CHE 461/543 Polymer Science & Technology Fall 2024

Instructor: Dr. Richard J. Spontak, Distinguished Professor
Engineering Building I, Room 2088E
North Carolina State University
Raleigh, NC 27695

Office: 919-515-4200
Mobile: 919-417-3554 (preferred)
E-mail: spontak@ncsu.edu

Course Description: This course is intended to provide a broad overview of polymer science and engineering. Emphasis will be placed on the synthesis and structure of polymeric materials, the crystalline and glassy states, solution and melt properties, phase behavior, and mechanical and rheological properties.

Prerequisites: Organic and preferentially physical chemistry; thermodynamics; mechanics (or a related physics course)

Textbooks:

(Required) R J. Young & P.A. Lovell, "Introduction to Polymers," 3rd ed., CRC Press, Baton Rouge, LA (2011).

F. Rodriguez, C. Cohen, C.K. Ober & L. Archer, "Principles of Polymer Systems," Taylor & Francis, New York, NY (2003).

P.C. Painter & M.M. Coleman, "Fundamentals of Polymer Science," 2nd ed., Technomic Publishing, Lancaster, PA (1997).

P.J. Flory, "Principles of Polymer Chemistry", Cornell University Press, Ithaca (1967).

Course Objectives: At the end of this course, each student should be able to:

- describe the manufacture (using both traditional and non-traditional synthesis schemes) of commercially important polymers using concepts from chemical kinetics and equilibrium thermodynamics;
- present a basic understanding of the structure of polymer chains in solution and in the melt (including, molecular weight, molecular weight distribution, chain conformation) and methods to characterize polymers in solution;
- calculate polymer phase behavior using the basic Flory-Huggins theory of polymer solutions/melts;
- identify the structure of polymers in the solid state and relate the effects of structural organization (i.e., crystallinity, liquid crystallinity, phase separation) on molecular and end-use properties of polymers; and
- recognize the basic stress/strain and viscoelastic behavior of polymers based on a knowledge of structure and thermal properties (e.g., melting and glass transition) and apply the time-temperature superposition principle and Williams-Landel-Ferry equation to predict the viscoelastic behavior of polymeric melts.

Course Structure and Grading:

Examinations:	2 in-class exams and 1 non-cumulative final exam (30% ea. for 461; 25% ea. for 543)
Homework:	Biweekly (10% of grade)
In-class Presentations:	One (1) 5-minute presentation (not graded, but required)
Literature critique:	5-page critique of an approved literary publication (15% of grade for 543 only)
Bonus Opportunity:	Creative video on an approved course topic (up to 5 pts on the course grade for 461 only)

Course Outline by Topical Areas:

1. The nature of polymer materials and polymer microstructure: including branching, networks, tacticity and copolymers;
2. Polymer synthesis: step-growth and chain polymerizations;
3. Kinetics of polymerization: the kinetics of step growth and free radical chain polymerizations; relationship to molecular weight;
4. Statistics of step-growth polymerization: the use of statistics in describing molecular weight distributions in step-growth polymerization;
5. Copolymerization: the kinetics of free radical copolymerization;
6. Structure: chain conformations, amorphous polymers, and the morphology of semi-crystalline polymers;
7. Crystallization, melting and the glass transition: an introduction to crystallization kinetics, melting and glass formation;
8. Polymer solutions and blends: the Flory-Huggins theory and phase behavior;
9. Measurement of molecular weight: osmometry, light scattering, viscosity and size exclusion chromatography; Mechanical and rheological properties: stress/strain behavior, visoelasticity, non- linear mechanical and rheological behavior, ultimate properties.

Reading Assignments: Topics to be covered and associated reading assignments will be administered at the start of each week.

Class Attendance: All students are expected to attend class on a regular basis. Students are not required to inform the instructor of missed classes, but they are responsible for all material covered during missed classes. Recorded classes will be available.

Course Material: The lecture notes and handouts provided in this course are provided as an educational courtesy to enrolled students. These materials become the property of enrolled students and may be used by said students in their future professional development, but course materials may not be distributed to or used by anyone not enrolled in this course. Course material will be available on the course website, which will be activated at the start of the semester.

Class Organization: In-person classes will be held at 8:30 – 9:45 a.m. (with a 5 min break at 9:10 a.m.) each Tuesday and Thursday. Students are encouraged to arrive early or at least on time so that the student-led presentations can begin promptly at the start of class. The 5-minute in-class presentations will be posted on the course website and will be the subject of bonus questions on the examinations. A template for the presentations, as well as the schedule for student speakers, will be included on the course website at the start of the semester. The presentations are not graded, but they are nonetheless required. They will be recorded as part of the lectures. These presentations are intended to give students an appreciation for and an awareness of polymer-related activities in contemporary society. Classes will be largely lecture-based, with time dedicated to classroom discussion and short objective-specific activities. Lectures will start with a series of well-defined learning objectives and will end with a summary of the day's important topics. On-line classes are asynchronous and the 5-minute presentations will be delivered on a single day at the end of the semester. Duplicate presentations on the same topic will not be permitted.

Course Organization: The lectures will closely follow the lecture slides/handouts available on the course website and loosely follow the organization of the textbook. Relevant reading material will be identified on a weekly basis. The two in-class examinations will be announced at least one week prior to the examination. A study guide outlining the topics to be covered on each examination will be provided on the course website. While no formal examination review sessions are planned, students are strongly encouraged to ask questions during class (see below) and during office hours. Details regarding the bonus opportunity will be announced during the course of the semester.

