states, resonating valence bonds and valence bond solid states. Breaking of inversion symmetry by magnetism. Exchange striction, multiferroics.