Outline :
Condensed Matter Physics-1

Instructors : Chandan Dasgupta and Subhro Bhattacharjee

Semester: January-April 2020 at ICTS,
Class Timings : *to be decided.*
First organisational meeting: 2/1/2020 at 3:15 PM, Chern Lecture Hall ICTS

Helpful Prerequisites

Quantum Mechanics II, Statistical Mechanics I.

Tentative Topics

1. **Topic 0 : Introduction to quantum condensed matter (3 lectures)**
   (a) What is this course about ?
   (b) Recap of the idea of identical quantum particles
   (c) Recap of application symmetries in quantum systems
   (d) Basic types of condensed matter experiments–
      (1) Measuring thermodynamic properties
      (2) Measuring transport properties.
      (3) Scattering experiments and correlations.
   (e) Elements of second quantization
2. **Topic 1 : Electron Gas (6 lectures)**
   (a) Jelium Model of electrons
   (b) Drude and Somerfeld theory of electrons
      (1) Ohm's law and conductivity
      (2) Hall effect and Hall coefficient
   (c) Boltzmann equation and idea of linear response
   (d) Coulomb interactions among electrons

(e) Hartree-Fock theory of interacting electrons and the idea of quasi-particles and their lifetime.

(f) Screening on interactions

(g) Phenomenological theory of fermi liquids

3. **Topic 2 : Lattice (6 lectures)**

(a) Crystallisation as spontaneous symmetry breaking

(b) Description of a crystal

(1) Bravais lattice and description of crystal in real space

(2) Reciprocal lattice and description of crystal in momentum space

(c) Experimental detection of crystal through X-ray diffraction

(d) Lattice vibrations

(1) Phonons as goldstone modes

(2) Harmonic theory of phonons

(3) Bloch theorem and Bloch states

(4) Detecting phonons in inelastic scattering experiments

(5) Raman and Infrared spectroscopy

(6) Anharmonic effects and thermal expansions

(e) Theory of elasticity

4. **Topic 3 : Electrons in crystalline solids (6 lectures)**

(a) Electron orbitals

(1) Atomic orbitals and periodic table

(2) Spin-Orbit coupling

(3) Hund's rules

(4) Crystal fields

(b) Hopping of electrons on a lattice

(1) Tight-binding models

(2) Role of symmetries

(3) Electron band structure

(4) Wanniner Orbitals

(5) Band Insulators, Band metals and semi metals

(6) Fermi surfaces

(7) Magnetic oscillations

(8) Graphene

(c) Semiclassical Dynamics of electrons

(d) Conductivity in metals

(e) Umpklapp scattering

(f) Electromagnetic response of electrons in a solid

(1) Dielectric properties

(2) Plasmons

5. **Topic 4 : Magnetism (4 lectures)**

(a) Origin of magnetism

(1) Single spin in a magnetic field as a model of dilute paramagnet

(2) Different contributions to magnetism in a material

(3) Magnetic susceptibility

(4) Neutron scattering

(b) Magnetic insulators

(1) Spin model and their origin

(2) Spin rotation symmetry breaking and magnetic orders– Ferromagnetism, Antiferromagnetism.

(3) spin waves

(4) Curie-Weiss Mean field theory (Ising Model)

(5) Toric code as example of topological order

6. **Topic 5 : Superconductivity (4 lectures)**

(a) What is superconductivity ?

(b) Electron-phonon interactions and Cooper instability

(c) Cooper pairs

(d) Landau theory of superconductivity

(e) Electromagnetic response of a superconductor

(1) Meissner effect

(2) Josephson effect

Grading

1. **Assignments (30 %) :** Typically one assignment every 2 weeks.
2. **Midsemester Exam (30 %)**
3. **End semester Exam (40 %)**