Instructor Contact: Students are always encouraged to interact with the instructor to ensure effective learning. To expedite such interaction, in- class students will have access to the instructor during office hours at the following times:

Each Tuesday and Thursday at 10:30 – 11:30 a.m. ET

On-line students can meet with the instructor during virtual office hours at the following times:

Each Tuesday and Thursday at 5:00 – 6:00 p.m. ET

Individual appointments can be requested (or specific questions can be asked) by e-mail (spontak@ncsu.edu; **be sure to list CHE461/543 in the subject line**) or by phone (see contact information on previous page). Students can always request to hold in-person or zoom meetings with the instructor on an individual basis.

Teaching Assistants: The course will have one (1) teaching assistant. Students are encouraged to contact the TA in addition to the instructor. The TA will be responsible for grading homework and examinations.

Academic Integrity: With regard to examinations and projects, all students are expected to adhere strictly to the University policy provided in the Code of Student Conduct Policy (POL11.35.1), which is posted on the University website at www.ncsu.edu/policies/student_services/student_discipline/POL11.35.1.php. Honesty and integrity constitute cornerstones of the University, and society as a whole, and are required in this course. Cheating, which includes plagiarism, will not be tolerated and will result in swift disciplinary action.

Physical Disabilities: Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with Disability Services for Students at 1900 Student Health Center, Campus Box 7509, 515-7653. For more information on NC State's policy on working with students with disabilities, please see the Academic Accommodations for Students with Disabilities Regulation (REG02.20.1).

Supporting Fellow Students in Distress: As members of the NC State Wolfpack community, we each share a personal responsibility to express concern for one another and to ensure that this classroom and the campus as a whole remains a safe environment for learning. Occasionally, you may come across a fellow classmate whose personal behavior concerns or worries you. When this is the case, I would encourage you to report this behavior to the NC State Students of Concern website:http://studentsofconcern.ncsu.edu/. Although you can report anonymously, it is preferred that you share your contact information so they can follow-up with you personally.

Captured Lectures: This on-campus course is recorded for all students. These video recordings may contain an image of you asking questions or being part of a discussion. Previously recorded lectures are available on the course website.

Health and Participation in Class

We are always concerned about your health and the health of your classmates and instructors/TAs.

- If you feel unwell, please do not come to an in-person class or activity.
- If you are in quarantine, or have a personal or family situation related to a contagious infection that prevents you from attending this course in person, please connect with your instructor to make alternative plans, as necessary.

Health and Well-Being Resources

These are difficult times, and academic and personal stress are natural results. Everyone is encouraged to take care of themselves and their peers. If you need additional support, there are many resources on campus to help you:

- Counseling Center (NCSU Counseling Center)
- Student Health Services (Health Services | Student)
- If the personal behavior of a classmate concerns or worries you, either for the classmate's well-being or yours, we encourage you to report this behavior to the NC State CARES team: (Share a Concern).
- If you or someone you know are experiencing food, housing or financial insecurity, please see the Pack Essentials Program (Pack Essentials).

Need Help?

If you find yourself in a place where you need help, academically or otherwise, please review these Step-by-Step Help Topics.

Other Important Resources

- **Keep Learning:** Keep Learning
- **Protect the Pack FAQs:** Frequently Asked Questions | Protect the Pack
- **NC State Protect the Pack Resources for Students:** Resources for Students | Protect the Pack
- **Academic Success Center** (tutoring, drop in advising, career and wellness advising): Academic Success Center.
- **NC State Keep Learning, tips for students opting to take courses remotely:** Keep Learning Tips for Remote Learning
- **Introduction to Zoom for students:** https://youtu.be/5LbPzzPbYEw
- **Learning with Moodle, a student's guide to using Moodle:** https://moodle-projects.wolfware.ncsu.edu/course/view.php?id=226
- **NC State Libraries** Technology Lending Program

Lectures, slides and homework assignments:

Week of Aug 19: View Lectures of Slides 1 & 2 for Exam 1

Week of Aug 26: View Lecture of Slide 3 for Exam 1

Week of Sep 2: View Lectures of Slides 4 & 5 for Exam 1 and turn in **HW #1** on Aug 29

Week of Sep 9: View Lecture of Slide 6 for Exam 1 and turn in **HW #2** on Sep 12

Week of Sep 16: View Lecture of Slide 1 for Exam 2

Week of Sep 23: View Lecture of Slide 2 for Exam 2 and take **Exam #1** on **Sep 26**

Week of Sep 30: View Lectures of Slides 3 & 4 for Exam 2 and turn in **HW #3** on Oct 3

Week of Oct 7: View Lecture of Slide 5 for Exam 2

Week of Oct 14: View Lecture of Slide 1 for Final and turn in **HW #4** on Oct 17

Week of Oct 21: View Lecture of Slide 1 for Final

Week of Oct 28: View Lectures of Slides 2 & 3 for Final and take **Exam #2** on **Oct 31**

Week of Nov 4: View Lecture of Slide 4 & 5 for Final; submit critique and project topics for approval

Week of Nov 11: Turn in **HW #5** on Nov 14 (tentative)

Weeks of Nov 18/25: Finish any remaining topics; EOL students present on Nov 21 starting at 5:00 p.m.
Turn in **critique (543)** and **creative project (461)** on Nov 19 and Nov 26, respectively

Week of Dec 2: Take **Final Exam** on **Dec 3**

(EOL students will take their exams during normal class time as above unless otherwise approved)

Corresponding readings in the text:

Homework 1
Chapters 1, 2, 3 and 6

Homework 2
Chapters 3 and 4

Homework 3
Chapters 9, 16 and 17

Homework 4
Chapters 10, 17 and 18

Homework 5
Chapters 20, 21 and 22