# Macromolecular Solids
## MSE 455
## Spring 2026

**Instructor:**

**Dr. Abigail Nason**
email: anason@illinois.edu
Office hours: TBD.

**Course Website:**

Canvas: http://canvas.illinois.edu

**Text:**

*Mechanical Properties of Solid Polymers*, 3rd ed. (2013) by I. M. Ward and J. Sweeney
This textbook is available for free (as a PDF) on the Illinois library website (library.illinois.edu). The text can also be purchased on Amazon.

**Lectures:**

Tuesdays / Thursdays, 9:30 am-10:50 am CST
106B6 Engineering Hall
We will have approximately 26 lectures during the semester. The complete schedule is listed in the syllabus.
It is your responsibility to attend all lectures per student code at UIUC:
https://studentcode.illinois.edu/article1/part5/1-501/
If you cannot attend class, send Dr. Abigail Nason your excuse via email before class.

**Problem Sets & Exams:**

There will be approximately 5 problems sets. There will be 2 exams and no final exam. The second exam will be given during the final exam timeslot for the course and may include some amount of cumulative material from the entire course.

**Grading:**

| | |
|---|---|
| Homework | 20% |
| Exam #1 | 25% |
| Exam #2 | 30% |
| Final project | 25% |

The grade assignment is: A+: 96-100; A: 90-95; A-: 85-89; B+: 80-84; B: 75-79. B-: 70-74

# Macromolecular Solids
## MSE 455
## Spring 2026

**Course Description:**
This course is designed to provide students with the fundamental knowledge and tools to solve quantitative problems in macromolecular science with a focus on the solid phase. Broadly, the course focuses on the mechanical behavior of amorphous and semi-crystalline polymers. The course begins with an overview of polymer structure, conformation, and isomerism, followed by a detailed discussion of the glass transition and properties of crystalline polymers. Additional topics include polymer characterization, polymer morphology, and orientation effects; rubber elasticity, polymer linear viscoelasticity using Boltzmann superposition and mechanical models; measurement of viscoelastic properties; polymer relaxation and transitions; polymeric yield phenomena and plastic flow; deformation mechanisms; fracture and craze formation; impact and fatigue.

**Course Textbook:**

- *Mechanical Properties of Solid Polymers*, I. M. Ward and J. Sweeney, Wiley, 3rd edition (2013). Acronym: **WS**

**(Unofficial) Course Textbook:**

- *Polymer Chemistry*, T. Lodge and P. C. Hiemenz, 3rd ed., CRC Press (2020). Acronym: **L**

**Other Textbooks that may be useful:**

**Polymer physics:**

- *An Introduction to Polymer Physics*, D. I. Bower, Cambridge (2002). Acronym: **B** – (this textbook is available for free on the Illinois university library website)
- *Polymer Physics*, M. Rubinstein and R. H. Colby, Oxford (2003). Acronym: **RC**

**Mathematics and mathematical principles:**

- *Advanced Engineering Mathematics*, M. Greenberg, 2nd ed., Prentice Hall (1998). Acronym: **G**
- *Elementary Differential Equations*, Boyce and DiPrima, 9th ed., Wylie (2008). Acronym: **BD** – (e.g. discussion on Laplace transforms)
- *Incompressible Flow*, R. L. Panton, 3rd edition, Wiley (2005). Acronym: **P** – (e.g. discussion on index or Einstein notation)

