Polymer Physics
MSE 458 / CHEM 482
Spring 2021

Instructor: Prof. A. Statt
statt@illinois.edu

Class:

Location:	online
Time:	2:00 – 3:20 pm
Days:	Tuesday, Thursday
Sections:	A3 (CRN-38260) – UG, 3 credit hours
	A4 (CRN-38261) – Grad, 3 or 4 credit hours

This class is completely online and utilizes Campuswire for communications and Gradescope for assignments. The course is divided by week and there are assignments and activities to be completed each week, including homework, watching/listening to lectures, quizzes, videos, and discussions. The class is designed to be interactive and your active participation is required.

Each week, there will be a set of *short* lecture videos for each sub-topic as well as synchronous sessions. The synchronous sessions on Tuesdays and Thursdays will be approx. 30-45 minutes long and will contain example calculations similar to the homework problems, discussions of past homework problems, discussions of lecture material, any questions raised during the week, and review of essential topics. Students are encouraged to watch the short lecture videos, read the corresponding chapters in R&C, and familiarize themselves with the current homework problem set *before* the corresponding synchronous session.

During our synchronous sessions on Tuesdays and Thursdays, I encourage you to use your webcam so we can see your face and connect with one another. If you have a question or want to participate in a discussion, you can use the chat feature to type your question or ask it verbally during the discussion. When you are not speaking, please keep your microphone on mute in order to minimize background noise and distractions. Disruptive behavior will not be tolerated.

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 Campuswire 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. Campuswire 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).

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.

Prerequisites

MSE 401 – Thermodynamics of Materials

OR 300-level course in thermo, statistical thermodynamics, or physical chemistry

****Required Text****

M. Rubinstein and R.H. Colby, *Polymer Physics* (Oxford University Press, 2003, any edition)

Secondary Texts

A.Y. Grosberg & A.R. Khoklov, *Statistical Physics of Macromolecules* (AIP, 2002)
P.-G. de Gennes, *Scaling Concepts in Polymer Physics* (Cornell University Press, 1979)
G. 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)
M. 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.C. Hiemenz, *Polymer Chemistry* (CRC Press, 1984)
P.J. Flory, *Principles of Polymer Chemistry* (Cornell University Press, 1953)
C. Branden & J. Tooze, *Introduction to Protein Structure* (Garland, 1999)

Homework

Eleven (11) homework assignments for this class will be issued via Gradescope for each week (see schedule). Students will have one week to complete the assignment and they are to be submitted on Gradescope before Class (2pm) on the day that they are due, usually Tuesdays. Late work up to 24 hours will be accepted three times. *Students with valid reasons precluding on-time submission beyond 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 Campuswire. 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 Gradescope each week, usually Thursdays, to gauge elementary understanding and mastery of the course material.

Exams

There will be one (1) midterm exam, and one (1) final exam. Both exams will be issued and submitted via Gradescope, specific details will be made available a week before the exam. We will not utilize any proctoring service, but instead rely on the academic integrity and responsibility of each student. 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 (including fellow students, textbooks, lecture notes, and online resources) are explicitly not permitted. The midterm will take place during scheduled class time, the final during the university final exam period. 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 schedule.

Topic: Term paper topic selections are due via Gradescope. Submissions should take the form of a one-sentence topic title and short (≤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 Gradescope. 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 Gradescope. Each submitted paper will be assigned to two other randomly selected students in the class for peer review. Each student will write a *short* (≤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 Gradescope.

Plagiarism

Each student is responsible for submitting their own original quiz responses, homework assignments, and (if applicable) term paper. Collaborative interaction is permissible and encouraged via Campuswire, 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 (https://studentcode.illinois.edu/article1/part4/1-401/.). 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: https://provost.illinois.edu/policies/policies/academic-integrity/students-quick-reference-guide-to-academic-integrity/. 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):		**A4 (4-credits):**	
Quizzes:	5%	**Quizzes:**	5%
Participation:	10%	**Participation:**	10%
Homework:	25%	**Homework:**	20%
Midterm:	30%	**Midterm:**	25%
Final:	30%	**Final:**	25%
		Term Paper:	15%

Participation includes class attendance, participating in discussions & questions during class, watching class videos, posting content questions on Campuswire, and answering content questions on Campuswire.
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).

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 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.

Other information about resources and reporting is available here: wecare.illinois.edu.

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.

Tentative Schedule

Class	Date	Day	Lecture Topic	HW, Quiz & Paper
1	Jan 26	Tu	Course Introduction I. Polymer Structure & Ideal Chain Statistics	
2	Jan 28	T	I. Polymer Structure & Ideal Chain Statistics	
3	Feb 2	Tu	I. Polymer Structure & Ideal Chain Statistics	HW #1 & Quiz #1 due
4	Feb 4	T	I. Polymer Structure & Ideal Chain Statistics	
5	Feb 9	Tu	I. Polymer Structure & Ideal Chain Statistics	HW #2 & Quiz #2 due
6	Feb 11	T	I. Polymer Structure & Ideal Chain Statistics	
7	Feb 16	Tu	II. Dilute Solutions & Real Chain Statistics	HW #3 & Quiz #3due, Paper topics due, 6pm CT
8	Feb 18	T	II. Dilute Solutions & Real Chain Statistics	
9	Feb 23	Tu	II. Dilute Solutions & Real Chain Statistics	HW #4 & Quiz #4 due
10	Feb 25	T	II. Dilute Solutions & Real Chain Statistics	
11	Mar 2	Tu	II. Dilute Solutions & Real Chain Statistics	HW #5 & Quiz #5 due
12	Mar 4	T	III. Liquid-Liquid Phase Separation	
13	Mar 9	Tu	III. Liquid-Liquid Phase Separation	HW #6 & Quiz #6 due
14	Mar 11	T	III. Liquid-Liquid Phase Separation	Paper draft due, 6pm CT
15	Mar 16	Tu	III. Liquid-Liquid Phase Separation	HW #7 due, Quiz #7 due
16	Mar 18	T	**Midterm Review**	
17	Mar 23	Tu	**MIDTERM EXAM**	
18	Mar 25	T	IV. Dense Solutions & Melts	
19	Mar 30	Tu	IV. Dense Solutions & Melts	HW #8 & Quiz #8 due
20	Apr 1	T	IV. Dense Solutions & Melts	Paper reviews due
21	Apr 6	Tu	V. Rubber Networks & Chemical Gelation	HW #9 & Quiz #9 due
22	Apr 8	T	V. Rubber Networks & Chemical Gelation	
23	Apr 13	Tu	**BREAK**	
24	Apr 15	T	V. Rubber Networks & Chemical Gelation	HW #10 & Quiz #10 due
25	Apr 20	Tu	V. Rubber Networks & Chemical Gelation	

26	Apr 22	T	V. Rubber Networks & Chemical Gelation	HW #11 & Quiz #11 due
27	Apr 27	Tu	VI. Polymer Physics at U of I	Final paper due, 6pm CT
28	Apr 29	T	VI. Polymer Physics at U of I	HW #12 & Quiz #12 due
	May 4	Tu	**Final Review**	
	May 7-14		**FINAL EXAM**	