Phys 481/681 - Condensed Matter Physics - 3 credits

Bulletin Description:

Introduction to the physics of soft (macromolecular) condensed matter, composed of polymers, colloids, amphiphiles, and liquid crystals, and of hard (atomic) condensed matter, including metals, semiconductors, and superconductors, emphasizing phase transitions and materials properties (electrical, magnetic, optical, elastic). Prereq: PHYS 350

Course Objectives:

The main objective of the course is to develop the conceptual and quantitative methods that are critical for a working knowledge of soft and hard condensed materials. Building on an understanding of classical calculus-based physics at the level of PHYS 251-252 and quantum physics at the level of PHYS 350, the course develops the necessary formalisms of statistical mechanics, quantum mechanics, and continuum mechanics. Emphasis is placed on a quantitative description of condensed matter properties directly relevant to measurements and applications.

Content Listing:

<u>Part 1: Soft Condensed Matter</u>

- **Energy and forces:** length, time, and energy scales
- **Interactions:** covalent, non-covalent, electrostatic, van der Waals, steric inter-molecular interactions
- **Phase transitions:** free energy, entropy, binary mixing and separation, phase equilibrium
- **Colloids:** Stokes force, diffusion, Einstein relation, electrical double layer, DLVO theory
- **Polymers:** Gaussian polymers, stability of polymers, polymer solutions, polymer blends
- **Amphiphiles:** surfactants and lipids, bilayers, micelles, vesicles, biomembranes
- **Liquid Crystals:** nematic, smectic, columnar ordering; lyotropic and thermotropic materials
- **Self-assembly:** energy vs. entropy, critical aggregation concentration

<u>Part 2: Hard Condensed Matter</u>

- **Band structure:** free electron, periodic potential, energy band in crystals, Brillouin zones
- **Metals:** electrical conductivity, thermoelectric effect, galvanoelectric phenomena
- **Semiconductors:** carriers, Fermi energy, Hall effect, semiconductor devices, field effect transistors
- **Superconductors:** magnetic flux, Meisner effect, type I and type II, Cooper pairs, BCS theory
- **Optical properties:** free electrons with/without damping, dispersion relations, absorption and emission
- **Magnetism:** dia-, para-, ferro-, anti-ferro-, and ferri-magnetism, magnetic phase transitions
- **Thermal properties:** heat capacity, thermal conductivity, melting

If time permits, special topics may be included. Examples may include: biopolymers (DNA, RNA, proteins), dynamics in the cell, single-molecule biophysics.