CE 599: Soft Matter in Civil and Environmental Engineering

Units: 2.0
Fall 2023

Location: TBD

Instructor: Thomas A. Petersen, Assistant Professor, Department of Civil & Environmental Engineering
Office: KAP 230C
Office Hours: TBD
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Course Description

Prerequisites: CE 325 (Mechanics of Deformable Bodies), CE 309 (Fluid Mechanics), Math 226 (Calculus III)

Textbook:

Primary textbook: Soft Matter Physics by Masao Doi (Oxford University Press, 2013)
Other references: Intermolecular and Surface Forces by Jacob Israelachvili (Academic Press, 2011); The Colloidal Domain by Evans and Wennerström (Wiley-VCH, 1999); The Structure and Rheology of Complex Fluids by Ron Larson (Oxford University Press, 1999); Review articles.

Course Overview

The purpose of this course is to introduce students to the topics of soft matter physics and their applications in civil and environmental engineering. While the term "soft matter" was first used to describe materials with intermediate properties between those of solids and liquids – materials that can undergo large deformations without irreversible damage – it now more broadly encompasses complex materials, including polymers, colloids, surfactants, granular media, and electrochemical systems, that generally interact through weak interparticle forces. On the civil engineering side, soft matter concepts will be used to characterize muds, sedimentary rocks, and cement-based materials for use in construction and energy. On the environmental engineering side, topics will include electrochemical processes, sedimentation, diffusion, and permeation for use in, *e.g.*, contaminant separation and transport. As this is a 2.0 Unit course, each topic and the important governing engineering equations will be introduced, focusing on how the underlying physics connect to the engineering application.

Learning Objectives

After completing this course, students will be able to:

- Define and identify soft matter materials and their use in engineering applications.
- Describe the origin of the intermolecular, interparticle, and inter-surface forces of soft matter materials.
- Characterize and understand the challenges in characterizing the complex rheological and mechanical behavior of granular materials, polymers, gels, surfactants, and suspensions.
- Describe the thermodynamics and phase behavior of precipitating solids and phase separating gels.
- Identify the forces driving transport of diffusing and electrochemically coupled species in and out of porous media.
- Identify experimental techniques for quantifying intermolecular forces and characterizing material microstructure.

Homework and Project Guidelines

- Homework will cover the varying soft matter topics introduced in class and may include commenting on or applying concepts from a review article or solving problem statements in the context of civil and environmental engineering applications. Students will generally have ~2-3 weeks to complete each homework, which will be graded on a scale from 0-20. No late homework assignments will be accepted.
- Mini Research Projects will be proposed by the students in the half of the semester. Students will have the remainder of the semester to plan and execute their research projects, which should include an experimental component (either numerical or physical). The research project will include a summary report on the research objective, methods, outcomes, and conclusions and a presentation in the final week of class. Depending on the number of students in the class, projects will be either collaborative (performed in groups of 2-3 students) or individual.

Grading Breakdown

Homework (50%), Final Project (50%)

Grading Scale

Course grades will be determined using the following scale:

Letter grade	Corresponding numerical point range
A	[90,100]
B	[80,90)
C	[70,80)
D	[60,70)
F	[0,60)

Classroom and course expectations

Instructor expectations: Students are expected to form an independent understanding of the course material by reading assigned sections of the book and research articles and by working through homework problems. Students should expect to dedicate around 2-4 hours of out-of-class time reviewing the course material, completing the homework assignments, and developing their research project deliverables.

Instructor commitment: Students can expect that the instructor will be punctual, well-organized, and prepared for office hours. The instructor will respond to email inquiries within 24 hours during the week (M-F) but may not be able to respond to inquiries over the weekend. If the instructor is unable to answer questions effectively during class or office hours, they will follow up online or through email.

Collaboration: In this class, you are expected to submit work that demonstrates your individual mastery of the course concepts.

- Working on HW problems collaboratively in groups is permitted and encouraged. If collaborating, the expectation is that students come to an understanding of how problems are solved through collaborative discussion and are subsequently able to write up their solution approach *independently*. (No two HW solutions should look identical or correspond to a solution found in a solution manual)

Course-specific information on academic integrity

Any evidence of unapproved collaboration or inappropriate use of resources during the completion of homework assignments will be considered an academic integrity violation. **At a minimum**, this violation will result in the **forfeit of the entire homework score.**

