

Condensed Matter Physics - Electronic Properties of Solids

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Synopsis and reading material

Aims; to introduce the electronic properties of solid matter, building on the earlier Part A courses on quantum mechanics, atomic physics and statistical mechanics.

Objectives; to understand basic ideas about band structure and the electrical and magnetic properties of solids. After careful study of the material in the lectures, together with practice in problem-solving for the associated tutorials, the student should achieve a broad competence in the subjects covered, and be able to apply it to the solution of problems such as those in the condensed matter physics questions in Paper B2 of Finals.

Suggested texts:

Core textbooks:

'Solid State Physics' J.R. Hook and H.E. Hall (Wiley)

'Introduction to Solid State Physics' C. Kittel (Wiley),

'The Solid State' H.M. Rosenberg (OUP)

Additional material can be found in more advanced books such as:

'Solid State Physics' N.W. Ashcroft and N. Mermin (Saunders)

'Solid State Physics' G. Burns (Academic)

'Solid State Physics' H. Ibach and H. Luth (Springer)

'Band Theory and Electronic Properties of Solids' J. Singleton (OUP)

Lecture Synopsis:

Lectures 1-3: Free electron theory of metals.

Free electron approximation, densities of states, concept of Fermi energy and the Fermi surface. Fermi energies and Fermi surfaces for typical metals. Free electron description of Heat Capacity and Pauli paramagnetism.

Electron transport - simple expressions for electrical and thermal conductivity, and Hall effect. Simple description of scattering processes. Summary of successes and failure of Free electron model.

Lectures 4-7: Band structure.

Nearly free electron approximation. Simple treatment of scattering by one reciprocal lattice vector leading to appearance of band gap at Brillouin Zone boundary. Discussion of dispersion relations and reduced and extended zone schemes. Inclusion of multiple scattering and generalization to Bloch Theorem and its consequences. Number of states per Zone and relation to the formation of a 1-D metal. Fermi surfaces for monovalent and divalent metals in 2-D. Divalent Semiconductors and Insulators.

Covalent bonding, exchange interactions and Hydrogen model. Tight binding model with two and four electrons per atom. Description of silicon and other group IV elements.

Lectures 8-11: Semiconductors.

Typical semiconductor Band structures. Optical absorption and the concept of direct and indirect semiconductors. Concept of holes, definition and meaning of effective mass. Expressions for concentrations of electrons and holes as a function of temperature and Law of Mass Action.

Doping of semiconductors, concept of Donor and Acceptor impurities, intrinsic and extrinsic semiconductors. Carrier density and conductivity of semiconductors. Simple description of p-n junction and rectification. Introduction to semiconductor heterostructures and quantum wells.

Lectures 12-14: Magnetic properties.

Magnetic Energy, permeability and susceptibility. Diamagnetism. Paramagnetism, Curie's Law and Brillouin function. Magnetic resonance measurements - EPR and NMR. Magnetic cooling.

Collective magnetism, interactions between spins -ferromagnetic and antiferromagnetic exchange. Molecular Field model and Curie-Weiss Law. Band model of ferromagnetism. Magnetisation, domains and domain boundaries. Simple ideas of antiferromagnetism.

Lectures 15-16: Superconductivity.

Basic facts and systematics. Critical Field and Meissner Effect. Surface currents. Evidence for superconducting energy gap. Simple picture of superconducting tunnelling. Qualitative ideas of BCS theory, Cooper pairs and coherence, Flux quantisation.

Type II superconductors, High T_c materials and formation of flux vortices.