Syllabus for PHYS 231: Introduction to Condensed Matter Physics

Prerequisites: basic knowledge of Quantum and Statistical Mechanics
This course covers electronic structure theory, and basic topics in solid state physics.
Lecture notes will be provided, the following textbooks are also recommended:
-*Quantum Theory of the Solid State* by Lev Kantorovich,
-*Condensed Matter Physics* by Michael Marder
Instructor: Keivan Esfarjani

- **Crystal structure and X-ray diffraction**
  Topics to be discussed: Crystal and reciprocal space, Brillouin zone, X-ray diffraction, structure factor and extinction rules.

- **Chemical bonding**
  Topics to be discussed: The simplest example: H_2^+, the tight-binding approximation, hybridization and covalent bonding, effect of overlap, eigenvectors and population analysis, charge transfer and ionic bonding, Jellium model and metallic bonding, Van der Waals bonding, cohesive energy of a solid.

- **Crystals: Bloch theorem and band structure methods**
  Topics to be discussed: Plane wave and LCAO formulation of Bloch theorem, Periodicity and gap openings, band structure methods, DOS, k-point sampling, thermodynamic properties of non-interacting Fermi systems.

- **Hartree and Hartree-Fock theories**
  Topics to be discussed: The variational approach, HF equations, Koopman theorem, ionization potential and electron affinity, chemical potential, chemical hardness and gap as derivatives of the total energy, shortcomings of HF, derivation of the exchange functional.

- **Density Functional Theory**
  Topics to be discussed: variational formulation, LDA.

- **Thomas-Fermi theory**
  Topics to be discussed: Kinetic energy functionals, finite temperature generalization, linear TF screening, linear response and Lindhard static susceptibility.

- **Self-consistent electronic structure methods of atoms, molecules and solids**

- **Vibrations in molecules and crystals**
  Topics to be discussed: Classical and quantum treatment, dynamical matrix and phonon spectrum, ZPE, acoustic and optical modes, thermodynamic properties, long wavelength limit and elasticity theory.

- **Transport theory**
  Topics to be discussed: Dynamics of electrons, Boltzmann equation, application to electrons and phonons, relaxation time approximation (RTA) from Fermi's Golden rule, Matthiessen's rule, thermoelectric effects, Drude model of transport and Einstein relations.