Welcome to the class! "Soft Condensed Matter 1: Polymer Physics"

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This course is intended to introduce main concepts of polymer physics, including statics and dynamics, single molecules and solutions, phase transitions, polyelectrolytes, networks etc. Biopolymers will also be considered in polymer physics context. The course will emphasize physical ideas involved in experimental and theoretical understanding of biological and synthetic macromolecules.

MAJOR TOPICS TO BE INCLUDED:

1. Polymers and biopolymers. Basic terminology: linear chains, branched polymers; architecture; membranes and gels - two- and three-dimensional polymers; homo- and hetero-(co-) polymers.
2. Forces in molecular world. Hierarchy of energies: chemical bonds versus other interactions. Charges, Van der Vaals forces, hydrophobic interactions, hydrogen bonds.
3. Thermal motion of chain molecules. Statistical mechanics of an ideal single polymer chain. Single molecule manipulation techniques.
4. Specifics of biological polymers, DNA and proteins. Helix-coil transition.
5. Excluded volume problem and coil-globule transition. Mean field theory and scaling.
6. Proteins: structure, function, evolution. Protein folding.
7. DNA topology.
8. Polymeric and other soft materials. Liquids, solids, liquid crystals, glasses. Crystalline and amorphous polymers. Melts.
9. Solutions of chain molecules. Concentration regimes. Mean field and scaling theories.
10. Polyelectrolytes.
11. Block-copolymers and microphase segregation.
12. Elasticity, viscosity, and viscoelasticity.
13. Polymer dynamics. Frequency dependent elastic properties. Rouse and Zimm models. Reptation.

This is an "ideal world" plan. In reality, because of time constraints, some of the topics will be only mentioned, while others will be developed to some depth.

MAJOR TOPICS NOT INCLUDED

Polymer chemistry, polymer synthesis

PRE-REQUISITES

The class is designed for advanced graduate students. Although no sophisticated mathematics will be used, the sufficiently mature understanding across major physics disciplines is expected. Good working knowledge of equilibrium statistical mechanics is a must. No programming virtuosity is required, but simple computations are expected.

BOOKS AND OTHER SOURCES

There is no book which can serve as a single text for the class. Useful sources include, but are not limited to, the books [1–12]. Additional reading from current journals will be assigned during the semester.

CONSTANTS AND UNITS

In this class, $c = \infty$ (nothing relativistic), $\hbar = 0$ (although quantum mechanical analogies are actively used), $k_B = 1$, Avogadro's number N_A is not in use, i.e., concentration is defined as the number of molecules (not moles!) per unit volume, $\nabla \cdot \mathbf{E} = 4\pi\rho$ (i.e., no ϵ_0), magnetic susceptibility of vacuum μ_0 is also not in use. In many (but not in all) cases, $2 \sim \pi \sim 2\pi \sim 1$.

HOME WORKS

The VERY IMPORTANT part of the course will be problem solving in frequent home works. The solutions of some (not all!) home works will be handed out, they will be considered as a hand-out material and students will be expected to study them carefully, like a text. In general, a significant amount of reading and thinking will be expected to succeed in class.

GRADING

Grading will be based on home works and exams.

Every homework assignment will include about 5 or so problems. Every problem will be graded on the scale from 0 to 3 (0,1,2,3). That means, $3n_j$ is the maximal grade for the home work j with n_j problems; if you receive ξ_{ij} for problem i in home work j, where $i = 1, 2, \ldots, n$, then percentage will be computed as $x_j = \sum_{i=1}^{n} \xi_{ij}/3n_j$, and this will be done for every homework assignment. Homeworks will be due one week after they are handed out (i.e., placed on the web). No late homeworks will be accepted. There will be one mid-term test (possibly conducted close to the end of the semester) and one final exam. The dates for both tests will be adjusted later. Mid term test will be given in regular class time. The 3-hours final exam will be scheduled for one of the days of the finals week. Tests and exams will be graded by the same scheme as homeworks. Final overall percentage, x, will be chosen as the better of the two:

- average of all HW's except the two weakest ones (55%), midterm (10%) and final (another 35%).

- average of all HW's (75%) except the weakest one and the better of the two tests (another 25%).

Final letter grade will be determined based on the percentage using the following formula: A if $x \geq 0.85$; $A-$ if $0.85 > x \geq 0.8$; $B+$ if $0.8 > x \geq 0.75$; B if $0.75 > x \geq 0.7$; $B-$ if $0.7 > x \geq 0.65$; $C+$ if $0.65 > x \geq 0.55$; C if $0.55 > x \geq 0.5$; $C-$ if $0.5 > x \geq 0.45$; Anything below 0.45 is not a passing grade. There will be no "curve".

[1] M.Rubinstein and R.Colby, *Polymer Physics* (Oxford University Press, 2003).
[2] M.Doi and S.F.Edwards, *The Theory of Polymer Dynamics* (Oxford University Press, 1986).
[3] P.-G. de Genness, *Scaling Concepts in Polymer Physics* (Cornell University Press, 1979).
[4] T.Witten, *Structured Fluids* (Oxford University Press, 2004).
[5] J. des Cloizeaux and G.Jannink, *Polymers in Solution* (Clarendon Press Oxford, 1990).
[6] A.Y.Grosberg and A.R.Khokhlov, *Statistical Physics of Macromolecules* (AIP Press, 1994).
[7] A.Y.Grosberg and A.R.Khokhlov, *Giant Molecules* (World Scientific, 2010).
[8] P. M. Chaikin and T. C. Lubensky, *Principles of condensed matter physics* (Cambridge University Press, 1995).
[9] M. Doi, *Soft Matter Physics* (Oxford University Press, 2013).
[10] D. F. Evans and H. Wennerström, *The colloidal domain: Where physics, chemistry and biology meet* (Wiley-VCH, 1999).
[11] A. V. Finkelstein and O. B. Ptitsyn, *Protein Physics* (Elsevier, 2016).
[12] A. D.Bates and A. Maxwell, *DNA Topology* (Oxford University Press, 2005).