MATH 559: Complex Fluids

Course Material and Topics: This course will give students an overview of Non-Newtonian Fluid Dynamics, and discuss two approaches to building constitutive models for complex fluids: continuum modeling and kinetic-microstructural modeling. In addition, it will provide an introduction to multiphase complex fluids and to numerical models and algorithms for computing complex fluid flows.

Topics to be covered:

I. Introduction
   - Background and motivation
   - Review of required mathematics

II. Continuum theories
   - Oldroyd's theory for viscoelastic fluids
   - Ericksen-Leslie theory for liquid crystals
   - Viscoplastic theories

III. Kinetic-microstructural theories
   - Dumbbell theory for polymer solutions
   - Doi-Edwards theory for entangled systems
   - Doi theory for liquid crystalline materials

IV. Heterogeneous/multiphase systems
   - Suspension theories (Einstein, Taylor, Batchelor, etc.)
   - Kinetic theory for emulsions and drop dynamics
   - Energetic formalism for interfacial dynamics
   - Numerical methods for moving boundary problems
   - Applications in physical and biological systems

Prerequisites: Undergraduate-level course on Partial Differential Equations (MATH 257 or MATH 400), and graduate-level course on Fluid Mechanics (one of MATH 519, CHBE 557, MECH 502).

Evaluation: The instructional format for the course will consist of lectures of 3 hours per week. The final grade is computed as such: 50% from cumulative marks of 5 biweekly homework assignments, and 50% on a final presentation based on a cluster of research papers. Typically there is no final exam.

Possible references:

- R. G. Larson, *The Structure and Rheology of Complex Fluids*, Oxford (1999).
- R. B. Bird, R. C. Armstrong and O. Hassager, *Dynamics of Polymeric Liquids*, Vols. 1 & 2, Wiley and Sons (1987).
- P. G. deGennes and J. Prost, *The Physics of Liquid Crystals*, Clarendon (1993).
- D. Barthes-Biesel, *Microhydrodynamics and Compex Fluids*, Taylor & Francis (2012).
- M. Doi and S. F. Edwards, *The Theory of Polymer Dynamics*, Oxford (1988).