PHY 7560 Advanced Condensed Matter Physics: Soft Matter Fall 16

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Office hours: Th: 1:00pm – 3:00 pm, or by appointment

Lecture time and location: T & Th 6:00 pm – 7:25 pm, 177 Physics Building

Prerequisite: Thermodynamics

The course will introduce students to physics soft matter. It will be taught primarily for the graduate students. We will start with a discussion on the importance of thermal energy and Brownian motion at the molecular scale. After a brief detour to phase transition and critical phenomena, we will discuss some individual components of soft matter systems and advanced experimental as well as computational techniques. Towards the end, I hope to introduce students with more up-to-date topics, such as active fluids, pattern formation, stochastic dynamics, directed and programmable assembly, origami, etc.

Learning objectives:

- Get familiar with key theories describing structure and dynamics of soft matter.
- Calculate the strength and range of interactions between particles and extended surfaces.
- Be able to do back-of-the-envelope calculations to determine relevant length-scale, time-scale, and energy-scale associated with a system.
- Explain how starting from basic building blocks large scale structures are assembled either spontaneously or by external fields.
- Analyze and explain phase diagrams, force curves, static and dynamic structure factors, pair-correlation functions, rheology data, etc.
- Learn different experimental and computational methodologies used in soft matter research, their strengths and limitations.
- Read research articles, write a paper on a topic with the format of a paper, present a seminar, and answer questions from the audience.

Tentative Course Content:

[Many of the following topics are interrelated and I may not follow the particular order as given below. Some topics may not be covered due to time constraint.]

Overview of soft matter: Energies and forces, importance of thermal energy, Boltzmann factor, building blocks of soft matter, viscoelasticity, scale invariance.

Diffusion and Brownian motion: Random walk, diffusion equation, fluctuation-dissipation theorem and Stokes-Einstein equation, Brownian motion in a potential.

Phase transition and critical phenomena: Universality, power-laws, correlation length, van der Waals gas, Ising model, Landau theory.

Colloids and interfaces: What is a colloid? fundamental interactions, DLVO theory and

colloidal stability, electrophoresis and other electrokinetic phenomena, dynamics of colloids, colloids as model systems for liquids, crystals, and glasses, packing of hard spheres, self, directed, and programmable assembly of colloids.

Membrane biophysics: Langmuir films, phase behavior of Langmuir monolayers, energetics and thermodynamics of lipid self-assembly, membrane curvature, thermal fluctuations of membrane, Nerst potential.

Polymers: Scaling concepts, ideal chains and chains in good solvent, entropic elasticity, Flory theory, Rouse and Zimm dynamics, entanglements and importance of reptation, polyelectrolyte solutions, network and gels.

Experimental and computational methodologies: Scattering vs. microscopy, x-ray, neutron, and light, single-molecule techniques, pair correlation function, structure factor, optical and magnetic tweezer, rheology, main ideas and some examples of basic Monte Carlo, molecular dynamics, Brownian dynamics, and dissipative dynamics.

Non-equilibrium soft matter: Glasses: viscosity and relaxation times, dynamic heterogeneity, aging; Active matter: self-propelled colloids, molecular motors, actin self-assembly, bacterial motility.

GRADE DETERMINATION:

Two mid-term exams: In class written exam, open note. Dates to be announced in the class at least one week before the exam. Tentatively: Early October & middle of November.

Final Exam: It will consist of a term paper, 10-15 pages, single-spaced. You can choose your own topic, but it should not be too close to your research area. You must obtain approval from me before start working. I can also give you suggestion. You will give an oral presentation on your paper (15 minutes + 5 minute for Q & A). The oral part should follow the style of a seminar presentation. The written part will be graded based upon clarity of writing, depth of your research, and the originality of your thinking. You should select and start working on the term-paper within four weeks of the semester. Do not wait for the last minute. I will be available for comments on early drafts. All written reports will be checked at self-assign for plagiarism and credits will be deducted if any evidence of plagiarism is found.

Homework: There will be about 5 homework. They will be posted at the blackboard. They will involve problem solving and some kitchen-top experiment. Group work is encouraged.

Quiz: I will a short quiz in class at least once a week.

Grading:	Mid-terms	30%
	Final exam:	35%
	Homework:	15%
	In class participation and quiz:	20%

A: 85 – 100%; A-: 80– 84%
B: 65-79%
C: 50-64%
D: 40-49%
F: 0 – 39%

References: I will use a variety of sources and give you many hand-outs, which will be posted at the blackboard. It will be a good idea to develop a habit of good note-keeping. You will need it for the mid-term. Below is an incomplete list of references I plan to use:

1. R. A. L. Jones, Soft Condensed Matter, Oxford (2002).

2. J. N. Israelachvili, Intermolecular and surface forces, Academic, New York (1985).
3. S. A. Safran, Statistical Thermodynamics of Surfaces, Interfaces, and Membranes, Addison Wesley, New York (1994).
4. J. Dhont and G. Gompper, G. Nagele, D. Richter, and R. G. Winkler, Soft Matter, Springer (2008).
5. Rubinstein and Colby, Polymer Physics, Oxford (2003).
6. Philip Nelson, Biological Physics, W. H. Freeman (2013).
7. Boulder School for Condensed Matter and Materials Physics. http://boulderschool.yale.edu/
8. T. A. Waigh, The Physics of Living Processes, Wiley (2014).

STUDENT DISABILITY SERVICES: If you have a documented disability that requires accommodations, you will need to register with Student Disability Services (SDS) for coordination of your academic accommodations. The Student Disability Services (SDS) office is located at 1600 David Adamany Undergraduate Library in the Student Academic Success Services department. SDS telephone number is 313-577-1851 or 313-577-3365 (TDD only). Once you have your accommodations in place, I will be glad to meet with you privately during my office hours to discuss your special needs. Student Disability Services' mission is to assist the university in creating an accessible community where students with disabilities have an equal opportunity to fully participate in their educational experience at Wayne State University.

Please be aware that a delay in getting SDS accommodation letters for the current semester may hinder the availability or facilitation of those accommodations in a timely manner. Therefore, it is in your best interest to get your accommodation letters as early in the semester as possible.