# Macromolecular Solids
## MSE 455

**Course Outline (tentative)**

| Lec | Date | Topic | Reading* |
|---|---|---|---|
| Lec 1 | Jan 20 | Course introduction; general concepts in polymer structure | WS §1; L §1 |
| Lec 2 | Jan 22 | Classification of polymers; polymer architecture | L §1 |
| Lec 3 | Jan 27 | Molecular weight characterization | L §1 |
| Lec 4 | Jan 29 | Isomerism; polymer conformations | L §1.6 and L §6 |
| Lec 5 | Feb 3 | Polymer conformations: FJC, FRC, HRC | L §6 |
| Lec 6 | Feb 5 | Conformations: WLC, persistence length, $R_g$, distributions | L §6 |
| Lec 7 | Feb 10 | Amorphous polymers & glass transition; thermodynamics | L §12.1-12.4; 12.6 |
| Lec 8 | Feb 12 | Glass transition: free-volume concepts, VFTH, properties | L §12.1-12.4; 12.6 |
| Lec 9 | Feb 17 | Polymer crystallinity: structure, measurement, unit cells | B §3.4; B §4 |
| Lec 10 | Feb 19 | Intro to scattering: light, SAXS, WAXS | L §8.1-8.2, 13.1-13.2 |
| Lec 11 | Feb 24 | Polymer crystallinity: thermodynamics of melting | L §13.3-13.4 |
| Lec 12 | Feb 26 | Polymer crystallinity: kinetics, nucleation, growth | L §13.5-13.6 |
| Lec 13 | Mar 3 | Deformation, stress, strain, constitutive equations | WS §2; B §6.1-6.2 |
| Lec 14 | Mar 5 | Linear viscoelasticity & mechanical models | WS §5.1-5.2; L §11.2 |
| Lec 15 | Mar 10 | Catch-up and Review | |
| | Mar 12 | Exam #1 – in class | |
| | Mar 17 | Spring Break - no class | |
| | Mar 19 | Spring Break - no class | |
| | Mar 24 | No class (ACS conference) | |
| | Mar 26 | No class (ACS conference) | |
| Lec 16 | Mar 31 | Linear viscoelasticity: SLS, dynamic behavior | WS §5.2, 5.3, 5.4 |
| Lec 17 | Apr 2 | Time-temperature superposition & WLF equation | L §12.5; WS §7.1-7.4 |
| Lec 18 | Apr 7 | Modeling linear viscoelasticity, Boltzmann superposition | L §11.3; WS §7.1-7.4 |
| Lec 19 | Apr 9 | Sample Problems: linear viscoelasticity, TTS, Boltzmann | |
| Lec 20 | Apr 14 | Rubber elasticity: networks, Carothers equation, Flory | L §10; WS §4 |
| Lec 21 | Apr 16 | Rubber elasticity: elastomers, thermodynamics | L §10; WS §4 |
| Lec 22 | Apr 21 | Rubber elasticity: deformation of Gaussian networks | L §10; WS §4 |
| Lec 23 | Apr 23 | Mechanical properties of solid polymers: intro | L §12.7 |
| Lec 24 | Apr 28 | Yielding, instability, and Consider´e construction | WS §12.1-12.6 |
| Lec 25 | Apr 30 | Breaking, brittle fracture, crazing | WS §13.1-13.5 |
| Lec 26 | May 5 | Catch-up/Review | |
| | May 12 | Exam #2 - final exam time slot 7:00 – 10:00 pm | |

*Refer to page 2 of the syllabus for textbook acronyms.

# Macromolecular Solids
## MSE 455

**Problem Sets (tentative)**

| Assignment | Handout Date | Due Date |
|---|---|---|
| HW 1 | Jan 27 | Feb 10 |
| HW 2 | Feb 10 | Feb 24 |
| HW 3 | Feb 24 | Mar 10 |
| HW 4 | Mar 24 | Apr 14 |
| HW 5 | Apr 14 | Apr 28 |

**Important Dates**
**Exam #1**: Thursday, March 12
**Exam #2**: Tuesday, May 12, 7:00 – 10:00 pm
**Project Due**: Tuesday, May 5 (in class)

**Course Project - choose one of two options Option 1 -**
**Quantitative analysis of polymer data**
For this option, you will be asked to quantitatively analyze a set of mechanical characterization data from a polymer sample. This could include dynamic mechanical analysis (DMA) or rheological data such as linear viscoelasticity and dynamic moduli. You will be expected to write a brief paper summarizing your results, including plots and figures showing your analyzed data, with physical interpretations of the results. The summary paper should contain the following sections: abstract (200 word maximum), introduction and discussion of polymeric system, overview of experimental method(s) and quantitative analysis methods, results & discussion, ideas for potential new directions for 'next' experiments, and conclusion. More information for the project will be provided later in the semester. General length: 5 pages, single spaced, not including figures or supplementary sections.

**Option 2 - Critical review of literature**
For this option, you are asked to search the primary research literature (journal publications) and to write a *critical review* of publications reporting on polymer design, development, or characterization from the recent literature. Your paper should constitute a *critical review* of a current topic in polymer science, focusing on macromolecular solids. You should focus on recent developments (over the last 5 years), but consideration should also be given to classic papers from the literature where appropriate. The paper should be sufficiently focused so that you can delve into the topic with reasonable depth. The paper should contain the following sections: abstract (200 word maximum), introduction/motivation, brief summary of work, critique of scientific contribution (including possible errors in original scientific contribution), ideas for potential new directions for 'next' experiments, conclusion, and references. More information for the paper will be provided later in the semester. General length: 5 pages, single spaced, not including figures or supplementary sections.

