MCEN 6228-001
Wetting, Adhesion and Friction
Fall 2021

Lectures: 11:10-12:25pm on Tuesdays and Thursdays
Norlin Library (LIBR) M300D

Instructors:

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Office hours: By Appointment (please email the instructors to set up office hour appointment)

Course Description:
This course will introduce fundamental concepts, measurements, theories, and practical applications related to wetting, adhesion and friction with a focus on soft material systems. Topics to be discussed include: surface tension & energy; capillarity; contact mechanics; interfacial tension/energy; contact angle; droplet spreading; wetting in porous materials; topographic influence on wetting; electric wetting; fluid instabilities related to surface energy; adhesive contact theories; thin film adhesion; elasto-capillarity; classical friction laws; microscopic mechanism of friction; lubrication theory; rubber friction theory; friction of multiphase materials.

References:
No textbook is required for this course. Lecture notes and assignments will be distributed online through Canvas. Below is a list of suggested references:

- J. Israelachvili, 2011, *Intermolecular and Surface Forces*, 3rd edition, Academic Press.
- K.L. Johnson, 1985, *Contact Mechanics*, Cambridge University Press.
- F.P. Bowden & D. Tabor, 1973, *Friction: An Introduction to Tribology*, Anchor Press.
- P.G. de Gennes, F. Brochard-Wyart, D. Quere, 2004, *Capillarity and Wetting Phenomena: Drops, Bubbles, Pearls,* Waves, Springer-Verlag.

Grading:
The final grade will be evaluated based on three components: assignments (optional), a midterm presentation (50%), a term paper (50%).

- *Assignments* (optional): There will be 3 assignments throughout the semester. Each assignment will consist of 2 questions. Completion of the assignments will be optional. Solution will be provided together with the assignments.
- *Midterm Presentation* (50%): Students are required to work in groups of two to make a 35-minute presentation on an assigned topic in the middle of the semester (October 7-14). Details of the presentation are described in the next page.
- *Term paper* (40%): Students are required to work in groups of two to complete a term paper on an assigned topic at the end of the semester. Details of the term paper are described in the next page.

Online resources: Lecture notes, assignments, and solutions will be posted on Canvas.

Midterm Presentation and Term Paper

Students in this class are required to work in groups to complete a *midterm presentation* and a *term paper*. The purpose of the presentation and term paper is to encourage active learning and provide training in technical writing, reporting and teamwork.

Group formation: The instructors will assign groups (2 students per group) and the topic for each group. This process will be completed by mid-September.

Topics: the topics are organized around a common theme: *Adhesion and friction of soft materials: interface, geometry and mechanics.* These topics include:

Midterm Presentation:

- Elastocapillarity: wetting on soft substrate.
- Novel surface treatment for wettability control. (aqueous, oil, structural).
- Surface architecture and adhesion in soft materials.
- Underwater adhesion.
- Hydrogel adhesion.
- Adhesives in biological/medical systems.

Term paper:

- Topics for the term paper be announced after the Midterm Presentation is completed.

Grading: The guidelines for grading are described below. It is assumed that every member of one group will contribute equally and thus will receive the same grade.

Midterm Presentation: (50% of the final grade): The students should present their project in a clear and concise manner. Relevance to the topic, clarity and organization of the presentation will be the main considerations for grading.

Term paper: (50% of the final grade): the term paper should be written in the format and quality of journal publications: a title, a brief abstract, sections of main texts and references. The maximum number of pages is 10 (with 12-point font, 1-inch margin, and 1.2 line spacing). The paper will be graded based on the following components: relevance to this topic, technical quality, writing, and clarity. Plagiarism is strictly prohibited and will lead to a zero for the entire paper.

Course Outline

1: Introduction and preliminaries

- Applications of wetting, adhesion and friction: overview
- Basic concepts
- Introduction to contact mechanics

2: Wetting

- Capillarity length
- Interfacial tension and interfacial energy
- Contact angle
- 3-Phase contact line
- Young-Laplace equation
- Spreading coefficient
- Wetting in porous materials
- Topographic influence on wetting
- Electrical wetting
- Fluid Instabilities related to surface energy (dewetting, capillary instability).
- Applications

3: Adhesion

- Adhesive contact theories: Hertz, JKR, DMT, Maugis
- Modeling adhesion: traction-separation relationships
- Thin film adhesion: peeling, blister, buckling-delamination
- Adhesion-included collapse in flexible structures.
- Elasto-capillarity.
- Other topics of interests.
- Applications

4: Friction

- Classical friction laws
- Microscopic mechanism of friction
- Hydrodynamic lubrication theory
- Rubber friction theory: true contact, viscoelastic loss.
- Friction of multiphase materials (hydrogels, phase separated structures, composites)
- Other topics of interests.
- Applications

Note: this outline is tentative and is subjected to change during the semester.

University Policies:

Classroom Behavior

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. For more information, see the policies on classroom behavior and the Student Conduct & Conflict Resolution policies.

Requirements for COVID-19

As a matter of public health and safety due to the pandemic, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements and all public health orders in place to reduce the risk of spreading infectious disease. Students who fail to adhere to these requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct and Conflict Resolution. For more information, see the policy on classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please follow the steps in the "Accommodation for Disabilities" statement on this syllabus.

As of Aug. 13, 2021, CU Boulder has returned to requiring masks in classrooms and laboratories regardless of vaccination status. This requirement is a temporary precaution during the delta surge to supplement CU Boulder's COVID-19 vaccine requirement. Exemptions include individuals who cannot medically tolerate a face covering, as well as those who are hearing-impaired or otherwise disabled or who are communicating with someone who is hearing-impaired or otherwise disabled and where the ability to see the mouth is essential to communication. If you qualify for a mask-related accommodation, please follow the steps in the "Accommodation for Disabilities" statement on this syllabus. In addition, vaccinated instructional faculty who are engaged in an indoor instructional activity and are separated by at least 6 feet from the nearest person are exempt from wearing masks if they so choose.

Students who have tested positive for COVID-19, have symptoms of COVID-19, or have had close contact with someone who has tested positive for or had symptoms of COVID-19 must stay home. In this class, if you are sick or quarantined, ***email me about your absence and I will try my best to accommodate your needs.***

Accommodation for Disabilities

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website.

Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

Honor Code
All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code academic integrity policy. Violations of the Honor Code may include, but are not limited to: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu); 303-492-5550). Students found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found on the Honor Code website.

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation
The University of Colorado Boulder (CU Boulder) is committed to fostering an inclusive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or harassment by or against members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or email cureport@colorado.edu. Information about OIEC, university policies, reporting options, and the campus resources can be found on the OIEC website.

Please know that faculty and graduate instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about their rights, support resources, and reporting options.

Religious Holidays
Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, please inform me through email.

See the campus policy regarding religious observances for full details.

Mechanical Engineering Department Policies:
Racist Language, Behavior, and Discrimination:
The ME department holds students, faculty, and staff accountable for racist comments and behavior, whether intentional or unintentional. We expect members of our community to take responsibility for understanding why some comments and actions may be racist and actively eliminating language and behaviors that perpetuate racial inequities. More information is available at An Antiracist CU.

Discrimination and Harassment:
Discriminatory and harassing behavior will not be tolerated in the Department of Mechanical Engineering. A safe and inclusive environment will be created and maintained by the students and instructing faculty member. Students with concerns about discrimination or harassment actions should immediately contact the instructor, the Department Chair or their academic advisor, or the Office of Institutional Equity and Compliance.