PHY606A: Fundamentals of Soft Matter: Concepts and Methods

Instructor: Manas Khan

Course Description:

A) Objectives:

We encounter soft matter systems, *i.e.,* the systems that are soft and easily deformable in ambient temperature and pressure, everywhere around us. Starting from the building blocks of our body to most of the food we eat or drink and toiletries we use every day, all fall under the domain of soft matter. They possess many fascinating mechanical properties that are governed by intriguing physical phenomena. In the first half of this course, I will introduce you to fundamental concepts and their applications in understanding different soft matter systems or designing a soft material with desired properties. In the second half, I will discuss various experimental techniques commonly used to study soft matter systems and their working principles. These concepts will particularly be useful in pursuing soft matter research.

B) Contents:

Introduction to soft matter

- What is the soft condensed matter?
- Colloids, polymers, amphiphiles, liquid crystals
- Forces, energies, timescales

Brownian motion

- Equilibrium fluctuation properties
- Diffusion in simple fluids and Stokes' drag
- Fluctuation dissipation theorem

Colloids

- Colloidal dispersions
- Excluded volume, depletion interactions
- van der Waals attractions, electrostatics, ions, and DLVO
- Tunable colloids, active colloids and applications

Polymers

- Structure of maromolucules
- Random walks and relaxation dynamics
- Viscoelasticity

Surface and interface

- Surface tension, interfacial tension and capillary action
- Wetting
- Adhesion and friction
- Slip behavior

[Mid-sem Exam]

Microscopy Techniques

- Bright field, polarization, phase contrast microscopy
- Fluorescent microscopy
- Confocal microscopy
- Imaging, Image processing and particle tracking

Rheology

- Measuring stress-strain properties
- Different measurement geometries

Optical Micromanipulations

- Optical forces at different regimes
- Calibration of optical forces
- Measuring and applying forces using optical tweezers

Microrheology

- Passive microrheology
- Active Microrheology

[End-sem Exam/presentation]

C) Pre-requisites, if any: Basic statistical physics

D) Short summary:

This course will introduce the fundamental concepts of soft matter systems, their applications, and the relevant experimental techniques that can probe these systems. Starting with a basic introduction, i.e., what soft matters are, different types of soft materials and their characteristics and properties, and important phenomena that describe the equilibrium and non-equilibrium behavior of soft matter systems will be taught. Two such generic soft matter systems, namely, colloidal dispersions and polymer systems, will be discussed in particular. A few lectures on the surface and interfacial properties of liquids will conclude the first part of this course. In the second half, the working principles of some commonly used experimental techniques, such as microscopy, rheology, microrheology, and optical tweezers, will be discussed.

E) Reading materials:

Textbooks:

- "Soft Condensed Matter" by R.A.L. Jones
- "Soft Matter Physics" by M. Doi
- Additional topic-specific references will be shared with the class as and when required.

Reference:

- "Fundamentals of Soft Matter Science" by Linda S. Hirst

F) Grading policy:

- Quizzes/ assignments: 20%
- Mid-sem exam: 40%
- Final exam/ presentation: 40%