MSE-4140 (3-0-3): POLYMER PHYSICS

Physical chemistry of polymer solutions, polymer miscibility, adsorptions, sorptions, plasticization, molecular weights, molecular weight distributions. Study of polymer surfaces.

Course description:

Study of polymer solutions, physical chemistry of polymer solutions, scattering as a method to probe polymer solutions and melts, polymer miscibility, solutions of rod-like macromolecules and formation of ordered phases (liquid crystals), and dynamics of polymers in solution and in melt. This includes studies of diffusion, rheology of polymer solutions and melts, and molecular theories to understand the rheological behavior.

Pre-requisite: MSE-3001 and MSE-4775

Lecture period: TThurs, 3:30 - 4:45 PM
Lecture room: College of Computing Rm 52

Textbook: *Polymer Physics* by Michael Rubenstein and Ralph Colby

Instructor: Dr. Mohan Srinivasarao (404-894-9348, Love-166, mohan@mse.gatech.edu)
Office hour: Tuesday mornings from 11:00 to 12:00.

TA:

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Course Page: Canvas will be used to post the course syllabus, lecture notes, papers for your reading as well as any other material that is deemed necessary. You may also be asked to submit your assignments via Canvas. Important announcements will be sent to your Canvas account so please check it regularly.

Extenuating Circumstances:

Please be sure to meet with the Dean of Students if you encounter extenuating circumstances that interfere with your ability to attend class and/or prepare for exams. The Dean's office is your best resource so that you do not need to discuss the details of your personal situation with the instructor.

Course Outcomes:

The student will grasp fundamental knowledge of polymer physics, including structure-property relationship, polymer-polymer or polymer-solvent interaction, phase behavior of the flexible and liquid crystalline polymers, the effect of polymer structure on the viscoelasticity, and so on. Some of the objectives are listed below:

1. The student will learn basic chain conformations of polymers and the models to describe them. This will provide them with a working knowledge of correlating the chain dimension with the molecular weight, an essential aspect of polymer physics.
2. The student will demonstrate an ability to use dilute solution viscometry and light scattering methods to determine the molecular weights of polymers and how these methods can manifest the polymer-solvent interactions.
3. The student will learn the thermodynamics of polymer-solvent and polymer-polymer mixing and the phase diagrams. The mechanisms of the phase separation and how to use them will be demonstrated to create target-oriented morphologies and products.
4. The student will learn the phase behaviors, optical properties, viscoelastic properties, and applications of the liquid crystalline polymers. The student will also learn theories, phases, materials properties, and applications of small molecule liquid crystals.
5. The student will learn how the viscoelastic properties of polymers depend on the nature of the polymer backbone and side chains, mostly via experimental results.

Tentative topical outline:

1. Introduction

   What are polymers? Why do they behave differently from other materials? How are their molecular weights defined and *measured*?

2. What are the chain characteristics?

   Included in this are things dealing with the size of polymer chains, different models for chain conformation and *why is an understanding of the chain conformation of paramount importance in dealing with polymers either in the melt or in solution*.

3. How do flexible polymers behave in solution?

   What properties change with the addition of polymers to a solvent? Included in this are things that deal with Osmotic Pressure, light scattering and the connection between the two – scattered intensity and osmotic pressure – analogy to ideal gas law, molecular weight determination using light scattering, viscosity, and osmotic pressure, among other things.

4. What governs the miscibility and phase diagram of a polymer in solution?

   Included in this are things dealing with entropy of mixing, lattice model, and the derivation of Flory-Huggins expression for the free energy of polymers in solution, and calculation of phase boundaries – modes of phase separation and how does one interrogate phase separation?

5. How do rod-like polymers and small molecule liquid crystals behave in solution?

   Why do liquid crystalline materials have anisotropic properties? How do the properties change when the polymer added to a solvent has a rod-like nature as opposed to random

chain conformation? Viscosity, phase behavior and formation of ordered phases will be included in the discussion.

6. How do polymer chains deform and flow in melt or in solution?

   Discussion will include: theories of viscosity, dependence of viscosity on molecular weight of the polymer, reputation, etc. The rheological behavior is discussed mostly under shear stress, with various stress history.

7. How do polymer chains behave on various surfaces? (This may or may not be covered)

   Topics will include surface tension, contact angle, wetting/dewetting, etc.

