Polymer Physics
MSE 458 / CHEM 482
Spring 2018

Instructor: Prof. A.L. Ferguson
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Grader: Bryce Thurston
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Class:

Location:	4101 MSEB
Time:	2:00 – 3:20 pm
Days:	T, Th
Sections:	A3 (CRN-38260) – UG, 3 credit hours
	A4 (CRN-38261) – Grad, 3 or 4 credit hours

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)

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

Six (6) homework assignments for this class will be issued via Compass at the end of each unit (see schedule). Students will have approximately one week to complete the assignment, and

are to be submitted to Prof. Ferguson at the **beginning of class** on the day that they are due. **Late work will not be accepted,** *but students with valid reasons precluding on-time submission should contact Prof. Ferguson well in advance of the deadline***.** Students are strongly encouraged to complete all assignments to assess their own understanding of the course material. 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

Six (6) short online multiple-choice quizzes will be issued via Compass at the end of each unit to gauge elementary understanding and mastery of the course material. Quizzes are due the same day as the associated homework, and must be completed **before the beginning of class**. Access to the quiz will close at this time, and solutions will be immediately posted. **Accordingly, late work cannot be accepted and no extensions given.**

Exams

There will be one (1) 75-minute midterm exam, and one (1) three-hour final exam. Both exams will be closed book, but students will be permitted to bring a calculator and a single, double-sided, letter-sized sheet of notes into the exam hall. 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. Ferguson well in advance of the exam dates***. It may not be possible to resolve conflicts brought to Prof. Ferguson's attention within one week or less of the scheduled exam date.

Paper (4-credit option only)

Students in the 4-credit option will write a term paper on a student-selected topic in polymer physics.

Topic: **Term paper topic selections are due via Compass by 11:59pm on Thu March 15**. 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. Ferguson will be available to discuss and advise topic choice. Early topic identification and submission is encouraged.

Paper: Papers should be 5-8 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. Ferguson 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 (25%), (iii) identification and motivation of open challenge (25%), (iv) analysis of current research into identified challenge (25%), (v) clarity of report (10%), (vi) appropriate citations and formatted bibliography (5%). **Papers are due via Compass by 11:59pm on Thu April 19. Late submissions will not be accepted,** *but students with valid reasons precluding on-time submission should contact Prof. Ferguson well in advance of the deadline***.**

Plagiarism

Each student is responsible for submitting his or her own original quiz responses, homework assignments, and (if applicable) term paper. Collaborative interaction is permissible, 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. 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".

Grading

A3/A4 (3-credits):	
Quizzes:	5%
Homework:	25%
Midterm:	30%
Final:	40%

A4 (4-credits):	
Quizzes:	5%
Homework:	20%
Midterm:	25%
Final:	35%
Term Paper:	15%

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).

Office Hours

Prof. Ferguson – Thu 8:30-9:30 am, 204 MSEB
TA Bryce Thurston – Wed 4-5 pm, 205A MSEB

Compass

Course announcements, quizzes, homework assignments, and solution keys will be posted via Compass (https://compass2g.illinois.edu). Term papers will be submitted via this portal. It is students' responsibility to periodically check Compass for announcements and updates.

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; experimental measurements of mass distributions and chain size.

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. Biopolymer Structure & Conformation (B&T §1, 2, 7)

DNA and protein chemistry; the double helix and higher-order DNA organization; elements of protein secondary structure; protein tertiary structure and function; molecular forces in protein folding; the "new view' of protein folding.

Tentative Schedule

Class	Date	Day	Lecture Topic	PS & Quiz	Paper
1	Jan 16	T	I. Polymer Structure & Ideal Chain Statistics		
2	Jan 18	Th	I. Polymer Structure & Ideal Chain Statistics		
3*	Jan 23	T			
4	Jan 25	Th	I. Polymer Structure & Ideal Chain Statistics		
5	Jan 30	T	I. Polymer Structure & Ideal Chain Statistics		
6	Feb 1	Th	I. Polymer Structure & Ideal Chain Statistics		
7	Feb 6	T	I. Polymer Structure & Ideal Chain Statistics		
8	Feb 8	Th	II. Dilute Solutions & Real Chain Statistics		
9	Feb 13	T	II. Dilute Solutions & Real Chain Statistics		
10	Feb 15	Th	II. Dilute Solutions & Real Chain Statistics	#1 due	
11	Feb 20	T	II. Dilute Solutions & Real Chain Statistics		
12	Feb 22	Th	II. Dilute Solutions & Real Chain Statistics		
13*	Feb 27	T	III. Liquid-Liquid Phase Separation		
14	Mar 1	Th	III. Liquid-Liquid Phase Separation	#2 due	
15	Mar 6	T	III. Liquid-Liquid Phase Separation		
16	Mar 8	Th	III. Liquid-Liquid Phase Separation		
17	Mar 13	T	IV. Dense Solutions & Melts		
18	Mar 15	Th	IV. Dense Solutions & Melts	#3 due	Topic due
	Mar 20	T	**SPRING BREAK – NO CLASS**		
	Mar 22	Th	**SPRING BREAK – NO CLASS**		
19	Mar 27	T	IV. Dense Solutions & Melts		
20	Mar 29	Th	**MIDTERM EXAM**		
21	Apr 3	T	V. Rubber Networks & Chemical Gelation		
22	Apr 5	Th	V. Rubber Networks & Chemical Gelation		
23	Apr 10	T	V. Rubber Networks & Chemical Gelation		
24	Apr 12	Th	V. Rubber Networks & Chemical Gelation	#4 due	
25	Apr 17	T	V. Rubber Networks & Chemical Gelation		
26	Apr 19	Th	VI. Biopolymer Structure & Conformation		Paper due
27*	Apr 24	T			
28	Apr 26	Th	VI. Biopolymer Structure & Conformation	#5 due	
29	May 1	T	VI. Biopolymer Structure & Conformation		
	May 3	Th	**READING DAY – NO CLASS**	#6 due	
	May 4-11		**FINAL EXAM – *8-11 am, Fri 5/4, 119 MSEB***		

* Prof. Ferguson will be on travel these dates, appropriate arrangements TBA.