Biotransport Phenomena BIEN 264 and BIEN 264V
Spring 2016

COURSE OUTLINE

Course Time: Mon Wed 4:10 –5:30 p.m. Surge 170 Disc Fri 12:10 – 1:00 pm Surge 170

Instructor: V. G. J. Rodgers (victor.rodgers@ucr.edu)

TA: Dieanira Erudaitius (derudait@gmail.com)

Textbooks: *Transport Phenomena in Biological Systems*, G. Truskey, F. Yuan, D.F. Katz, Pearson Prentice Hall, New Jersey, 2nd Edition, ISBN: 978-0-13-156988-1 (2009) (Truskey)

Transport Phenomena, 2nd Edition, John Wiley & Sons, Inc., R. Byron Bird, Warren E. Stewart and Edwin N. Lightfoot (2002) (BSL)

Other References: *Advanced Engineering Mathematics*, Alan Jeffrey, Harcourt Academic Press, San Diego, 0-12-382592-X (2002)

Fields, Forces, and Flows in Biological Systems, Alan J. Grodzinsky, Garland Science, Taylor & Francis Group, ISBN 978-0-8153-4212-0 (2011)

Course Description:

Transport phenomena consist of momentum transport (both fluid and solid systems), heat transfer and mass transfer. In biomedical and biological systems this is arguably one of the most important fields to understand biological activity. (The other two are thermodynamics and reactive systems). It only takes a moment to see the importance of transport phenomena in such areas as development of drug-delivery patches, analyzing nutrient delivery to cells, understanding biological thermal regulation, investigating the complex system response to signaling pathways across cellular compartments and solution and so many others.

As interdisciplinary research continues to become increasingly more complex, it remains paramount that the research-grade bioengineer is truly grounded in transport phenomena so that they can make significant contributions in their area of interest. While biologists, biochemists, life-scientists and others provide tremendous input in defining the characteristics of the observed problem, the well-equipped bioengineer has the responsibility in coupling the observed system to the conservation laws to provide solid predictive understanding and insight of the phenomena. This course will provide such a foundation, however its emphasis is mass transport.

It is the goal of this course to move the graduate student from the introductory level of transport phenomena (undergraduate) to a level that will allow them to communicate, be confident, and be effective in researching transport-related topics in a variety of biomedical engineering and bioengineering areas.

Because transport phenomena are based on the conservation laws, they naturally require the language of mathematics. Therefore it is assumed that the student has had a basic foundation in solutions to ordinary linear differential equations and an elementary course in vector and tensor analysis. *More importantly, it is the physical interpretation of the problem that will be emphasized via the appreciation of the problem's mathematical form.* An emphasis will also be placed on illuminating the similarities in a variety of different problems due to their mathematical similarities. Thus this course will focus on analytical approximations of systems.

The course will be presented in two parts; the conservation of momentum and mass and their applications and combined biotransport systems. The book *Transport Phenomena in Biological Systems*, *Transport Phenomena* and the class notes will be used throughout the course.

Grading: Homework, three exams, one individual project with two reports and two oral presentations

The grading will consists primarily of three closed-book exams (Confidence Builders) and one individual project with two reports/two presentations. Homework is administered to help hone the students' skills in the appropriate areas. This is because the philosophy of graduate education is to develop the ability to teach ourselves new subject matter and to be accountable for our technical performance. Thus students will not be penalized for incorrectness during the "intermediate stages" of learning (homework) but they will be accountable for knowing the correct approach to a problem in the exams. Therefore it is essential that the student is responsible for their individual understanding of the problems and their assigned purpose. To this end, I will have an open-door policy for help and support with any aspect of this course. Answers to the homework will be made available when necessary. The closed-book exam will be on the appropriate mathematical techniques and transport phenomena. The project will be based on the topics from which the student (with approval) chooses. It is expected that the students will be resourceful with projects using tools well outside of those presented in this class. The project will require the graduate student to develop and, then solve, a tractable problem related to an area of their interest (this may be their research area). As an example, a student may want to analytically model the mass transport of a drug through the portal vein and compare the results to the numerical example provided by COMSOL.

Exam Schedule and Grading:

EXAM	WEIGHT, %	DAY and DATE
Project Assigned		Monday, April 4, 2016
Homework Grade	5	Weekly
1st Confidence Builder	15	Wednesday, April 26, 2016
Midterm Project Presentation	10	Week of May 2, 2016
Midterm Project Report	10	Monday, May 2, 2016
2nd Confidence Builder	15	Friday, May 13, 2016
3rd Confidence Builder	15	Thursday, June 3, 2016
Final Project Presentation	10	Week of June 6, 2016
Final Project Report	20	Week of June 6, 2016
TOTAL	**100**	

Schedule:

Week 1:	**Please Review (from undergraduate preparation and iLearn notes)**	iLearn Notes
	Vectors and vector operations	
	Dyadic products, scalar fields	
	Applications of gradients, material derivatives, calculus of vectors	
	Mean value theorem, divergence, Gauss divergence theorem, cylindrical coordinates	
	Stokes theorem, curvilinear coordinates, tensor analysis	
	Separations of variables	
	Similarity transforms	
Week 2:	**Review of Closed-Form and Numerical Solutions**	
	Numerical Approaches to Solving Transport Problems	Notes
	Computational Fluid Dynamics (COMSOL)	Notes
	Regression of Coefficients of Non-Linear Algebraic Equations	Notes
	Regression of Coefficients for Systems of Differential Equations (MATLAB)	Notes
Week 3:	**Review of Momentum and Mass Transfer**	Truskey, Chapters 3 and 7
Week 4:	**Analytical Transient Processes**	Notes, Chapters 6-9
	Low Re: Creeping Flow Approximation	BSL Chapter 3
	Hi Re: Potential Flow Systems	BSL Chapter 3
	Stokes Law	BSL Chapter 4
Week 5:	**Dimensionless Analysis**	Notes
Week 6:	**Boundary Layer Theory and Approximate Solutions**	BSL, Chapter 4, Notes
	Boundary Layer for Single Phenomenon	Notes
	Blasius Solution	Notes
	Binary Boundary Layer Systems	BSL, Chapter 20
Week 7:	**Film Theory and Mass Transport Coefficients**	BSL, Chapter 18
Week 8:	**Systems of Reactions in Biological Processes**	Truskey, Chapters 10-12
Week 9:	**Advanced Diffusional Processes**	
	Taylor Dispersion	Notes
	Generalized Stefan-Maxwell Equations	BSL, Chapter 24
Week 10:	**Facilitated Transport**	Notes, Truskey Chapter 10
Week 10:	**Membrane Transport**	Notes, Truskey Chapter 8