ChE677 Introduction to Polymer Physics and Rheology

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Guidelines for Mini-project

This course aims to introduce you to the phenomena and concepts to describe physical properties of polymers and polymer rheology. However, there are a host of other complex fluid systems that are encountered in chemical engineering, and significant progress has been made in the understanding of the structure and rheology of these complex fluids. Through this mini-project, I want each of you to learn a particular aspect of thermodynamcis/dynamics of one such complex fluid, and share it with the class through a presentation at the end of the semester. I also want you to write a brief review of the topic you studied. You are free to choose, with my consent, any other topic of interest to you which comes within the purview of complex fluids.

A possible list of topics with some representative references are given below:

1. The rheology of dilute solutions of flexible polymers: recent progress and unresolved problems.

   R. G. Larson (2005), *Journal of Rheology*, **49**, 1 - 70, and references therein.

   Also see Larson's textbook.

2. Rheology of solid-liquid suspensions: spherical particles (both Brownian and non-Brownian)

   R. G. Larson, *Structure and Rheology of Complex fluids*, Chap. 6, and references therein.

   W. B. Russel *et al*, *Colloidal dispersions.*

   W. B. Russel (1980), Review of the role of colloidal forces in the rheology of suspensions, *Journal of Rheology*, **24**, 287 - 317.

   A. B. Metzner (1985), Rheology of suspensions in polymeric liquids, *Journal of Rheology*, **29**, 739 - 775.

   C. Macosko (1994), Rheology: Principles, Measurements and Applications.

3. Rheology of suspensions: nonspherical particles (both Brownian and non-Brownian)

   R. G. Larson, *Structure and Rheology of Complex fluids*, Chap. 6, and references therein.

   C. S. Petrie (1999), The rheology of fibre suspensions, *Journal of non-Newtonian fluid mechanics*, **87**, 369 – 402.

   C. Macosko (1994), Rheology: Principles, Measurements and Applications.

Several papers of D. L. Koch, for example:

Journal of non-Newtonian Fluid Mechanics **95**, 101-133 (2000).

Physics of Fluids A, **5**, 849 – 862 (1993).

4. Rheology of nematic liquid-crystalline polymers.

   R. G. Larson, *Structure and Rheology of Complex fluids*, Chap. 11, and references therein.

   Papers of M. Doi, G. Marucci etc.

5. Thermodynamics of block copolymers,

   F. S. Bates and G. H. Fredrickson (1990), *Annual Review of Physical Chemistry*, **41**, 525 - 557.

   F. S. Bates and G. H. Fredrickson (1999), *Physics Today*, February 1999, page 32.

6. Rheology of block-copolymers.

   Fredrickson and Bates (1996), *Annual Review of Materials Science*, **26**, 501 - 550.

   Larson's text.

7. Principles of Microbead rheometry.

   http://www.deas.harvard.edu/projects/weitzlab/papers/urheo_chapter.pdf

   Crocker *et al* (2000), Two-point microrheology of inhomogeneous soft materials, *Physical Review Letters*, **85**, 888.

   Cheng and Mason (2003), Rotational diffusion microrheology, *Physical Review Letters*, **90**, 018304

   MacKintosh and Schmidt (1999), Microrheology, *Current Opinion in Colloid and Interface Science*, **4**, 300 - 307.

8. Flow of granular materials: dense and slow flows.

   Rajchenbach (2000), Granular flows, *Advances in Physics*, **49**, 229 - 256

   P. G. de Gennes (1999), Granular matter: a tentative view, *Reviews of Modern Physics*, **71**, S374 - S382.

9. Flow of granular materials: dilute and rapid flows.

   L. P. Kadanoff (1999), Built upon sand: Theoretical ideas inspired by granular flows, *Reviews of Modern Physics*, **71**, 435 - 444.

H. M. Jaeger *et al* (1996), The Physics of Granular Materials, *Physics Today*, **49**, 32-38.

H. M. Jaeger *et al* (1996), Granular solids, liquids, and gases, *Reviews of Modern Physics*, **68**, 1259 - 1273.

10. Further modifications to the classical tube theory for rheology of entangled linear polymer systems.

    T. C. B. McLeish, Tube theory of entangled polymer dynamics, *Advances in Physics*, **51**, 1379 - 1527 (2002).

    Larson's text.

11. Structure and Rheology of foams.

    Chap. 9 of Larson's text and references therein.

12. Structure and Rheology of liquid-liquid emulsions and blends.

    Chap. 9 of Larson's text and references therein.

13. Statics and dynamics of polyelectrolytes (charged polymers)

    J. L. Barrat and J. F. Joanny (1996), Theory of polyelectrolyte solutions, *Advances in Chemical Physics*, **94**, 1-66.

    M. Muthukumar (1996), Double screening in polyelectrolyte solutions: Limiting laws and crossover formulas, *Journal of Chemical Physics*, **105**, 5183-5199

    M. Muthukumar (1997), Dynamics of polyelectrolyte solutions, *Journal of Chemical Physics*, **107** 2619-2635.

    M. Muthukumar (2001), Theory of viscoelastic properties of polyelectrolyte solutions, *Polymer*, **42**, 5921-5923.

    D. Long *et al* (1996), A Zimm model for polyelectrolytes in an electric field, *Journal of Physics-Condensed Matter*, **8**, 9471-9475

14. Structure and dynamics of semidilute solutions of flexible polymers.

    Chap 5 of Doi & Edwards,

    de Gennes, Scaling concepts in polymer physics.

15. Mechanics of stiff polymers (e.g DNA) and their behaviour in flow fields (worm-like chain; Marko-Siggia models, Chu's experiments etc.).

    Marko & Siggia (1995), Stretching DNA, *Macromolecules*, **28**, 8759

    Bustamante *et al* (2000), Single-molecule studies of DNA mechanics, *Current Opinion in Structural Biology*, **10**, 279 - 285.

Larson *et al* (1997), Hydrodynamics of DNA molecule in a flow field, *Physical Review E*, **55**, 1794 - 1797.

Smith *et al* (1999), *Single polymer dynamics in steady shear flow*, *Science*, **283**, 1724 - 1727

Other papers by Steven Chu and C. Bustamante.

16. Rheology of entangled worm-like micellar solutions

    Chap 12. of Larson's text.

17. Principles of Rheometry

    C. Macosko (1994), Rheology: Principles, Measurements and Applications.

    G. H. McKinley, T. Sridhar (2002), Filament stretching rheometry of complex fluids, *Annual Review of Fluid Mechanics*, **34**, 375 - 415.

Guidelines for writing the review:

- Intoduction: General concepts, clear definition of the problem and the physical system under consideration.
- What are the major questions in the field ?.
- Briefly discuss the experimental results of your system.
- Then discuss the theoretical models that are used to understand the problem.
- Conclusions: Summarize the state of the art, discussion of unresolved questions.
- References and Notes.
- Total length should not exceed 15 *double spaced pages* including references and figures.

Guidelines for presenatation:

1. Prepare a 15 minute talk (about 10 transparencies/power-point slides) on the subject.
2. Give a brief introduction about the problem, its motivation and the general concepts necessary (2 - 3 transparencies).
3. Describe the various approaches taken, and the relative merits of the approaches (4 - 5 transparencies). Avoid writing down equations on the transparencies as far as possible, and provide physical explanations for the approaches taken (with figures instead of equations if possible).
4. Provide a summary of the state of the art and the scope of future work (2 - 3 transparencies).