BioE 104: Biotransport Phenomena

Instructor: Anand Subramaniam, PhD

Syllabus, topics covered, and learning assessment scheme may be modified with prior notification.

Catalog Description: Introduces methods for deriving and solving differential equations that govern the transport of momentum, mass, and energy. Applications include quantitative modeling of transport in biological and biomedical systems.

Course Objectives: This course presents, through bi-weekly lectures and one section, an opportunity for students to explore a variety of techniques for applying conservation equations of mass and momentum to living and non-living systems. The course uses advanced mathematical techniques for solving problems. As such, this course addresses certain ABET outcome criteria at a variety of levels.

Course learning outcomes (CLOs) and relationship to PLOs

By the end of the course, students should be able to:

1. Understand conservation of mass, momentum, and energy as applied to the flow of mass and fluids. (PLO 1, 7, 8, 9, 10)
2. Use control-volume analysis to formulate governing equations for simple flow and mass transport geometries. (PLO 1, 7, 8, 9, 10)
3. Analyze complex fluid flows via approximate analytical tools. (PLO 1, 7, 8, 9, 10)
4. Derive appropriate conservation equations, select boundary conditions, and apply analytical and computational techniques to solve flow and mass transfer problems in biological and medical systems. (PLO 1, 7, 8, 9, 10)
5. Estimate fluid behavior in compliant structures and unsteady flows. (PLO 1, 7, 8, 9, 10)
6. Specify characteristics of fluid and mass transport of components in bio/medical systems. (PLO 1, 7, 8, 9, 10)

Bioengineering Program Learning Outcomes (PLOs)

Graduates of the Bioengineering program at UC Merced will possess:

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. An ability to communicate effectively with a range of audiences.

4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.
8. Experience in applying principles of engineering, biology, human physiology, chemistry, calculus-based physics, mathematics (through differential equations) and statistics.
9. Experience in solving bio/biomedical engineering problems, including those associated with the interaction between living and non-living systems.
10. Experience in analyzing, modeling, designing, and realizing bio/biomedical engineering devices, systems, components, or processes.
11. Experience in making measurements on and interpreting data from living systems.

Prerequisites:

1. BIO 002: Introduction to Molecular Biology
2. MATH 024: Linear Algebra and Differential Equations
3. PHYS 009: Introductory Physics II for Physical Sciences or PHYS 009H: Honors Introductory Physics II for Physical Sciences or PHYS 019: Introductory Physics II for Biological Sciences.

	Day		Lecture	Chapter from Truskey	HW
Week 1	August 25	1	No Class		
	August 27	2	Introduction (Online Video on Catcourses)	Self-study Chapter 1	PS 1: Math Review
Week 2	Section 1		No Section		
	Sept 1	3	Fluid Kinematics: Control Volume, Velocity Field, Flow Rate, Lagrangian Frame of Reference and Eulerian Frame of Reference	2.2, 2.2.2	
	Sept 3	4	Acceleration, Material Derivative, Generalized Vector Notation, Gradient, Divergence, Fluid Streamlines	2.2.4	PS1 Due, PS 2 Assigned
Week 3	Section 2		Acceleration and Streamlines		
	Sep 8	4	Forces acting on a control volume, the stress tensor	2.3.3	
	Sept 10	5	Constitutive relations, Relationship between shear stress and fluid velocity, Derivation of Newton's Law of Viscosity, Non-Newtonian Rheology	2.5.1, 2.5.2	
Week 4	Section 3		Viscosity		
	Sept 15	6	Conservation relations, Boundary Conditions, Flow-induced by a sliding plate on a Newtonian Fluid	2.3.1, 2.3.2, 2.3.4, 2.7.1	PS 2 due, PS 3 assigned
	Sept 17	7	Pressure Driven Flow of a Newtonian Fluid through a Rectangular Channel	2.7.2,2.7.3	
Week 5	Section 4		Flow-induced by a sliding plate on a Bingham Plastic	2.7.4	
	Sep 22	8	Pressure Driven Flow of a Newtonian Fluid through a Cylindrical Tube, Laminar and Turbulent Flow	2.4.2, 2.4.3, 2.6	
	Sept 24		Surface Tension, Membrane and Cortical Tension	Topics Week 1-5	PS 3 due
Week 6	Section 5		Flow of a Power Law Fluid through a Cylindrical Tube		
	Sept 29		Midterm Review	Topics Week 1-Week 5	

	Oct 1	9	**Midterm 1**	3.2.1, 3.2.2, 3.3.1	PS 4
Week 7	Section 5		Walk through of Midterm 1		
	Oct 6	10	Differential Form of the Equation of Conservation of Mass and Momentum in Three Dimensions	3.3.1, 3.3.2	
	Oct 8	11	Differential Form of the Conservation of Linear Momentum, Navier Stokes Equation		
Week 8	Section 6		Flow-Between Rotating Cylinders		
	Oct 13	12	Flow between concentric rotating cylinders, flow down an inclined plane	3.4.1	
	Oct 15	13	Fluid Motion with More than One Dependent Variable	3.4.1	
Week 9	Section 7				
	Oct 20	14	Continuation of 2D solution of the Navier-Stokes for pressure-driven flow in a rectangular channel	3.5.1, 3.5.2	
	Oct 22		Dimensional Analysis, Buckingham Pi theorem, non-dimensional form of Navier-Stokes, and Dimensional Groups	Topics Week 7-Week 10	PS 4 Due
Week 10	Section 8		Dimensional Analysis		
	Oct 27		Midterm Review		
	Oct 29	15	**Midterm 2**		
Week 11	Section 9		Walkthrough Midterm 2		
	Nov 3	16	Conservation Relations, Boundary Conditions. Fick's Law of Diffusion	6.7.1,6.7.2,6.7.3	Self-Study (6.1-6.2)
	Nov 5		Steady-state diffusion, Slabs in series, Radial diffusion through a cylinder, Radial diffusion from a sphere	6.8.2	
Week 12	Section 10				
	Nov 10	17			

