AME 416
Mechanics and Transport in Medicine and Biology
Units: 4 (MW 4-5:50 PM)

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Course Description

This course provides an analytical and theoretical introduction to the mechanics and transport phenomena of biological systems. Topics include scaling in biology, modeling physiological and biological systems (dimensional analysis), biological forces in fluids and solids, Fick's law, Darcy's law, surface tension, viscosity, pressure, Bernoulli equation, Poiseuille flow, stress, strain, viscoelasticity, mechanics of living organs, transports in living organs, bio-inspired design, and special topics. No prior background in physiology or biology is needed.

Learning Objectives and Academic Rationale

After taking this course, the students will be able to analyze the mechanics of living organs, cells, and other biological systems from a mechanical viewpoint. They will learn how to tackle unsolved problems in biology and how to address the unmet clinical need in medicine using basic principles of fluid mechanics, solid mechanics, and transport phenomena. Overall, students will be able to use laws of mechanics to link mechanical insights back to physiological and biological functions. While this course is designed mainly to prepare mechanical engineering students for careers in the biotech industry and research in medical and bio-related fields, it can also serve other engineering, biology, and medical students who are interested in understanding the mechanics and transport phenomena of biological systems.

Prerequisite(s): N/A

Co-Requisite(s): None
Concurrent Enrollment: None
Recommended Preparation: Fundamental physics and the understanding of static forces at the level of AME 201 and differential equations at the level of MATH 245 are recommended.

Course Notes
Letter grade. Copies of lecture slides and other class information will be provided.

Technological Proficiency and Hardware/Software Required
None

Grading Breakdown

Assessment Tool (assignments)	Points	% of Grade
Homeworks	600 (100/hw)	20%
Midterm exam	100	30%
Final Exam	100	30%
Final Project	100	20%
TOTAL	900	100%

Grading Scale

Course final grades will be determined using the following scale

A	93-100
A-	87-92
B+	80-86
B	73-79
B-	67-72
C+	60-66
C	53-59
C-	47-52
D+	40-46
D	33-39
D-	27-26
F	26 and below

Textbook:

Required textbook:
Ethier, C. Ross, and Craig A. Simmons. “Introductory biomechanics: from cells to organisms”. Cambridge University Press, 2007. (ISBN-10 : 0521841127)

The following textbooks are suggested as supplements to the required text book, lecture notes, and handouts:
1- Vogel, Steven. “Life's devices: the physical world of animals and plants”. Princeton University Press, 1988. (ISBN-10 : 0691024189)
2- Westerhof, Nicolaas. “Snapshots of hemodynamics”. Springer, 2018. (ISBN-10 : 9783319919317)
3- Li, John KJ. “Comparative cardiovascular dynamics of mammals”. CRC press, 1995. (ISBN-10 : 0849301696)
4- Bartel, Donald L., Dwight T. Davy, and Tony M. Keaveny. “Orthopaedic biomechanics: mechanics and design in musculoskeletal systems”. Upper Saddle River: Pearson/Prentice Hall, 2006. (ISBN-10 : 0130089095)
5- Truskey, G. A., F. Yuan, and D. F. Katz. "Transport phenomena in biological systems." Pearson Prentice Hall bioengineering (2008). (ISBN-10 : 0131569880).

Description and Assessment of Assignments

Problem sets and final project: Collaboration is allowed for problem sets. Details about the final project and Homework assignments are provided below.

Homework assignments: HWs are usually assigned on Mondays and due dates will be two weeks from the assigned dates. The typical hours for each HW assignment is eight hours. Collaborations are allowed for HWs. Equations and formulas that have been derived in the class can be directly used in HW problems.

Final project: The final project can be one of the following: 1- Comprehensive review of an application of mechanical engineering or transport phenomena in biology or medicine (e.g. fluid dynamics of Glaucoma), 2- Computational modeling of a physiological system (e.g. deformation of red blood cells), 3-analytical modeling of a physiological or biological system (e.g. hip modeled as a ball and socket joint), and 4-experimental investigation of the mechanics of a biological or physiological system (pressure wave reflection in coronary network). Working as a group is allowed if the workload of the project can be justified. Maximum number of people allowed in each group is two.

Final project timeline:

- Week 11: Final project proposal due (team member, topics, and milestone)
- Week 15: Project presentation
- Last day of final exams: Final project report due

Final project report component: It must include an abstract, introduction/background, methods (not required for comprehensive review projects), result/discussion, and future direction.