# Macromolecular Solids
## MSE 455

**Course Policies:**

- **Submitting assignments.** All assignments are due on the assignment due date at the beginning of the class period, as explained in class and listed in the syllabus.
- **Late policy.** Late assignments are subject to a 25% per day penalty, unless the absence is officially excused. Missed exams without a valid excuse will lead to a zero on the exam.
- **Academic integrity.** The University of Illinois at Urbana-Champaign expects its faculty, staff, students, and guests to conduct themselves in accordance with the community values of civility, respect, and honesty; to maintain the highest level of integrity and exercise critical judgment in all dealings, decisions and encounters; and to maintain and strengthen the public's trust and confidence in our institution. It is the responsibility of each student to refrain from infractions of academic integrity, from conduct that may lead to suspicion of such infractions, and from conduct that aids others in such infractions. Students have been given notice of this Part by virtue of its publication. Regardless of whether a student has actually read this Part, a student is charged with knowledge of it. Ignorance is not a defense.

  Academic misconduct (cheating, plagiarism,), as a form of fraud, undermines the public trust, both in the institution and in the degree. When you sign your name to work, you are stating that the work is yours, you created it or contributed to it, and you comprehend everything in it. For all individual assignments, the work that you turn in must be your own work. Working in groups to discuss overall approaches to solving problems is fine (and encouraged), but you need to turn in your own work for individual assignments. University and departmental policies will be followed cases of suspected cheating incidents. You are encouraged to read and consider the University of Illinois at Urbana-Champaign Student Code as a part of this syllabus. Students should pay particular attention to Article 1, Part 4: Academic Integrity. Please read the Code here: http://studentcode.illinois.edu/. Academic dishonesty may result in a failing grade. Do not hesitate to ask the instructor(s) if you are in doubt about what constitutes plagiarism, cheating, or any breach of academic integrity.
- **AI Policy.** Generative AI tools, such as ChatGPT, Co-pilot, and Gemini are welcome in this class, provided that you cite when and how you use the tool. You will be provided with examples of how to cite your use of this tool for your assignments.

  There are a variety of AI programs available to assist students. AI programs are not a replacement for critical thinking, analysis, creativity, originality, and problem-solving. Engineering is a craft that you must develop over time by learning skills and building intuition. However, AI tools may be used to assist with engineering design as long as proper attribution is provided.
- **Copyright Course Materials.** All materials for this course are considered copyright of the University of Illinois at Urbana-Champaign. It is wholly unacceptable for students to post course materials (homeworks, quizzes, exams, solutions, lecture notes, etc.) in public places, including unauthorized websites, for sale or otherwise. Any act of making course materials available on the WWW, or in any other format, is considered copyright violation.

# Macromolecular Solids
## MSE 455

**Sexual Misconduct Reporting Obligations:** The University of Illinois is committed to combating sexual misconduct. Faculty and staff members are required to report any instances of sexual misconduct to the University's Title IX Office. In turn, an individual with the Title IX Office will provide information about rights and options, including accommodations, support services, the campus disciplinary process, and law enforcement options. A list of the designated University employees who, as counselors, confidential advisors, and medical professionals, do not have this reporting responsibility and can maintain confidentiality, can be found here: wecare.illinois.edu/resources/students/#confidential. Other information about resources and re- porting is available here: wecare.illinois.edu.

**Religious Observances:** Illinois law requires the University to reasonably accommodate its stu- dents' religious beliefs, observances, and practices in regard to admissions, class attendance, and the scheduling of examinations and work requirements. You should examine this syllabus at the beginning of the semester for potential conflicts between course deadlines and any of your re- ligious observances. If a conflict exists, you should notify your instructor of the conflict and follow the procedure at https://odos.illinois.edu/community-of-care/resources/students/religious- observances/ to request appropriate accommodations. This should be done in the first two weeks of classes.

**Disability-Related Accommodations:** To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor and the Disability Re- sources and Educational Services (DRES) as soon as possible. To contact DRES, you may visit 1207 S. Oak St., Champaign, call 333-4603, e-mail disability@illinois.edu or go to: https://www.disability.illinois.edu.