Course Schedule

	Topics/Daily Activities	
Week 1	Introduction of soft matter: What is soft matter and why is it important engineering applications?	
Week 2	Interactions involving atoms and molecules / Interactions involving particles and surfaces	
Week 3	Surface tension (Applications: Flow through porous media, drying forces in porous materials, oil spills)	HW1 Assigned
Week 4	Surface tension (Applications: Flow through porous media, drying forces in porous materials, oil spills)	
Week 5	Diffusion and permeation (Application: Flow through porous media; contaminant transport)	HW 1 Due
Week 6	Diffusion and permeation (Application: Flow through porous media; contaminant transport)	
Week 7	PROJECT PROPOSALS	HW 2 Assigned
Week 8	Ionic soft matter (Application: Batteries, 3D printing, membranes)	
Week 9	Ionic soft matter (Application: Batteries, 3D printing, membranes)	HW 2 Due
Week 10	Flow and deformation - viscosity, elasticity, creep (Application: asphalt/pavements, foods, personal care prodcuts)	
Week 11	Flow and deformation - viscosity, elasticity, creep (Application: asphalt/pavements, foods, personal care prodcuts)	HW 3 Assigned
Week 12	Thermodynamics of solutions, nucleation & growth, and phase separation (Application: Cement, carbonates)	
Week 13	Thermodynamics of solutions, nucleation & growth, and phase separation (Application: Cement)	HW 3 Due
Week 14	Granular Media, Packing and Constitutive Relations (Applications: Geotechnical engineering, geophysics, flow of grains)	
Week 15	PROJECT PRESENTATIONS	

Academic Integrity

The University of Southern California is foremost a learning community committed to fostering successful scholars and researchers dedicated to the pursuit of knowledge and the transmission of ideas. Academic misconduct is in contrast to the university's mission to educate students through a broad array of first-rank academic, professional, and extracurricular programs and includes any act of dishonesty in the submission of academic work (either in draft or final form).

This course will follow the expectations for academic integrity as stated in the USC Student Handbook. All students are expected to submit assignments that are original work and prepared specifically for the course/section in this academic term. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s). Students suspected of engaging in academic misconduct will be reported to the Office of Academic Integrity.

Other violations of academic misconduct include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity, see the student handbook or the Office of Academic Integrity's website, and university policies on Research and Scholarship Misconduct.

Course Content Distribution and Synchronous Session Recordings Policies

USC has policies that prohibit recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Recording a university class without the express permission of the instructor and announcement to the class, or unless conducted pursuant to an Office of Student Accessibility Services (OSAS) accommodation. Recording can inhibit free discussion in the future, and thus infringe on the academic freedom of other students as well as the instructor. (Living our Unifying Values: The USC Student Handbook, page 13).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which had been distributed to students or in any way had been displayed for use in relationship to the class, whether obtained in class, via email, on the internet, or via any other media. (Living our Unifying Values: The USC Student Handbook, page 13).

Statement on Academic Conduct and Support Systems

Academic Integrity:

The University of Southern California is a learning community committed to developing successful scholars and researchers dedicated to the pursuit of knowledge and the dissemination of ideas. Academic misconduct, which includes any act of dishonesty in the production or submission of academic work, comprises the integrity of the person who commits the act and can impugn the perceived integrity of the entire university community. It stands in opposition to the university's mission to research, educate, and contribute productively to our community and the world.

All students are expected to submit assignments that represent their own original work, and that have been prepared specifically for the course or section for which they have been submitted. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s).

Other violations of academic integrity include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), collusion, knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university. All incidences of academic misconduct will be reported to the Office of Academic Integrity and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see the student handbook or the Office of Academic Integrity's website, and university policies on Research and Scholarship Misconduct.

Please ask your instructor if you are unsure what constitutes unauthorized assistance on an exam or assignment, or what information requires citation and/or attribution.

Students and Disability Accommodations:

USC welcomes students with disabilities into all of the University's educational programs. The Office of Student Accessibility Services (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at osas.usc.edu. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

988 Suicide and Crisis Lifeline - 988 for both calls and text messages – 24/7 on call
The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline is comprised of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL) – 24/7 on call
Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

Office for Equity, Equal Opportunity, and Title IX (EEO-TIX) - (213) 740-5086

Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

The Office of Student Accessibility Services (OSAS) - (213) 740-0776
OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

USC Campus Support and Intervention - (213) 740-0411
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity, Equity and Inclusion - (213) 740-2101
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-1200 – 24/7 on call
Non-emergency assistance or information.

Office of the Ombuds - (213) 821-9556 (UPC) / (323-442-0382 (HSC)
A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

Occupational Therapy Faculty Practice - (323) 442-2850 or otfp@med.usc.edu
Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.