Syllabus for BE504 / ME 504 / MS 504 / PY744 Polymer Physics and Soft Matters (Fall 2015)

Lecturer: Ophelia K.C. Tsui  
Office: SCI 215, Tel: 8-4669, Email: okctsui@bu.edu.

Grader: Ruofan Wang (wangrf@bu.edu)  
Lectures: There will be lectures every Tue. & Thur. 12:30 - 2:00pm (CAS 326).

Office hours: Monday 3:00-4:30pm in Rm. SCI 215 (This time may change if it doesn’t work well for most.)  
Prerequisite: PY410

Course Objective  
This is a senior to beginning graduate level course, designed to introduce the basic concepts and fundamental principles relevant to contemporary applications and characterizations of polymers and soft matters. Most discussions will emphasize molecular descriptions, namely molecular structures as well as thermodynamics of the constituent molecules based upon approaches familiar in statistical mechanics. It is from these molecular descriptions that fundamental understandings of common macroscopic properties such as elasticity, rheology and phase behaviors in blends and solutions are elicited. In addition to these physical properties, common methods of polymer synthesis, the reaction kinetics involved, and methods of characterizing the structure, phase and dynamics will also be discussed. Familiarity with the basic principles of thermodynamics and statistical mechanics is assumed.

Recommended text  
Paul C. Hiemenz & Timothy P. Lodge, “Polymer Chemistry” (CRC Press, 2007 or later) (main text)

Other references:  
2. G. R. Strobl, “The Physics of Polymers” (Springer, 2007 or later)

Course Outline

1. Introduction (H&L Ch. 1)  
   - Nomenclature of Polymers  
   - Skeletal structure, homopolymers, copolymers, classification of polymers  
   - Isomerism in polymers  
   - Molar mass distribution, molar mass average

2. Step-Growth Polymerization (H&L Ch. 2)

3. Chain-Growth Polymerization (H&L Ch. 3)

4. Polymer Conformations (H&L Ch. 6)  
   - Average end-to-end distance for model chains (freely-jointed, freely-rotating and hindered rotation chains)  
   - Characteristic ratio and statistical segment length
- Semiflexible chains and the persistence length
- Radius of gyration
- Spheres, rods and coils
- Distributions for end-to-end distance and segment density

5. Thermodynamics of Polymer Solutions and Blends (H&L Ch. 7, Strobl Ch. 4)
   5.1 Regular solution theory (for solution mixtures)
   5.2 Flory-Huggins theory (for polymer solutions)
   5.3 Osmotic pressure of solutions
      - Number-average molecular weight based on osmotic pressure
      - Predictions by Flory-Huggins theory
   5.4 Phase behaviour of polymer solutions
      - Finding the binodal, spinodal, and critical point
      - Miscibility phase diagrams (UCST and LCST): Interpretation and prediction by the Flory-Huggins theory
   5.5 Flory-Huggins interaction parameter, $\chi$
   5.6 Excluded volume

6. Light Scattering by Polymer Solutions (H&L Ch. 8)
   6.1 Basic concepts
      - Scattering from randomly placed objects
      - Scattering from a perfect crystal
      - Origins of incoherent and coherent scatter
      - Bragg’s diffraction law
   6.2 Scattering by an isolated small molecule
   6.3 Scattering from a dilute polymer solution
   6.4 The Form factor, Zimm equation and Zimm plot
   6.5 Scattering regimes and form factor of spheres, rods and coils

7. Dynamics of Dilute Polymer Solutions (H&L Ch. 9.1-9.9)
   7.1 Friction and viscosity
   7.2 Stokes’ law and Einstein’s law
      - Viscous forces on rigid spheres
      - Suspension of spheres
   7.3 Intrinsic viscosity and Mark-Houwink equation
   7.4 Measurement of viscosity
      - Poiseuille equation and capillary viscometers
      - Concentric cylinder viscometers
   7.5 Diffusion coefficient and friction factor
      - Tracer diffusion and hydrodynamic radius
      - Mutual diffusion and Fick’s laws
   7.6 Dynamic light scattering
   7.7 Hydrodynamic interactions and draining
   7.8 Size Exclusion Chromatography (SEC)

8. Linear Viscoelasticity (H&L Ch. 11.1-11.7)
   8.1 Basic concepts
      - Stress and strain
      - Viscosity, modulus and compliance
      - Viscous and elastic responses
8.2 Response of the Maxwell and Voigt elements
- Transient response: Stress relaxation and creep
- Dynamic response: loss and storage moduli; complex modulus and complex viscosity

8.3 Boltzmann superposition principle
8.4 Bead-spring model
8.5 Zimm model for dilute solutions, Rouse model
8.6 Phenomenology of Entanglement
8.7 Reptation model

9. Glass Transition (H&L Ch. 12)
9.1 Introduction
- Definition of a glass
- Glass and melting transitions
9.2 Thermodynamic aspects of the glass transition
- First-order and second-order phase transitions
- Kauzmann temperature
9.3 Locating the glass transition temperature
- Dilatometry
- Calorimetry
- Dynamic mechanical analysis
9.4 Free volume description of the glass transition
- Temperature dependence of the free volume
- Free volume changes inferred from the viscosity
- Williams-Landel-Ferry (WLF) equation
9.5 Time-temperature superposition
9.6 Factors affecting the glass transition temperature
- Dependence on chemical structure
- Dependence on molecular weight
- Dependence on composition
9.7 Mechanical properties of glassy polymers

10. Colloids (Distributed reading material)
- Introduction: Applications of colloidal particles
- Characterizations of colloidal particles: Size distribution
- Inter-particle interactions and Aggregation phenomena
- Dynamics of colloidal particles in a suspension
- Jamming phenomenon

Course Grade
Grades will be based according to homework (50%), an open-book mid-term (tentatively on Oct 29, 25%) and a final examination (25%).

Tentative schedule of the homework: Homework assignments are due during a Tuesday class. Listed below are the tentative due dates.

HW1 (Sep 22), HW2 (Oct 6), HW3 (Oct 20), HW4 (Nov 10), HW5 (Nov 24)