**Family Educational Rights and Privacy Act (FERPA):** Any student who has suppressed their directory information pursuant to Family Educational Rights and Privacy Act (FERPA) should self-identify to the instructor to ensure protection of the privacy of their attendance in this course. See https://registrar.illinois.edu/academic-records/ferpa/ for more information on FERPA.

# Macromolecular Solids
## MSE 455

**Statement on Anti-Racism:**
The Grainger College of Engineering is committed to the creation of an anti-racist, inclusive community that welcomes diversity along a number of dimensions, including, but not limited to, race, ethnicity and national origins, gender and gender identity, sexuality, disability status, class, age, or religious beliefs. The College recognizes that we are learning together in the midst of the Black Lives Matter movement, that Black, Hispanic, and Indigenous voices and contributions have largely either been excluded from, or not recognized in, science and engineering, and that both overt racism and micro-aggressions threaten the well-being of our students and our university community. The effectiveness of this course is dependent upon each of us to create a safe and encouraging learning environment that allows for the open exchange of ideas while also ensuring equitable opportunities and respect for all of us. Everyone is expected to help establish and maintain an environment where students, staff, and faculty can contribute without fear of personal ridicule, or intolerant or offensive language. If you witness or experience racism, discrimination, micro-aggressions, or other offensive behavior, you are encouraged to bring this to the attention of the course director if you feel comfortable. You can also report these behaviors to the Office of the Vice Chancellor for Diversity, Equity & Inclusion:

https://diversity.illinois.edu/diversity-campus-culture/belonging-resources/

Based on your report, campus staff members will follow up and reach out to students to make sure they have the support they need to be healthy and safe. If the reported behavior also violates university policy, staff in the Office for Student Conflict Resolution may respond as well and will take appropriate action.

**Dealing with Stress, Personal Issues:**
Counseling services are available to all of our students here on campus. College can be stressful for a variety of reasons. We believe that your mental health is as important as your physical health and intellectual growth. If you are feeling overwhelmed, depressed, or anxious, there are many resources on campus to assist you. The Counseling Center offers same-day first time appointments, time-limited counseling, long-term group therapy, and several skill development workshops. Please call them at 217-333-3704 to make an appointment, or visit their website, www.counselingcenter.illinois.edu, for more information. If you are experiencing a mental health crisis and feel you are in immediate danger, please call 911. The Champaign County Crisis Line (217-359-4141) is also available 24 hours a day, 7 days a week, 365 days a year.

**Emergency Situations:**
Run, Hide, Fight (what to do in an emergency situation – such as an active shooter) - please see ‘run, hide, fight’ attachment appended at the end of this syllabus.

# Run > Hide > Fight

Emergencies can happen anywhere and at any time. It is important that we take a minute to prepare for a situation in which our safety or even our lives could depend on our ability to react quickly. When we're faced with almost any kind of emergency – like severe weather or if someone is trying to hurt you – we have three options: Run, hide or fight.

## Run

**Leaving the area quickly is the best option if it is safe to do so.**

- Take time now to learn the different ways to leave your building.
- Leave personal items behind.
- Assist those who need help, but consider whether doing so puts yourself at risk.
- Alert authorities of the emergency when it is safe to do so.

## Hide

**When you can't or don't want to run, take shelter indoors.**

- Take time now to learn different ways to seek shelter in your building.
- If severe weather is imminent, go to the nearest indoor storm refuge area.
- If someone is trying to hurt you and you can't evacuate, get to a place where you can't be seen, lock or barricade your area if possible, silence your phone, don't make any noise and don't come out until you receive an Illini-Alert indicating it is safe to do so.

## Fight

**As a last resort, you may need to fight to increase your chances of survival.**

- Think about what kind of common items are in your area which you can use to defend yourself.
- Team up with others to fight if the situation allows.
- Mentally prepare yourself – you may be in a fight for your life.

Please be aware of people with disabilities who may need additional assistance in emergency situations.

## Other resources

- **police.illinois.edu/safe** for more information on how to prepare for emergencies, including how to run, hide or fight and building floor plans that can show you safe areas.
- **emergency.illinois.edu** to sign up for Illini-Alert text messages.
- **Follow the University of Illinois Police Department** on Twitter and Facebook to get regular updates about campus safety.