

# MSE 458/CHEM 482 - Polymer Physics

## Course Summary

An intermediate-level introduction to the fundamental physical chemistry and physics of polymeric systems. The focus is entirely on equilibrium phenomena: structure and properties of polymer solutions, dense liquids, gels and rubber networks, mixtures, surfaces and interfaces, confined polymers, and biopolymers. For a detailed list of topics see [Course Coverage](#). An online version of the syllabus can be found here: <https://statt.matse.illinois.edu/polymer-physics/>

## Prerequisites

MSE 401 – Thermodynamics of Materials or a 300-level course in thermo, statistical thermodynamics, or physical chemistry

## Class

**Location:** MSEB 305 (first week online)

**Time:** 2:00 – 3:20 pm on Tuesdays and Thursdays, for a detailed schedule see [Class Schedule](#).

**Sections:** A3 (CRN-38260) – UG, 3 credit hours and A4 (CRN-38261) – Grad, 3 or 4 credit hours

**Enrolled students will receive the Zoom link for the first week of class.**

This class utilizes Canvas for communications and assignments. The course is divided by weeks and there are assignments and activities to be completed each week, including homework, lectures, quizzes, videos, and discussions. The class is designed to be interactive and your active participation is required.

All class communications and interactions with other students, TAs, Graders, and me should follow common social standards for respect and courtesy; rude, abusive, or discriminatory language will not be tolerated. I will communicate with students using Canvas and your Illinois email account; please check both regularly. Students can expect graded work to be returned within 10 days and questions will be answered as quickly as possible. Canvas is the best way to communicate, but I am also available via email and Zoom (during office hours/class time or a 1:1 meeting scheduled in advance).

## Required Textbook

Rubinstein and R.H. Colby, *Polymer Physics* (Oxford University Press, 2003, any edition)  
Additional texts of interest are listed at the end of the syllabus.

## Course Coverage

\*R&C – M. Rubinstein and R.H. Colby, *Polymer Physics* (Oxford University Press, 2003)

\*B&T – C. Branden & J. Tooze, *Introduction to Protein Structure* (Garland, 1999)

## **I. Polymer Structure & Ideal Chain Statistics (R&C §1, 2)**

*Macromolecular structure; fractal nature of polymer conformations; molar mass distributions; chain flexibility; ideal chain models; persistence length; radius of gyration; end-to-end vectors; conformational statistics; elementary statistical mechanics; ideal chain free energy; scaling arguments; coarse graining; pair correlation functions;*

## **II. Dilute Solutions & Real Chain Statistics (R&C §3, 5.5-5.6)**

*Monomer-monomer interactions; excluded volume; solvent quality; Flory theory; polymer deformation; temperature effects; role of spatial dimension; polymer collapse; three-body effects; virial expansion; tethered polymer brushes; chain adsorption and confinement.*

## **III. Liquid-Liquid Phase Separation (R&C §4)**

*Energy and entropy of mixing; mean field binary mixture theory - regular solution theory, polymer solutions, polymer blends; Flory interaction parameter; stability conditions; metastability, binodals, and spinodals; phase diagrams; lever rule; osmotic pressure; temperature-induced phase separation.*

## **IV. Dense Solutions & Melts (R&C §5.1-5.4, 5.7)**

*Dilute, semi-dilute, and concentrated regimes; theta, poor and good solvents; scaling concepts; osmotic pressure; correlation length.*

## **V. Rubber Networks & Chemical Gelation (R&C §6, 7.1-7.2)**

*Sol-gel model; random branching; percolation transition; crosslinking; hyperbranching and dendrimers; mean field gelation; scaling, hyperscaling, and universality; rubber thermodynamics; affine network model; phantom network model.*

## **VI. Polymer Physics at U of I**

*Discussion of ongoing research topics in different groups on Campus and how their research relates to the course content.*

## **Homework**

Twelve (12) homework assignments for this class will be issued via Canvas for each week (see [Class Schedule](#)). Students will have one week to complete the assignment and they are to be submitted on Canvas, usually on **Tuesdays 6pm CT**.

Late work will be generally be not accepted. The lowest score for homework and quiz will be dropped. *Students with valid reasons precluding on-time submission that should contact Prof. Statt well in advance of the deadline.* Students are strongly encouraged to complete all assignments to assess their own understanding of the course material. It is acceptable to work with fellow students on homework problems, and to ask as well as answer questions pertaining homework online on Canvas. Provision will be made for office hours during which to discuss the problems and solutions. Exam questions will be loosely based on assigned homework problems.

## Quizzes

Twelve (12) *short* online multiple-choice quizzes will be issued via Canvas each week (see [Class Schedule](#)), usually due on **Tuesdays 6pm CT**, to gauge elementary understanding and mastery of the course material. Each quiz has a time limit of 30 minutes and can only be taken once.