Pre-Semester Exam: The purpose of the pretest is to document your knowledge when you enter the class, so there is no expectation that you will answer the questions correctly. *This is just for my information only.*

Grading:

Writing Assignments	10%
Group Assignments	10%
Pre-semester Exam	5% Full Credit if you take it!
Examination 1 (1st October 2026)	20 %
Examination 2 (10th November 2026)	20 %
Final exam (***Cumulative***, TBD)	35 %

Grades: Your grade in the course will be assessed based on your performance on three written examinations. The first two examinations will be held during the regular meeting time of the class on the dates indicated on the syllabus. The last examination will be administered during the final exam period (2 hours 50 minutes). Final grades will be based on the following:

Course Grades: **Score** 89.5% - 100% (A); 74.5% - 89.4% (B); 59.5% - 74.4% (C); 49.5% - 59.4%(D); < 49.5% (F)

Written Assignments: This is important for appreciating the material that will be covered in the semester.

I *will provide writing assignments* for you every so often – When you write, you will have to organize your thoughts, and present the arguments in a logical fashion, which enables you to "learn" the material. I have been doing this for the past two years, and it has helped students understand the material better. I am asking you to write, because I believe that writing requires serious thinking. In addition, serious thinking is what I am really after – in other words, I want to make you curious.

These are not to be graded, but they carry 10% of the grades of the course. If you make an earnest attempt, you will get the 10% assigned. These assignments maybe given, to be completed during class, say at the end of the class; or a longer assignment asking you to describe an experiment that was described in class or some other combination, *all with the idea of helping you understand the material that is presented*.

Final Exam Conflicts: The Institute has established the policies for final exam scheduling conflicts that are summarized in the list below. If you request an accommodation, please contact the instructor via email and include a list of all of your courses (course numbers and sections) and their exam periods on the day in question. If you have additional questions about the Institute's policies, please refer to the Office of the Registrar's website which is located at http://www.registrar.gatech.edu/students/examguide.php . Please note the following Institute policies:

- "All students should check the Final Exam Schedule against their own class schedule and report any conflicts to the instructor(s) as soon as possible. It is the responsibility of each student to see that all possible conflicts are resolved by the instructor and the proper authorization received no later than 2 weeks before the Monday of exam week. A special period is provided as a conflict period in which to reschedule conflicting examinations. Refer to the Final Exam Schedule for the conflict date. Other periods within the exam week may also be used for conflicting examinations provided no student is forced to take more than two examinations in one day."
- "Any course that is offered outside the normal scheduling format must make arrangements to give way to courses offered in the normal time slot. If a conflict arises between two courses that offer finals outside the normal scheduling format, the conflict will be resolved by the instructor rescheduling the examination for the course with the lower number. The common final for any course may not take up more than one exam period."
- "In the event a student has two examinations scheduled for the same period, the conflict will be resolved by the course having the lower course level number being considered in conflict. The final examination in that course shall be given during the conflict examination period or, by agreement of the instructor and the student, at a mutually satisfactory time."
- "In the event a student is scheduled for three examinations in one day, the examination scheduled for the middle period will be considered in conflict. The conflict will be resolved by giving the examination during the conflict period at another time mutually

agreed upon by the instructor and the student."

Academic Integrity: All students in this class are expected to respect the *Georgia Tech honor code* and behave in a professional manner when it comes to academic integrity. Any students violating the honor code or suspected of academic misconduct will be turned over to the office of Academic Integrity, Dean of Students to investigate the incident(s). Cheating off of another person's test or quiz is unethical and unacceptable. Cheating off of anyone else's work is a direct violation of the GT Academic Honor Code, and will be dealt with accordingly. *For any questions involving any Academic Honor Code issues, consult me, my teaching assistants, or* www.honor.gatech.edu.

Word: Use of any previous semester course materials is allowed for this course; however, I remind you that while they may serve as examples for you, they are not guidelines for any tests, quizzes, homework, or any other coursework that may be assigned during the semester.

Special Needs: The Georgia Institute of Technology encourages qualified persons with disabilities to participate in its programs and activities. If you anticipate needing any type of accommodation in this course or have questions about physical access, please tell the instructor as soon as possible.

Finally something about *Netiquette (This is very important, especially in communications)*

- Netiquette refers to etiquette that is used when communicating on the Internet. Review the Core Rules of Netiquette. When you are communicating via email, discussion forums or synchronously (real-time), please use correct spelling, punctuation and grammar consistent with the academic environment and scholarship.

Rules of Academic Etiquette (From: Molly Worthen, UNC – Chapel Hill)

General rules of thumb:

- When in doubt about how you should speak, write, or act, *always err on the side of formality.* You will never offend or annoy someone by being overly formal and polite.
- While you are in college, your coursework is your job. You should behave as you would in a professional work environment.

