PHYS421

Advanced Solid State Physics (Magnetism) and Elements of Nanophysics

I. Elements of theory of magnetism. Magnetic field, magnetic induction, magnetic vector potential. Magnetic field of magnetic dipole moment. Phenomenology of solid state magnetic phenomena: paramagnetism (Curie law), diamagnetism. Van Fleck's description of diamagnetism, diamagnetism as quantum phenomenon.

II. Ferromagnetism and antiferromagnetism. Ferromagnetic exchange and the Heisenberg model, self-consistent mean field theory description of ferromagnetic phase transitions, Curie temperature. Elements of Gizburg-Landau theory of magnetic phase transitions. Domains and domain walls. Ferromagnetic insulators and metals. Magnetic memory devices and readheads. Multilayers of normal and ferromagnetic metals, giant magneto-resistance phenomenon and its application.

III. Two-dimensional electron systems: heterostructures, quantum wells, field-effect transistors, graphene. Conductivity and resistivity. Drude formula for conductivity and the Einstein relation. Electron scattering and role of disorder. Screening of impurities in metals. Friedel oscillations of electron density around impurities.

IV. Quantum transport in disordered low-dimensional electron systems: interference and the enhanced backscattering of waves in disordered media, localisation effect in two- and one-dimensional electron systems. Universal conductance fluctuations in small phase-coherent conductors. The Aharonov-Bohm effect in small ('mesoscopic') metallic and semiconductor rings.

IV. E-beam and optical lithographies. Semiconductor quantum wires (1D subbands in quantum wires). Carbon nanotube as an ideal one-dimensional conductor. Ballistic wires in semiconductors structures and the conductance quantum, e^2/h. The Buttiker-Landauer conductance formula. Impurities in quantum wires. Electronic transport in a magnetic field, Hall effect. Skipping orbits and electron focusing. Landau levels. Edge states of Landau level as ideal one-dimensional conductors. Quantum Hall effect and its relevance for metrology.

VI. Metallic point contacts. The point-contact spectroscopy of the electron-phonon interaction. Atomic break-junctions and the scanning tunnelling microscope. Examples of applications of scanning tunnelling microscopy.

VII. Semiconductor quantum dots. Resonance tunnelling phenomenon. The Coulomb blockade phenomenon.

Slides: www.lancs.ac.uk/users/esqn/phys421/

Books:

C. Kittel, *Introduction to Solid State Physics*, Wiley (any edition); Chapters on magnetism

S. Datta, *Electronic Transport in Mesoscopic Systems*, Cambridge UP (any edition)
ISBN 0 521 59943 1; Chapters 1,2,4,5,6.