AME 536
Biofluid Mechanics: Transport and Circulatory Systems
Units: 4 (MW 7-8:50 PM)

Instructor: Niema M Pahlevan, PhD
Office: Online
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Course Description

This course provides an analytical and theoretical introduction to fluid dynamics and transport phenomena of the physiological systems such as cardiovascular, respiratory, and renal system. No prior background in physiology or biology is needed.

Learning Objectives and Academic Rationale

This course aims at introducing graduate students of engineering to the application of the fundamental principles of fluid mechanics and transport phenomena to the various physiological systems in the human body. The special focus will be on the cardiovascular, respiratory, and renal system. While this course is designed mainly to prepare students with mechanical engineering background for research in medical fields and biotech industry, it can also serve other engineering, biology, and medical students who are interested in deeper understanding of the physics of flow in biological systems.

Prerequisite(s): N/A

Co-Requisite(s): None
Concurrent Enrollment: None
Recommended Preparation: Elementary knowledge of fluid mechanics and solid mechanics is recommended. Standard coursework in mathematical techniques at the level that is common for undergraduate engineering majors is 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
Scheme 1:

Assignment	Points	% of Grade
Homework	600 (100/hw)	20%
Midterm exam	100	25%
Final Exam	100	25%
Final Project	100	30%
TOTAL	900	100%

Scheme 2: Final project: 100%. (You must attend at least 20 full session lectures to be eligible for this scheme)

- leaving out in the middle of the class does not count as a full session.
- Late attending more than 20 min does not count as a full session.
- For scheme 2, your project MUST NOT be a literature review. You MUST SUBMIT both midterm and final.
- Final presentation of the project is 30% of the total project points

Note 1: Your final grade will be the higher grade of the two schemes.
Note 2: Curved grading will be applied

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:

There is no required textbook for this course. However, the below text book is highly recommended:
Grotberg, James B. **Biofluid Mechanics: Analysis and Applications**. Cambridge University Press, 2021.

The following textbooks are suggested as supplements to lecture notes and handouts:
1-Caro, C. G., R. C. Schroter, T. J. Pedley, and W. A. Seed. "The mechanics of the circulation." (2011). ISBN-9781139013406
2-Truskey, G. A., F. Yuan, and D. F. Katz. "Transport phenomena in biological systems." Pearson Prentice Hall bioengineering (2009). ISBN- 9780131569881
3-Zamir, Mair, and M. Zamir. The physics of pulsatile flow. New York: AIP Press, 2000. ISBN-9781461212829
4-Fung, Yuan-cheng. Biomechanics: circulation. Springer, 1997. ISBN 9781475726961
5-Kheradvar. Principles of Heart Valve Engineering. Academic Pr, 2019 ISBN: 9780128146620

Other useful references:
1-Waite, L. (2005). Biofluid Mechanics in Cardiovascular Systems. McGraw-Hill, ISBN-10: 0071447881.
2-Waite, Lee, and Jerry Michael Fine. "Applied biofluid mechanics." (2007).
3-Rubenstein, D., Yin, W. & Frame, M. D. Biofluid Mechanics: An Introduction to Fluid Mechanics, Macrocirculation and Microcirculation (2011).
4-Kheradvar, Arash, and Gianni Pedrizzetti. Vortex formation in the cardiovascular system. Springer, 2012.

Description and Assessment of Assignments

Problem sets and final project.

Final project: The final project can be one of the following: 1- Comprehensive review of an application of fluid mechanics or transport phenomena in medicine (e.g. coronary blood flow), 2- computer simulation of a physiological system (e.g. mass transport in alveoli), 3-analytical modeling of a disease (e.g. aneurysm),

and 4- experimental investigation of a physiological fluid mechanics phenomenon (hemodynamics wave reflection in a vascular 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 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 introduction, conclusion and references.

Sample project: "Biofluid Mechanics of Coronary Artery Disease Bypass Grafting and Stents" the goal of the project is to complete in-depth review of emerging trends and challenges in coronary interventions that are relevant to engineers. The student will review seminal and recent articles and suggest improvement in design and delivery based on what they learned in the 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. 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	Introduction to cardiovascular physiology		
Week 2	Introduction to cardiovascular pathophysiology	Homework 1	HW 1 due Week 4

Week 3	Fluid/Solid Mechanics review		
Week 4	Fluid/ Solid Mechanics review	Homework 2	HW 2 due Week 6
Week 5	Rheology of blood flow and steady flow in tubes		Graded HW 1 returned
Week 6	Pulsatile flow in rigid tubes	Homework 3	HW 3 due Week 8
Week 7	Pulsatile flow in compliant tubes and vessels **Midterm exam**		Graded HW 2 returned
Week 8	Wave dynamics in cardiovascular system	Homework 4	HW 4 due Week 10
Week 9	Wave analysis methods and reduced-order models		Graded HW 3 returned
Week 10	Introduction to renal physiology and Flow and mass transport in renal system	Homework 5	HW 5 due Week 12
Week 11	Introduction to respiratory physiology, and Biomechanics of Respiratory System	Final Project assignment	Project report due Week 15, Graded HW 4 returned
Week 12	Interventional Cariology Bioengineering and Coronary Blood Flow		
Week 13	Introduction to Cardiovascular MRI	Homework 6	Graded HW 5 returned, HW 6 due Week 14
Week 14	Special Topics		
Week 15	Final Project presentations		Graded HW 6 returned
FINAL			Date: For the date and time of the final 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" 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, policy.usc.edu/scientific-misconduct.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
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
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
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
equity.usc.edu, 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
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
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

campussupport.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

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
dps.usc.edu, 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) 442-120 – 24/7 on call
dps.usc.edu
Non-emergency assistance or information.

Office of the Ombuds - (213) 821-9556 (UPC) / (323-442-0382 (HSC)
ombuds.usc.edu
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.