PH501 Solid State Physics

Credit: (3-0-0-3) Approval: Approved in 2nd Senate

Prerequisites: Quantum Mechanics

Students intended for: B.Tech

Elective or Core: Elective Semester: Odd/Even

Course objective:

This is the story of nearly free electrons in a solid: why and how we need quantum mechanics to understand condensed matter. With it, one discovers new physics beyond our classical intuitions. Most of electronics, spintronics and quantum devices are based on these fascinating realizations of quantum mechanics of electrons in condensed matter.

Course content:

- Crystal structure, Brillouin zone [2 Lectures]
- Quantum mechanics of electrons in a solid: Electronic degrees of freedom: *from a single atom to N atoms*, "Free" electron description – *why should it ever work*?, "Independent" electron description – *existence of a Fermi surface*, Electron bands: *metal, semiconductor and insulator*, Quantum well, dot, wire, nanotube. [6 Lectures]
- Electron Transport: Electrons in a field, Boltzmann transport, Quantum of conductance, Meaning of Ohm's law, coherent transport, From atoms to quantum devices. [6 Lectures]
- Phonons: Vibrations of crystals with monoatomic basis, Two atoms per primitive basis, Quantisation of elastic waves, Phonon Momentum [3 Lectures]
- Magnetism: A macroscopic quantum phenomenon, Magnetic coupling of electrons: *Para, Ferro and Diamagnets*, Curie's Law, Pauli Paramagnetism, Curie-Weiss theory, No classical analogue: *Bohr van Leueen theorem*, Magnetic interactions: *long range order, magnetic excitations*, Spintronics applications: *using itinerant electron spin for transport* - a *new paradigm, new electronic materials, GMR and CMR*

  [10 Lectures]
- Superconductivity: Basic phenomena, Meissner effect, London equation, Towards a pairing mechanism: *Cooper problem, BCS theory, experimental verification*, Type II superconductors

  [10 Lectures]
- Two dimensional electron gas in a FET, IQHE: MOSFET configuration: *2D electron confinement*, Electrons in a magnetic field: *Landau levels*, Hall effect: *the quantized version*.

  [5 Lectures]

Note: Experimental techniques associated with each chapter shall also be covered

Text Book

1. Solid State Physics, Ashcroft & Mermin (Cengage learning - Indian Edition)
2. Condensed Matter Physics in a Nutshell, G. D. Mahan (Princeton University Press)
3. Quantum Theory of Solids, Charles Kittel (Wiley)

References

1. Quantum Hall effect, A. H. MacDonald (Kluwer Academic)
2. Introduction to the theory of the integer quantum Hall Effect, Martin Janssen, JánosHajdú (VCH)
3. Physics of Semiconductor Devices, S.M. Szeandkwok K. Nag