When addressing your professor(s) in person:

- Always address them as "Professor Smith" or "Dr. Smith."
- Do not call them by their first names or anything else unless they explicitly ask you to do so.

When writing an email to your professor:

- Begin the email with "Dear Professor Smith," Dear Prof. Smith," or "Dear Dr.

Smith." Do not begin the email "Hi" without addressing your professor by their title and surname.

- Emails should ***not be in a confrontational tone***. For example, if you want to discuss your exam and how it is graded, do not write saying "I want to *contest* my exam" – This is confrontational and sets the tone for the meeting. Be mindful of the fact emails can be misread.
- *Be alert to the tone of your message*. Any email to a professor or teaching assistant should sound like a formal letter, not a text message or a demand to a customer service representative. For example, you should write:

Dear Professor Smith,
I cannot come to your office hours this week. Are you available at any time on Monday instead?
Sincerely, Jane

Do NOT write

Hi,
I need to talk to you about the test. Can I come by Mon? Thx Jane

Do NOT write

Hello,
I'm a senior and I need your class to graduate. ConnectCarolina says I need permission. I need you to enroll me immediately.
Jane

- Write in complete sentences with correct spelling, grammar, and punctuation.
- Proofread your email before sending it.

Course Policy:

The course is quite ***conceptual in nature*** and will require *you to understand the material* rather than memorize things for an exam. *If you do not understand the material, well, then the exams **as judged by you** will be difficult*. Hence, spending time to understand the fundamental concepts is quite important.

All the topics included may not be fully covered, while new topics may be included, depending on the need of the students. Often times covering all the topics comes at the expense of the student(s) learning the material and having a good understanding of the subject matter. Understanding of the material is defined as your ability to explain things to others in a clear fashion. You may be called upon to explain certain concepts to the class from time to time just so I know to what extent you have understood the material. You may

also be given papers from the literature that you will be responsible for, and again, understanding the literature is quite important.

Questions before, during, or after class are most welcome. Please do not hesitate to ask questions no matter how silly you might think the question is. Usually what one considers to be, "silly" questions, are the ones that lead to a better understanding of the material.

There will be no make-up exams for any missing one, unless there are extenuating circumstances. In this case, the student must inform me ***before*** the exam or contact the office of Dean of Students.

Useful References:

For the general Audience:

P. G. de Gennes and Jacques Badoz, *Fragile Objects - Soft Matter, Hard Science and the Thrill of Discovery*, Springer

Historical Aspect of Polymer Science

Herbert Morawetz, *Polymers: The origins and Growth of a Science*, Dover Publication 0-486-68732-5

Books that will be used during the course of the semester (It may not seem that way!)

- Michael Rubinstein and Ralph Colby, ***Polymer Physics***, Oxford University Press [Many things are taken from this book but not exclusively.]
- Bill Graessley, *Polymer Liquids and Networks*: *Structure and Properties*, Garland Science, 2003
- *Macromolecules: An introduction of Polymer Science*, Edited by F. A. Bovey and F. H. Winslow, Academic Press, 1979
- Paul J. Flory, *Principles of Polymer Chemistry*, Cornell University Press
  [Any student serious about learning polymer science and wants to work in areas related to polymer MUST possess this book.]
- Paul J. Flory, *Statistical Mechanics of Chain molecules*, Hanser Publishers
  [An advanced text on statistical mechanics of polymer chains.]
- Charles Tanford, *Physical Chemistry of Macromolecules*, John Wiley
  [A very nice book with a focus on biopolymers.]
- Maso Doi and Sir Sam Edwards, "*The Theory of Polymer Dynamics*", Oxford University Press [An advanced text but a very useful one.]
- P. G. de Gennes, *Scaling concepts in Polymer Physics*, Cornell University Press

[A classic book on scaling theories of polymer chains.]

- P. G. de Gennes, *Soft Interfaces – Focused on adhesion*
  [A very nice introduction.]
- P. G. de Gennes, *The Physics of Liquid Crystals*, Clarendon Press, 1974
  [A classic for liquid crystal physics.]

Required Items (from Georgia Tech Rules)

Students with special needs or accommodation, please contact the Office of Disability Services https://disabilityservices.gatech.edu

Student-Faculty expectations are given here: https://catalog.gatech.edu/rules/22/

Students are expected to fully comply with the Georgia Tech Honor Code given here: https://policylibrary.gatech.edu/student-life/academic-honor-code