2017FA-BIOM-421-001: Transport Phenomena in Biomedical Engineering

BIOM 421 – Transport Phenomena in Biomedical Engineering

Prerequisites: BMS 300, LIFE 210, **CBE 330**, **CBE 332** or MECH 344 and MECH 102
Lecture: MW 4:15 – 5:30 p.m.
Location: Scott 229

Instructor: Brian Munsky
Office: Scott 354
E-mail: munsky@colostate.edu

Office Hours: 12pm-1pm, Phoenix Deisign Studio

Grader: Charlie Mitchell

Texts and Resources:

Required:

- *Basic Transport Phenomena in Biomedical Engineering, 3rd Edition, by R.L. Fournier, Taylor & Francis, 2006.*

Optional:

- *Transport Phenomena in Biological Systems*, 2nd Edition, by G.A. Truskey, F. Yuan, and D.K. Katz, Pearson Prentice Hall, 2009
- *An Introduction to Modeling of Transport Processes, Applications to Biomedical Systems*, by A. Datta and V. Rakesh, Cambridge Texts in Biomedical Engineering, 2010. (Good place to look for examples of potential course projects).
- Texts from CBE 210, 332 and 442.
- Additional course materials will be posted on Canvas.

Course Description:

This course is intended for senior undergraduate biomedical engineering students who have already had courses in differential equations, numerical methods, basic cell biology, basic physiology, thermodynamics and transport phenomena. This course discusses in detail engineering models of active and passive mechanisms of momentum and mass transport in mammalian cell organelles, cells, tissues, organ systems, and organisms. Non-Newtonian properties of blood and biological fluids will be described. Mass transport concepts will include diffusion and thermodynamic partitioning at and across biological membranes, ion transport, oxygen transport, and mass transport coupled to biochemical reaction kinetics and reaction equilibria. Biomedical engineering applications of transport phenomena will include topics such

as thermal regulation, drug delivery (targeted, controlled, and localized), pharmacokinetic models (for drug distribution and clearance, toxicology, and biomedical imaging), and design of extracorporeal devices such as blood oxygenators, kidney dialyzers, and bioreactors for tissue engineering. *The course will emphasize the development and application of numerical methods to study transport problems*.

Course Objectives:

Students who complete this course will be able to:

1. Use equilibrium thermodynamics to describe driving forces for biological processes such as phase equilibria, interactions at mesophase interfaces (e.g. biological membranes), and partitioning across membranes.
2. Apply engineering models of momentum and mass transport, including both analytical and numerical solutions, to phenomena in biological systems such as flow of biological fluids and active transport across membranes.
3. Solve conservation equations that involve coupled biochemical reaction kinetics and transport phenomena.
4. Discriminate among and numerically simulate different pharmacokinetic models including one-compartment and multiple-compartment models for drug and toxin distribution and clearance in organs and organisms.
5. Use computational analyses of transport phenomena and thermodynamics to probe understanding of biological processes and to design and optimize biomedical devices.

Grading (100 pts + up to 5 pts E.C.):

- 1 Final Exam (cumulative) – 24pts
- 2 Group Computer Assignments – 15pts (7.5pts each)
- 6 Individual homework assignments – 36pts (6pts each)
- Group Project – 25 pts (total)
    - Project proposal and discussion: 5 pts
    - Project Website: 5 pts
    - Project Presentation: 5 pts
    - Software Tutorial: 5 pts
    - Individual Participation: 5 pts
- Extra credit poster: up to 5 pts

Grade Breakdown (out of 100 pts):

- 81 – 100 A
- 71 – 80 B
- 61 – 70 C
- 51 – 60 D
- <50 F

Homework Policies:

- Homework is due at the beginning of class, before the lecture starts. Late homework will not be accepted.
- **Group Computer Assignments:** You may choose groups of 2 for each computer assignment. Each group will hand in a single assignment. Assignments should be submitted as .zip files on CANVAS.
- **Individual Assignments:** You may discuss individual homework and computing assignments with other students, but each student must hand in their own individual assignment. <u>If you discuss the assignments with other students, you must disclose this in writing in your submission.</u>
- Students may not use a solutions manual, the Internet, or copy any part of an assignment from another student or group, including those from previous years. Students may use the textbook, resources listed above, and class notes. If you want to use a resource not listed, ask in class or email Dr. Munsky for permission.
- Homework solutions should be well organized with a logical structure. If the grader cannot follow your solution, you will not get credit for the problem. Final answers should be highlighted or boxed. Units have to be carried out all the way through the answer. In other words, all numbers must have the proper units. Work with algebraic expressions as far as possible before final computations.

