PHY 395/495, PSE 495: Soft Matter Physics

Fall 2025

Dimitrios Vavylonis
Department of Physics
415 Lewis Lab
vavylonis@lehigh.edu

Time and Location: Tuesdays and Thursdays 9:20-10:35 (ET) Lewis Lab 316. The lectures will be recorded and available on Course Site and Slack.

First Class: August 26. Last Class: December 4.
University Holidays (no class): November 4, 27

Office hours: To be determined

Description

Introduction to the physics of soft materials, including polymers, colloids, and liquid crystals. Topics include polymer conformations and elasticity, colloidal interactions and self-assembly, liquid crystalline order, hydrodynamics of complex fluids. The course also provides an introduction to active matter and to soft matter in biological systems. The course integrates theoretical concepts with descriptions of experimental methods and provides an introduction to computational investigations of soft matter systems.

Course Contents

1. Introduction to Soft Matter Physics. Classical fluids and elasticity theory. Physical cosntants and key dimensionless parameters.

3. Brownian motion. The Langevin, Smoluchowski and Fokker-Planck equations. The Einstein relation.

3. Colloids and Emulsions. The Asakura-Oosawa (depletion) force. Electrostatic stabilzation. Shear thinning and thickening. Jamming.

4. Polymers: Ideal and worm-like chains. Self-avoiding walks and the Flory exponent. Force-extension of a polymer chain. Scaling descriptions of polymer solutions. The Flory-Huggins

theory of polymer solutions. Models of polymer dynamics and rheology. Biological polymers: DNA, actin, and microtubules.

5. Liquid Crystals and Membranes. Molecular order and symmetry. Liquid crystalline phases and their mathematical description. Liquid crystal displays. Topological defects. Phases of amphiphilic molecules and lipid membranes.

6. Active Matter and Pattern Formation. Instabilities of homegeneous states. Rayleigh-Benard and Turing patterns. Collective phenomena in active nematics and flocking. Materials applications. Active gels in biological systems. Molecular motors and the cytoskeleton.

Initial Competences

Undergraduate students (395): Introductory physics, basic thermal physics, Calculus I-III.
Graduate students (495): Prior course with emphasis on thermodynamis or statistical mechanics, knowledge of multivariable calculus and differential equations.

Final Competences

1. Perform order of magnitude estimates in soft matter physics, including scaling arguments and dimensional analysis.
2. Comprehend and formulate quantitative, physics-based models that capture the essential behavior of soft matter systems.
3. Apply physical, computational or mathematical principles to model how soft matter systems behave under various conditions, including external forces and thermal fluctuations.
4. Analyze and interpret experimental data from soft matter systems.

Grading

The final grade will be based on:

1. Homework and Quizzes (55%). Assignments must be submitted on the assigned due date. Prior permission from the instructor is required for late submissions.
2. Course Project (45 %).

The homework/project degree of difficulty will adjusted accordingly for students taking the course at the 300 and 400 levels.

Reading

Reading material will be provided in notes and slides together with selected material from the main textbook of the course. The textbook is available as an e-book through the Lehigh

library:

1. Wim van Saarloos, Vincenzo Vitelli, and Zorana Zeravcic, *Soft Matter: Concepts, phenomena and applications* (Princeton University Press, 2024).

Other recommended books:
1. Israelachvili, J. N. *Intermolecular and Surface Forces* (Academic Press, 2011).
2. P.G. de Gennes, *Scaling Concepts in Polymer Physics* (Cornell University Press, 1979).
3. M. Doi and S. Edwards, *The Theory of Polymer Dynamics* (Oxford University Press, 1986).
4. Michael Rubinstein and Ralph H. Colby, *Polymer Physics* (Oxford University Press, 2003).
5. de Gennes, P.G. and Prost, J. *The Physics of Liquid Crystals* (Oxford University Press, 1993).
6. Jonathon Howard, *Mechanics of motor proteins and the cytoskeleton* (Sinauer Associates, Publishers, Sunderland, Mass., 2001).
7. Robert Phillips, Jane Kondev, and Julie Theriot, *Physical Biology of the Cell*, Second Edition (Garland Science, New York, 2012).

Slack and Course Site

We will use Slack for course announcements, questions, links, ideas, and group activities. Students are expected to check it regularly and submit any course-related communication to me or to other students there.
Homework will be submitted and graded on Course Site.

Course Project

The course project will involve a 10-15 min presentation as well as a written final report of 3000-4500 words (including text in figure legends but excluding citation references). The topic of the project could be related to anything covered in the course, upon instructor approval. The topic will ideally be related to your area of interest. A typical outline of a written report will be:

1. Statement of the project topic and overview
2. Review of current understanding, outstanding questions
3. Quantitative approach/analysis in the form of equations, plots, or computer simulations
4. Interpretation, Discussion

University Policies

Accommodations for Students with Disabilities:
Lehigh University is committed to maintaining an equitable and inclusive community and welcomes students with disabilities into all of the University's educational programs. In order to receive consideration for reasonable accommodations, a student with a disability must contact Disability Support Services (DSS), provide documentation, and participate in an interactive review process. If the documentation supports a request for reasonable accommodations, DSS will provide students with a Letter of Accommodations. Students who are approved for accommodations at Lehigh should share this letter and discuss their accommodations and learning needs with instructors as early in the semester as possible. For more information or to request services, please contact Disability Support Services in person in Williams Hall, Suite 301, via phone at 610-758-4152, via email at indss@lehigh.edu, or online at https://studentaffairs.lehigh.edu/disabilities.

Bias, Discrimination, Harassment, Retaliation, and Sexual Misconduct:
Lehigh University upholds the Principles of Our Equitable Community and is committed to an educational, working, co-curricular, social, and living environment for faculty, staff, and students. The University does not discriminate in its admissions practices, employment practices, or educational programs or activities on the basis of age, color, disability, ethnicity, familial status, gender expression, gender identity, genetic information, marital status, national origin (including shared ancestry), pregnancy or related conditions, race, religion, sex, sexual orientation, and veteran or military status. Harassment or discrimination is unacceptable behavior and will not be tolerated. The University strongly encourages (and, depending upon the circumstances, may require) students, faculty, or staff who experience or witness harassment or discrimination, or have information about harassment or discrimination in University programs or activities, to immediately report such conduct.
If you have questions about Lehigh's Policy on Harassment and Non-Discrimination or need to report harassment or discrimination, contact the Equal Opportunity Compliance Coordinator (Alumni Memorial Building / 610 758 3535 / eocc@lehigh.edu)

Academic Integrity:
All members of the Lehigh community have a responsibility to maintain academic integrity. Resources and details of expectations at Lehigh are available on the Provost's website. It is expected that all students will abide by these standards throughout the course (e.g., homework, quizzes, papers, exams, projects, etc.). Academic integrity case studies will be discussed on the first day of class, and students are encouraged to ask questions for further clarity throughout the semester. Violations of academic integrity standards will not be tolerated and will be handled according to the guidelines in the University's Student Conduct System.