

AME 599: Cardiovascular Biofluid Mechanics

Units: 3

Term—Day—Time: Spring 09-Wednesday- 6:40-9:20pm

IMPORTANT:

The general formula for contact hours is as follows:

Courses must meet for a minimum of one 50-minute session per unit per week over a 15-week semester. Standard fall and spring sessions (001) require a final summative experience during the University scheduled final exam day and time.

(Please refer to the [Contact Hours Reference](#) guide.)

Location: TBD.

Instructor: Niema Pahlevan

Office: 470 Michelson Bldg

Office Hours: Wednesdays 4:30-6:30; or by appointment

Contact Info: pahlevan@usc.edu, phone number: 213-740-7182 .

Teaching Assistant:

Office: TBD

Office Hours:

Contact Info: TBD

Midterm Exam: February 27th-In class

Final Exam: For the date and time of the final for this class, consult the USC Schedule of Classes at <https://classes.usc.edu/term-20191/finals/>

Course Description

This graduate course provides an analytical and theoretical introduction to fluid dynamics of the human circulatory system: heart, veins, and arteries (microcirculation). Wave reflection and vortex dynamics in cardiovascular system. Blood flow modeling in cardiovascular system. Fluid dynamics of cerebrovascular and cardiovascular diseases.

Learning Objectives

This course aims at introducing graduate students of engineering to the application of the fundamental principles of fluid mechanics to the various physiological systems in the human body. The special focus will be on the cardiovascular 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): Background in differential equations is necessary.

Co-Requisite(s): N/A

Concurrent Enrollment: N/A

Recommended Preparation: Elementary knowledge of fluid mechanics and solid mechanics is recommended

Course Notes

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

Technological Proficiency and Hardware/Software Required

N/A.

Required Readings and Supplementary Materials

There is no required textbook for this course. The following textbooks are helpful:

- 1-Caro, C. G., R. C. Schroter, T. J. Pedley, and W. A. Seed. "The mechanics of the circulation." (2011).
- 2-Truskey, G. A., F. Yuan, and D. F. Katz. "Transport phenomena in biological systems." Pearson Prentice Hall bioengineering (2009).
- 3-Zamir, Mair, and M. Zamir. The physics of pulsatile flow. New York: AIP Press, 2000.

Other useful references:

- 1-Fung, Yuan-cheng. Biomechanics: circulation. Springer, 1997.
- 2-Waite, L. (2005). Biofluid Mechanics in Cardiovascular Systems. McGraw-Hill, ISBN-10: 0071447881.
- 3-Waite, Lee, and Jerry Michael Fine. "Applied biofluid mechanics." (2007).
- 4-Rubenstein, D., Yin, W. & Frame, M. D. Biofluid Mechanics: An Introduction to Fluid Mechanics, Macrocirculation and Microcirculation (2011).
- 5-Kheradvar, Arash, and Gianni Pedrizzetti. Vortex formation in the cardiovascular system. Springer, 2012..

Description and Assessment of Assignments

Problem sets and Final project.

Grading Breakdown

Scheme 1: Problem sets: 20%; Midterm: 25%; Final exam: 25%; Final project:30%

Scheme 2: Final project: 100%. (You must attend at least 12 (out of 15) full sessions to be eligible for this scheme)

- Leaving in the middle of the class does not count as a full session.
- Being late more than 20 min does not count as a full session.
- For scheme 2, your project MUST NOT be a literature review. You MUST ATTEND 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 (Example)

Course final grades will be determined using the following scale

A	93-100
A-	87-93
B+	80-87
B	73-80
B-	67-73
C+	60-67
C	53-60
C-	47-53
D+	40-47
D	33-40
D-	27-33
F	27 and below

Assignment Rubrics

N/A.

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.

Grading Timeline

One week after each assignment.

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).
- Please schedule your work-related travel 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 Cardiovas. Pathophysiology	Homework 1	Two weeks from the assignment
Week 3	Fluid/Solid Mechanics review		
Week 4	Fluid/ Solid Mechanics review	Homework 2	Two weeks from the assignment
Week 5	Rheology of blood flow		
Week 6	Steady flow in tubes	Homework 3	Two weeks from the assignment
Week 7	Pulsatile flow in rigid tubes		
Week 8	Pulsatile flow in compliant tubes and vessels	Homework 4	Two weeks from the assignment
Week 9	Wave dynamics in cardiovascular system		
Week 10	Pulse wave analysis	Homework 5	Two weeks from the assignment
Week 11	Lumped models of the cardiovascular system	Final Project assignment	On Week 15
Week 12	Special topics		
Week 13	Special Topics		
Week 14	Special Topics		
Week 15	Final Project presentations		
FINAL			Date: For the date and time of the final for this class, consult the USC <i>Schedule of Classes</i> at classes.usc.edu .

List of the specific topics to be covered:

1. Introductory review of solid mechanics and fluid mechanics
2. Circuitry of the cardiovascular system
3. Cardiac cycle
4. Cardiac dynamics
5. Integrative functions of the cardiovascular system
6. Blood vessel structure
7. Conservation laws
8. Stream lines
9. Newton's law of viscosity
10. Non-Newtonian rheology
11. Steady flow in tubes

12. Pulsatile flow in rigid tubes
13. Pulsatile flow in compliant tubes
14. Wave reflections
15. Pulse waves
16. Wave intensity analysis
17. Wave propagation in the arterial system
18. Cardiac vortex dynamics
19. Coronary blood flow and fractional flow reserve (FFR)
20. Fluid mechanics of collapsible tubes and veins
21. Fluid dynamics of the Aneurysms
22. Lumped models of the cardiovascular system (Windkessel, Time-varying elastance, etc)
23. One-dimensional model of the systemic cardiovascular system
24. Cerebral blood flow
25. Biomechanics of heart failure
26. Biomechanics of myocardial infarction (heart attack)
27. Invasive hemodynamics measurement techniques
28. Non-invasive hemodynamics measurement techniques

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, <http://policy.usc.edu/scientific-misconduct>.

Support Systems:

Student Counseling Services (SCS) – (213) 740-7711 – 24/7 on call

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention. engemannshc.usc.edu/counseling

National Suicide Prevention Lifeline – 1 (800) 273-8255

Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. www.suicidepreventionlifeline.org

Relationship and Sexual Violence Prevention Services (RSVP) – (213) 740-4900 – 24/7 on call

Free and confidential therapy services, workshops, and training for situations related to gender-based harm. engemannshc.usc.edu/rsvp

Sexual Assault Resource Center

For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: sarc.usc.edu

Office of Equity and Diversity (OED)/Title IX Compliance – (213) 740-5086

Works with faculty, staff, visitors, applicants, and students around issues of protected class. equity.usc.edu

Bias Assessment Response and Support

Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. studentaffairs.usc.edu/bias-assessment-response-support

The Office of Disability Services and Programs

Provides certification for students with disabilities and helps arrange relevant accommodations. dsp.usc.edu

Student Support and Advocacy – (213) 821-4710

Assists students and families in resolving complex issues adversely affecting their success as a student EX: personal, financial, and academic. studentaffairs.usc.edu/ssa

Diversity at USC

Information on events, programs and training, the Diversity Task Force (including representatives for each school), chronology, participation, and various resources for students. diversity.usc.edu

USC Emergency Information

Provides safety and other updates, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible. emergency.usc.edu

USC Department of Public Safety – UPC: (213) 740-4321 – HSC: (323) 442-1000 – 24-hour emergency or to report a crime.

Provides overall safety to USC community. dps.usc.edu