Computer Assignments

- Assigned codes should be written in MATLAB.
- Each code assignment will require:
    1. One or more codes in a specified format.
    2. A script that runs this code and verifies results for specified test cases with known solution. These should be published as .doc, .txt, or .pdf documents;
- A brief statement (in bullet points) as to <u>why your solutions do or do not make sense</u>.
- It is CRUCIAL that you follow all instructions exactly, especially regarding required function name, inputs and outputs. If anything is unclear in a given assignment, make sure to contact the instructor as soon as possible.
- All codes must be documented and include a description. **Points will be taken off for poorly documented computer codes or unlabeled figures even if they work perfectly!**
- Codes will be graded according to the rubric or point list to be provided at the time of the assignment.

Course Projects:

A large portion of the grade for this course depends upon participation in a semester-long course project. Students will work in teams of 3 or 4 to produce (1) a short proposal, (2) a project website and (3) a 60-minute tutorial on a software package and presentation on a biomedical engineering topic of their choice (suggestions will be given in class).

A 1-page project proposal is due Sept. 18 (but may be submitted early).

- (1) Describe the background for a biomedical transport problem,
- (2) Present a schematic of a model that they would use to analyze this problem, and
- (3) Outline the requirements for a software package to be able which to analyze this problem.

The final project website must include:

- A brief description of a computational tool, its authors, its history, and a survey of the kinds of transport problems this tool has been used to address in past studies.
- A summary and link to a step-by-step guide for the acquisition and installation of the program.
- An introduction and brief literature survey that describes the importance of a specific transport problem in biomedical engineering topic and its relevance to the biomedical industry.
- The development of a computational model; including informative schematics, a detailed description of model assumptions, and an objective description of how these assumptions capture or deviate from realistic biomedical circumstances.
- A step-by-step tutorial on how the chosen computational tools can be applied to the analysis of the biological phenomenon under investigation. The object of this is not to develop new materials, but to boil down an existing tutorial from the product developer into a form that is easier for undergraduates in biomedical engineering to understand and implement. The focus models used in the tutorial should be related to transport in BME.
- A discussion of the model results and what they can tell us about the process under consideration.
- All references must be cited properly with links to the original sources.

The final project presentation must:

- Provide a 30-40 minute tutorial style introduction to a computational tool for the analysis of transport phenomena.
- Include a 20-30 minute demonstration on how that tool can be used to analyze specific transport phenomena in a biological system or biomedical device.

Students will be graded on the project as described above and in the project rubric (to be posted on Canvas).

Course projects must contain significant new work on the analysis of transport phenomena. In certain cases, students may be permitted to extend previous work from other courses, internships or similar activities. In these cases, students must clearly describe all previous efforts on the topic (who, when, where and why) and document what specifically is new in the current project. If you have questions, please see the instructor.

Academic Integrity Policy:

- The engineering profession is founded upon an expectation of utmost integrity among practicing engineers. Because of the trust placed in engineers by society, the college of engineering at Colorado State University expects its students to live up to a high standard of academic integrity. There is a zero tolerance policy in this class for violations of university academic integrity policies.
- Furthermore, to achieve the best possible learning experience, students must work on, and fully understand the solutions for, all of the course assignments. If a student fails to complete their own work and/or copies from an unauthorized source, they are cheating themselves out of their education and are committing plagiarism.
- This course will adhere to the CSU Academic Integrity Policy as found in the General Catalog - 1.6, pages 7-9 (Links to an external site.)Links to an external site. and the Student Conduct Code (Links to an external site.)Links to an external site.. At a minimum, violations will result in a grading penalty in this course and a report to the Office of Conflict Resolution and Student Conduct Services. In addition, a copy of the report will be sent to David Dandy and will be placed in your student file.
- If you have questions about academic integrity at CSU see the following web resource… http://learning.colostate.edu/integrity/index.cfm (Links to an external site.)Links to an external site.
- On homework assignments, **students may not use a solutions manual or copy any part of an assignment from another student, including those from previous years**. Both the student who copied and who allowed the copying of material will receive the same penalty.
- For open book exams, you may use your textbook and course notes. No electronic devices are allowed during exams. Talking to other students is not allowed during the exam.
- Homework and exams may not be shared with future students or on the Internet.

Accommodations:

Please let the instructor know as soon as possible if you have a disability, which may require some modification of seating, testing or other class requirements so that appropriate arrangements may be made.