

Department of Physics

Indian Institute of Technology Kanpur

Course Title: Introduction to Quantum Materials

Course Number: PHY302

Course Units: 3-0-0-0 (9)

Course Instructor: Chanchal Sow

Prerequisite: Knowledge of Quantum Mechanics [PHY204/PSO201A]

Course Objective:

The course, targeted towards undergraduates, will open a window to understanding materials around us that are important for science and technology. The course will introduce students to a variety of ideas in understanding different phases of matter – free electrons as in for metals, band theory for semiconductors, and will provide a basic understanding of their electrical and magnetic properties. This course will prepare the students well for the advanced courses and also guide them to see the quantum world around us.

Syllabus:

Overview: Scales and symmetries in physics, Bird's eye view of quantum materials around us, Brief Review of Quantum Mechanics, and Thermal Physics. Metals, Semiconductors, and Insulators: Free Electron Gas (Metals, fermi surface, density of states), Thermal and Mechanical Properties of metals and alloys, Lattices and Brillouin Zone, Brief Introduction to XRD, Electrons in Periodic Potentials, Bloch Theorem and Energy Bands in One Dimension, Insulators/semiconductors around us and their band structures, Concept of holes. Magnetism: Electron Spin and its Magnetic Moment, Exchange Energy and Hund's Rules, Dia and Paramagnetism (Larmor, Curie, Pauli), Ferromagnetism, Spin glass. Transport: Drude theory, Lorenz Number, Wiederman-Franz, Characteristic Length Scales in Different type of transport mechanism in materials. Crystal Vibrations: Introduction to Normal Modes, Acoustic Phonons and Specific Heat. Exotic/Emergent Phenomena in Quantum Materials: Spintronics, Superconductivity, Mott Transition, topological phases etc., Applications of Quantum Materials. State of the Art Experimental Methods.

References: Class notes of this course.

Suggested readings:

- (i) Solid State Basics, by Steven H. Simons. (ii) Solid State Physics, by Charles Kittel.
- (iii) Introduction to Quantum Mechanics, by DJ Griffiths.

Grading scheme:

Quiz (20%), Assignments (20%), Mid-Sem Examination (30%), Final Examination (30%).

Grading will be relative.

Assignment/ Exam/ Attendance Policy:

In Assignments: Participants are welcome to discuss among each other and refer to literature. Due credit should be provided in terms of references/people discussed with, when submitting the assignment. Copying an assignment from a colleague – will be penalized. Students may be asked to present their answers to assignment questions to the rest of the class, therefore please ensure you stand by your submitted scripts. In exams, any kind of malpractice will be severely penalized. Present examiner's discretion will be final in such instances. An attendance record will be maintained. Frequent casual absences/vegetative participation may be penalized, and/or sustained attendance with active participation may be rewarded. Exams/quizzes will *not be repeated* for absentees. Absence due to medical emergencies will be duly considered for re-examination, if informed with necessary documents through proper channel (DOAA).