PHYS421 academic year 2010/2011

Advanced Solid State Physics (Magnetism) and Elements of Nanophysics

1. 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 of insulators (Curie law), paramagnetic susceptibility due to the electron spin, Pauli spin susceptibility of metals. Diamagnetism, van Fleck's description of diamagnetism, diamagnetism as quantum phenomenon.

2. 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. Multilayers of normal and ferromagnetic metals, giant magneto-resistance phenomenon and its application. Magnetic memory devices.

3. Two-dimensional electron systems: field-effect transistor, heterostructures, quantum wells. Conductivity and resistivity. Drude formula for conductivity and the Einstein relation. Electron scattering and role of disorder. Electronic transport in a magnetic field, Hall effect.

4. E-beam and optical lithography, surface processing with an AFM tip as methods to produce semiconductor quantum wires (1D subbands in quantum wires). Split-gate structures. Ballistic wires in semiconductors structures and the conductance quantum, e^2/h. The Buttiker-Landauer formula for the two-terminal conductance.

5. Skipping orbits and electron focusing in ballistic 2DEG in a magnetic field. Landau levels and edge states of Landau levels. The quantum Hall effect and the quantum resistance standard.

6. Graphene: a truly two-dimensional crystal. Graphene manufacturing, electronic band structure, and applications.STM and electronic transport studies of graphene. Carbon nanotubes.

7. Metallic point contacts and atomic break-junctions. The scanning tunnelling microscope (STM). Examples of applications of scanning tunnelling microscopy. Screening of impurities in metals; Friedel oscillations.

8. The resonance tunnelling phenomenon in double-barrier structures. Quantum dots. The Coulomb blockade phenomenon in quantum dots and the single-electron transistor (SET). Coulomb blockade and the parity effect in quantum dots of a superconducting metal.

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

Books:

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

T. Heinzel, *Mesoscopic Electronics in Solid State Nanostructures*, Wiley-VCH, ISBN 3-537-40375-2

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