# Polymer Physics (ChE/Ch 148)

**Instructors:**

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**TA:**

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**Designation:**

One of the required track courses for the undergraduate "materials track"; elective for graduate students.

**Catalog Description:**

An introduction to the physics that govern polymer structure and dynamics in liquid and solid states, and to the physical basis of characterization methods used in polymer science. The course emphasizes the scaling aspects of the various physical properties. Topics include conformation of a single polymer chain under different solvent conditions; dilute and semi-dilute solutions; thermodynamics of polymer blends and block copolymers; rubber elasticity; polymer gels; linear viscoelasticity of polymer solutions and melts; glass transition and crystallization.

**Prerequisite:**

ChE/Ch 147 or instructor's permission.

**Course Objectives:**

To introduce the students to some basic phenomena and mechanistic explanations in the physical behavior of polymers and to enable the students to begin to read the modern literature in polymer sciences and engineering.

**Relationship to Program Goals:**

Polymer science and engineering has been one of the major areas of study in chemical engineering. Many of our graduates go into the polymer industry or go to graduate school to do polymer-related research. As an integral part of the materials track, this course introduces the students to some basic concepts in the physical behavior of polymers with an emphasis on how the various properties arise from the connectivity and large size of the polymer molecules. In the past, some of the undergraduate students taking this course ended up going to graduate school to study polymers; others found the course helpful in their undergraduate research.

**Text and Reference Books:**

Principal textbook: M. Rubinstein and R. C. Colby: *Polymer Physics* (Oxford University Press, 2003). Other references: (1) P.G. de Gennes: *Scaling Concepts in Polymer Physics*; (2) M. Doi and S.F. Edwards: *The Theory of Polymer Dynamics*; (3) P. Flory: *Principles of Polymer Chemistry*; (4) R. G. Larson: *Constitutive Equations for Polymer Melts and Solutions*; (5) R. G. Larson: *The Structure and Rheology of Complex Fluids*; (6) P. C. Hiemenz: *Polymer Chemistry: The Basic Concepts*. These books will be placed on reserve in the Sherman Fairchild Library.

**Topics Covered:**

1. Introduction: types of polymers; polydispersity; flexibility; universal properties.
2. Single ideal chain: mean-square end-to-end distance, radius of gyration; Gaussian chain; freely jointed chain; worm-like chain.
3. Deforming a polymer: stretching and confinement, weak vs. strong deformation.
4. Excluded volume effects: potential of mean force; solvent quality, Flory theory for the size of a polymer; theta-temperature.
5. Polymer solution thermodynamics: Flory-Huggins Theory, osmotic pressure; phase separation; fractionation.
6. Semidilute solutions: overlap concentration; scaling laws for good solvents, concentration fluctuation and correlation length; size of a polymer in semi-dilute solutions.
7. Polymer-polymer thermodynamics: phase behavior of polymer blends; stability and metastability.
8. Polyelectrolytes: Debye-Hückle theory, Donnan equilibrium.
9. Polymer networks: rubber elasticity; gels.
10. Dynamics of polymeric liquids: phenomenology and constitutive equations, Maxwell model.
11. Rouse theory: equations of motion, normal modes, time-temperature superposition; diffusion and viscoelasticity, experimental tests.
12. Zimm theory: hydrodynamic interactions, free-draining and non-draining limits, pre-averaging approximation, experimental tests.
13. Reptation theory: tube model; primitive chain, reptation dynamics.
14. The glass transition: free volume theory.
15. Current Topics: polymer brushes, self-assembly and order-disorder transitions of diblock copolymers; liquid crystalline polymers; polymer crystallization .

**Class Schedule:**

Lectures: T Th 10:30-12; TA sessions: T 4:30-6:30

**Grading:**

50%  term paper + 50% homework (10 total homework sets)