Final project report format: It must be at least 12 pages for comprehensive reviews (without references) and 8 pages for numerical simulation, analytical, and experimental projects (without references), typed, single-spaced, and maximum margin of 1" on each side. It must include an introduction, conclusion, and references.

Sample project: "The Effects of Space Flight on Human Body Biofluid Mechanics". The student will review seminal and recent articles and suggest improvements in design based on what they learned in class.

Grading breakdown of the final project:

- Proposal: 10%
- Presentation: 30%
- Final report: 60%

Assignment Submission Policy

Problem sets must be submitted as a hard copy (printout) in the class. No assignments will be accepted past the due date. In cases you cannot make it to campus, it is your responsibility to email a good-quality scan of HW to a classmate who can submit a printout on your behalf. The final project proposal and report can be submitted as hard copy, pdf, or MS word.

Additional Policies

• Final grade will depend entirely on the performance on the above components, and be independent of the financial support requirements (e.g., minimum grade requirement for tuition reimbursement).
• Work-related travel must be scheduled during time periods outside of the mid-term and final exams. Accommodation to take exams on different dates will be made for only family emergencies and documented illness or health-related emergencies. Other exceptions will be considered on a case-by-case basis.
• Curved grading will be applied

Course Schedule: A Weekly Breakdown

	Topics/Daily Activities	Readings and Homework	Deliverable/ Due Dates
Week 1	Scaling and Modeling in Biology and Medicine	Pages 53-69.	
Week 2	Diffusion, Fick's law, Surface Tension, Osmotic Effects	Pages 119-129, Homework 1	HW1 assigned

Week 3	Viscosity, Flow regimes, Pressure, Drag and Lift	Pages 129-142, Homework 1	
Week 4	Conservation laws, Poiseuille flow, Streamlines	Pages 143-163,Homework 2	HW2 assigned/HW1 due
Week 5	Bernoulli equation and its application in biology & medicine	Pages 419- 427, Homework 2	
Week 6	Bio-solid mechanics I: Material properties, Stress, Strain	Pages 428-443, Homework 3	HW3 assigned/HW2 due
Week 7	Bio-solid mechanics II: Structures, Buckling	Pages 164-178, Homework 3	
Week 8	Viscoelasticity **Midterm exam**		HW4 assigned/ HW3 due
Week 9	Hemodynamics, Dynamics of Microcirculation	Pages 179-239 Homework 4	
Week 10	Mechanics of a Living Organ: Cardiovascular System	Pages 240-249, Homework 5	HW5 assigned/ HW4 due
Week 11	Mechanics of a Living Organ: Renal System and Kidney	Pages 282-331, Homework 5	
Week 12	Mechanics of a Living Organ: Respiratory System	Pages 332-378, Homework 6	HW6 assigned/ HW5 due
Week 13	Mechanics of a Living Organ: Skeletal System	Pages, 379-439, Final project proposal	Project report/at final exam date
Week 14	Special Topics		HW6 due
Week 15	Special Topics		
Final Exam			Date: For the date and time of the final exam for this class, consult the USC *Schedule of Classes* at classes.usc.edu.

Statement on Academic Conduct and Support Systems

Academic Conduct:

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, "Behavior Violating University Standards" https://policy.usc.edu/scampus-part-b/. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct.

Support Systems:

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

National Suicide Prevention Lifeline - 1 (800) 273-8255 - 24/7 on call
http://www.suicidepreventionlifeline.org
Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL), press "0" after hours - 24/7 on call
https://studenthealth.usc.edu/sexual-assault/
Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED) - (213) 740-5086/Title IX - (213) 821-8298
https://equity.usc.edu/, http://titleix.usc.edu/
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
https://usc-advocate.symplicity.com/care_report/
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office of Equity and Diversity |Title IX for appropriate investigation, supportive measures, and response.

The Office of Disability Services and Programs - (213) 740-0776
http://dsp.usc.edu
Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Campus Support and Intervention - (213) 821-4710
https://uscsa.usc.edu/
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity at USC - (213) 740-2101
https://diversity.usc.edu/

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
http://dps.usc.edu/, http://emergency.usc.edu
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
http://dps.usc.edu
Non-emergency assistance or information.