	Nov 12	18	Unsteady Diffusion in 1-Dimensional Finite Medium	6.8.1	PS 5 assigned
Week 13	Section 11				
	Nov 17	19	Unsteady Diffusion: Semi-Infinite approximation, protein adsorption in biomaterials	6.8.4	
	Nov 19	20	Diffusion from a point source in an infinite domain		
Week 14	Section 12		No Section		
	Nov 24		Non-instructional Day		
	Nov 26	21	Thanksgiving Holiday		
Week 15	Section 13				
	Dec 1		Quasi-steady Transport Across Membranes	7.1-7.3	
	Dec 3	22	Molecular basis for diffusion, probability distribution of a particle in an infinite domain	7.6	PS 5 due, Self-Study (7.7, 7.8)
Week 16	Section 14		Go over problem set 4		
	Dec 8	23	Diffusion and Convection		Dimensional Analysis, Short Contact Time Solution I
	December 10		Review for Final Exam	Topics Week 10-16, One long form file upload question from either Midterm 1 or Midterm 2	
	December 13		**Final Exam (**8:00-11:00 am)		

Course Policies:

Academic Dishonesty Statement:

a. Each student in this course is expected to abide by the University of California, Merced's Academic Honesty Policy. Any work submitted by a student in this course for academic credit will be the student's own work.
b. You will gain the most from this class if you come prepared. Please do the readings prior to class and participate actively in class discussions.
c. You are encouraged to study together and to discuss information and concepts covered in lecture and the sections with other students. You can give "consulting" help to or receive "consulting" help from such students. However, this permissible cooperation should never involve one student having possession of a copy of all or part of work done by someone else, in the form of an e mail, an e mail attachment file, a diskette, or a hard copy. Should copying occur, both the student who copied work from another student and the student who gave material to be copied will both automatically receive a zero for the assignment. Penalty for violation of this Policy can also be extended to include failure of the course and University disciplinary action.
d. During examinations, you must do your own work. Talking or discussion is not permitted during the examinations, nor may you compare papers, copy from others, or collaborate in any way. Any collaborative behavior during the examinations will result in failure of the exam and may lead to failure of the course and University disciplinary action.

Disability Statement:

Accommodations for Students with Disabilities: The University of California Merced is committed to ensuring equal academic opportunities and inclusion for students with disabilities based on the principles of independent living, accessible universal design and diversity. Requests for academic accommodations are to be made during the first three weeks of the semester, except for unusual circumstances. Students must register with Disability Services Center to verify their eligibility for appropriate accommodations. Only registered and verified disabilities can be accommodated.

Textbooks:

Transport Phenomena in Biological Systems (2nd Edition)**,** George A. Truskey, Fan Yuan, David F. Katz. Pearson

Class Schedule: Wednesday, Friday 1:30-2:45 pm. Kolligian Library 217

Sections:

Section 1: Tuesday 12:30-1:20 pm

Section 2: Tuesday 1:30 -2:20 pm

Section 3: Tuesday 2:30 - 3:20 pm

Assessment/Grading Policy:

- 20% Section Participation and Problem Sets
- 20% Midterm#1 (in-class 90 minute exam)
- 20% Midterm#2 (in-class 90 minute exam)
- 30% Final Exam (in-class 90 minute exam)
- 10% Attendance, in-class participation, in class quizzes (Attendance percentage will be multiplied with the average of in class quizzes. The two lowest quiz grades will be dropped). Additional points may be added as described in class.

  All exams are closed book. Students must take both midterms and the final exam to pass the class. No makeup midterm exams will be given. Final exam grade may be substituted for one midterm if your final grade is higher.

Homework: Problem sets are due in CatCourses by the due date.

1. Write the names of collaborating students at the top of the first page for each problem. Collaboration and group work is encouraged to enhance learning.

2. Show all work/calculations (i.e. numerical answers that do not show which formulas and/or calculations were used will not receive full credit, even if the answer is correct)

3. If you use Excel, MATLAB, etc. to answer a question print out your excel sheet/MATLAB code/etc.

Homework Collaboration Policy:

1. List all students that worked together as a comment on Canvas to the problem set.

2. Each student must write up his or her own solutions.

3. Failure to do this may result in the assignment being discounted, and possibly more serious consequences.

Late Homework Policy:

Homework handed in after the due date on CatCourses will be considered late.

Lateness	**Total taken off HW score**
Same day (Due in CatCourses)	20 %
2nd Day	40 %
3rd Day (Last day to hand in HW)	60 %

Grading Scheme

A+	≥ 98-100
A	≥ 90- < 98
A-	≥ 87- < 90
B+	≥ 84- < 87
B	≥ 79- < 84
B-	≥ 74- < 79
C+	≥ 70- < 74
C	≥ 65- < 70
C-	≥ 60- < 65
D	≥57- < 60
F	< 57

Teaching Assistant: Vignesha Vijayananda

Contact Information:

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Office Hours:

Wednesday: 4:00-5:00 pm

Thursday: 2:00 – 3:00 pm

or by appointment