## Exams

There will be one (1) midterm exam, and one (1) final exam. Exams are planned to be in-person. Specific details will be made available a week before each exam. Both exams will be closed book, but students will be permitted to use a calculator and a single, double-sided, letter-sized sheet of handwritten notes. Resources outside of this are explicitly not permitted. The midterm will take place during scheduled class time, the final during the university final exam period (see [Class Schedule](#)). Efforts will be made to schedule exams to minimize scheduling conflicts, but *the responsibility lies with the student to anticipate and resolve scheduling conflicts with Prof. Statt well in advance of the exam dates.*

## Paper (4-credit option only)

Students in the 4-credit option will write a term paper on a student-selected topic in polymer physics. The term paper should be written in the style of a literature review or summary of a relevant research topic. *Students with valid reasons precluding on-time submission should contact Prof. Statt well in advance of the deadline.* The due dates are listed in the [Class Schedule](#).

**Topic:** Term paper topic selections are due via Canvas. Submissions should take the form of a one-sentence topic title and short ( $\leq 250$  word) abstract summarizing the topic and projected thrusts of the paper. Prof. Statt will be available to discuss and advise topic choice and general direction of the paper, overlap with relevant research projects of the student in the area of polymers are encouraged. Early topic identification and submission is also encouraged.

**Paper:** Both first draft and final version of the term papers are due via Canvas. Papers should be 5-6 pages in length (excl. figures and bibliography; 12-pt font, 1-inch margins, single-spaced). Students will research and summarize the state of the field, reference classic texts and papers, and identify the principal challenges, important questions, and current research directions in the field. Prof. Statt will be available to discuss and advise paper research and production. Papers will be graded on: (i) topic definition and motivation (10%), (ii) summary of status of field

(20%), (iii) identification and motivation of open challenges (25%), (iv) analysis of current research into identified challenge (20%), (v) clarity of report (10%), (vi) appropriate citations and formatted bibliography (5%).

**Peer review:** Reviews are due via Canvas. Each submitted paper will be assigned to two other randomly selected students in the class for peer review. Each student will write a *short* ( $\leq 1$  page) *constructive* review on their assigned papers, summarizing the content of the paper very briefly, and giving feedback on (i) topic, (ii) summary of the field, (iii) open challenges, (iv) analysis, (v) clarity of the term paper, as well as formatting/style. The remaining 10% of the grade will be the quality of the given peer review. Each student will receive the peer reviews on their paper, will incorporate the feedback and submit a final version via Canvas.

## Plagiarism

Each student is responsible for submitting their own original quiz responses, homework assignments, and (if applicable) term paper. Collaborative interaction online and in-person is permissible and encouraged via Canvas, but each student must perform all calculations themselves, and submit their own work. Plagiarism will not be tolerated, and verified incidents will result in all parties receiving a zero on their project and formal academic sanctions. Students are responsible for familiarizing themselves with the definition and penalties for plagiarism detailed in [Section I-401 of the UIUC Student Code](#). Ignorance of these policies is not an excuse for any academic dishonesty. As a student it is your responsibility to refrain from infractions of academic integrity and from conduct that aids others in such infractions. A short guide to academic integrity issues may be found [here](#). Do not hesitate to ask the instructor(s) if you are ever in doubt about what constitutes plagiarism, cheating, or any other breach of academic integrity. Note that the code's definition of plagiarism includes "copying another student's paper or working with another person when both submit similar papers without authorization to satisfy an individual assignment".

Please note that all course materials are protected by copyright and are considered intellectual property. Course materials should only be used for this course and should not be shared with anyone not in the course, including uploading to a study site, social media, or other online sharing mechanism.

## Grading

### A3/A4 (3-credits):

Quizzes:	10%
Participation:	5%
Homework:	25%
Midterm:	30%
Final:	30%

### A4 (4-credits):

Quizzes:	10%
Participation:	5%
Homework:	25%
Midterm:	20%
Final:	20%
Term paper:	20%

Participation includes participation via Socrative (<https://www.socrative.com/>), participating in discussions & questions during class, as well as posting content questions on Canvas, and answering content questions on Canvas. If a student participated actively in 50% of all weeks, the student will receive the full 5% credit.

Letter grades will be based on final aggregate student scores, with numerical cutoffs specified by the instructor. However, students with aggregate scores >95% are guaranteed *at least* an A, >85% *at least* a B, and >75% *at least* a C (i.e. cutoffs will not be higher than these values).

## Tentative Class Schedule

Class	Date	Day	Lecture Topic	HW, Quiz & Paper
			Course Introduction	
1	Jan 18	Tu	I. Polymer Structure & Ideal Chain Statistics	
2	Jan 20	T	I. Polymer Structure & Ideal Chain Statistics	
3	Jan 25	Tu	I. Polymer Structure & Ideal Chain Statistics	HW #1 & Quiz #1 due
4	Jan 27	T	I. Polymer Structure & Ideal Chain Statistics	
5	Feb 1	Tu	I. Polymer Structure & Ideal Chain Statistics	HW #2 & Quiz #2 due
6	Feb 3	T	I. Polymer Structure & Ideal Chain Statistics	
7	Feb 8	Tu	II. Dilute Solutions & Real Chain Statistics	HW #3 & Quiz #3 due, Paper topics due, 6pm CT
8	Feb 10	T	II. Dilute Solutions & Real Chain Statistics	
9	Feb 15	Tu	II. Dilute Solutions & Real Chain Statistics	HW #4 due & Quiz #4 due
10	Feb 17	T	II. Dilute Solutions & Real Chain Statistics	
11	Feb 22	Tu	II. Dilute Solutions & Real Chain Statistics	HW #5 & Quiz #5 due
12	Feb 24	T	III. Liquid-Liquid Phase Separation	
13	Mar 1	Tu	III. Liquid-Liquid Phase Separation	HW #6 & Quiz #6 due
14	Mar 3	T	III. Liquid-Liquid Phase Separation	Paper draft due, 6pm CT
15	Mar 8	Tu	III. Liquid-Liquid Phase Separation	HW #7 & Quiz #7 due
16	Mar 10	T	<b>Midterm Review</b>	
17	Mar 22	Tu	<b>MIDTERM EXAM</b>	

18	Mar 24	T	IV. Dense Solutions & Melts	
19	Mar 29	Tu	IV. Dense Solutions & Melts	HW #8 & Quiz #8 due
20	Mar 31	T	IV. Dense Solutions & Melts	Paper reviews due, 6pm CT
21	Apr 5	Tu	V. Rubber Networks & Chemical Gelation	HW #9 & Quiz #9 due
22	Apr 7	T	V. Rubber Networks & Chemical Gelation	
23	Apr 12	Tu	<b>BREAK</b>	
24	Apr 14	T	V. Rubber Networks & Chemical Gelation	HW #10 & Quiz #10 due
25	Apr 19	Tu	V. Rubber Networks & Chemical Gelation	
26	Apr 21	T	V. Rubber Networks & Chemical Gelation	HW #11 & Quiz #11 due
27	Apr 26	Tu	VI. Polymer Physics at U of I	Final paper due, 6pm CT
28	Apr 28	T	VI. Polymer Physics at U of I	HW #12 & Quiz #12 due
	May 3	Tu	<b>Final Review</b>	
	May 11		<b>FINAL EXAM</b>	

## Secondary Texts

P.C. Hiemenz, *Polymer Chemistry* (CRC Press, 1984)

P.-G. de Gennes, *Scaling Concepts in Polymer Physics* (Cornell University Press, 1979)

A.Y. Grosberg & A.R. Khoklov, *Statistical Physics of Macromolecules* (AIP, 2002)

Strobl, *The Physics of Polymers* (Springer, 2010)

A.Y. Grosberg & A.R. Khoklov, *Giant Molecules* (World Scientific Publishing, 2010)

U.W. Gedde, *Polymer Physics* (Springer, 1995)

Doi & S.F. Edwards, *The Theory of Polymer Dynamics* (Oxford University Press, 1988)

P.J. Flory, *Statistical Mechanics of Chain Molecules* (Oxford University Press, 1989)

P.J. Flory, *Principles of Polymer Chemistry* (Cornell University Press, 1953)

Branden & J. Tooze, *Introduction to Protein Structure* (Garland, 1999)

## **Anti-Racism and Inclusivity Statement**

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 Bias Assessment and Response Team (BART) (<https://bart.illinois.edu/>). Based on your report, BART 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.

## **Mental Health**

Diminished mental health, including significant stress, isolation, mood changes, excessive worry, substance/alcohol abuse, or problems with eating and/or sleeping can interfere with optimal academic performance, social development, and emotional wellbeing. The University of Illinois offers a variety of confidential services including individual and group counseling, crisis intervention, psychiatric services, and specialized screenings at no additional cost. If you or someone you know experiences any of the above mental health concerns, it is strongly encouraged to contact or visit any of the University's resources provided below. Getting help is a smart and courageous thing to do -- for yourself and for those who care about you.

Counseling Center: 217-333-3704, 610 East John Street Champaign, IL 61820

McKinley Health Center: 217-333-2700, 1109 South Lincoln Avenue, Urbana, Illinois 61801

## **Disability-Related Accommodations**

To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor and the Disability Resources 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](mailto:disability@illinois.edu) or go to <https://www.disability.illinois.edu>. If you are concerned you have a disability-related condition that is impacting your academic progress, there are academic screening appointments available that can help diagnosis a previously undiagnosed disability. You may access these by visiting the DRES website and selecting “Request an Academic Screening” at the bottom of the page.

## **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.

## **Religious Observances**

Illinois law requires the University to reasonably accommodate its students' 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 religious 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.

## **Sexual Misconduct Reporting Obligation**

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](http://wecare.illinois.edu/resources/students/#confidential).

Other information about resources and reporting is available here: [wecare.illinois.edu](http://wecare.illinois.edu).