BioE 104: Biological Mass Transport Phenomena

Department of Bioengineering, UC Berkeley

"Essentially, all models are wrong, but some are useful." - *George Box*

Instructor: Terry Johnson
GSIs: Mani Mahdinia and Mohammad Soheilypour

Texts:

- Course slides, notes, and lab protocols (required)
- Truskey, Yuan and Katz, *Transport Phenomena in Biological Systems*, 2nd edition (recommended, on reserve at the engineering library)
- Paul's Online Math Notes - Differential Equations (online reference)

Office hours:

- M 1-2:30PM in 419 HMMB (Mani)
- W 2:15-4PM in 418/419 HMMB (Terry)
- Th 11-12:30PM in 419 HMMB (Mani)
- Th 12:30-1:30PM in 418/419 HMMB (Terry)

GSI-supported labs (students may attend any lab section, but only the sections below will have a GSI available for questions):

- Tu 4-7PM
- W 4-7PM
- Th 4-7PM

Important dates:

- Midterm exam: Wednesday 3/16 6-8PM in 101 Moffitt
- Project poster file due (42"x18" poster in PDF format) by email to tdj@berkeley.edu: Tuesday 4/26 at noon
- Project poster session: Monday 5/2 10AM-noon in the b1 Stanley Hall atrium
- Final date for homework & midterm exam regrade requests: Wednesday 5/4 at 5PM
- Project paper (in PDF format) due by email to tdj@berkeley.edu: Friday 5/6 at 3PM
- Final exam: Tuesday 5/10, 7-9PM in 50 Birge

Course Description

The transport of mass, momentum, and energy are critical to the function of living systems and the design of medical devices. Biological transport phenomena are present at a wide range of length scales: molecular, cellular, organ (whole and by functional unit), and organism. This course develops and applies scaling laws and the methods of continuum mechanics to biological transport phenomena over a range of length and time scales. The course is intended for undergraduate students who have taken a course in differential equations and an introductory course in physics. Students should be familiar with basic biology; an understanding of physiology is useful, but not assumed.

While this syllabus is meant to be accurate description of the course and its content, it may be modified at the instructor's discretion.

Objectives

Students will understand the fundamentals of mass transfer and will be able to apply that knowledge to biological systems and to engineering design.

Grading Policy

25% Homeworks (1/2 credit for late homeworks turned in *before* solutions are posted, no credit afterwards)
25% Group projects (paper and poster)
25% Midterm exam
25% Final Exam

If you would like to contest a homework or exam grade, you must turn the homework or exam back in to one of the instructors with a note briefly describing the issue. Regrade requests should be based on an error on our part (e.g., adding up the points incorrectly) or what you suspect is a misunderstanding of your work. Regrade requests that argue with the rubric (e.g., "this is wrong, but you took too many points off") will be returned without consideration. Homeworks must be written in ink to be considered for regrades.

Your homeworks should stand alone. If a homework is disorganized or ambiguous, and requires an extensive explanation to the grader, you will likely still lose points. The homeworks are not only evaluating your understanding of the material - they are also meant to evaluate your ability to communicate that understanding clearly and concisely.

Also, be aware of UC Berkeley's Code of Student Conduct. Plagiarism or cheating will not be tolerated. Plagiarism includes appropriation of whole passages with or without credit, appropriation of words and phrases without credit, appropriation of both main and supporting ideas without credit, paraphrasing without credit, and, of course, submitting a paper written by someone else. If you are unsure of how to properly cite sources, please ask!

When deliverables are missed due to unavoidable circumstances, alternate arrangements can be made at the instructor's discretion. **Don't be shy! Dealing with unavoidable circumstances is part of my job. The sooner you contact me regarding issues such as these, the better.** If something is preventing you from a satisfactory engagement with this course, let me know so I can take the appropriate steps to accommodate you.

Lastly, **we expect you to work with others in this class**. While outright copying is not allowed, collaboration on assignments is very much encouraged. Find a study group and make them a regular part of your week!

Final project

Each group of four students will be jointly responsible for the final product as a whole, and though you may split the work up amongst yourselves, all of you will be expected to comprehend and be able to explain any part of the final product.

If any member of the group is unable to do their share of the work due to unforeseen and extraordinary circumstances, it is that student's responsibility to inform the instructor *as soon as possible* so that alternate arrangements can be made. The instructor reserves the right to assign different grades to various members of the group if the workload is not distributed and carried out evenly.

The final project consists of a six page *maximum* (including Works Cited; not including Appendix I, II, and the project contract) paper. This paper should be in a 2-column format consistent the IEEE submissions (Times New Roman, font size 10 for main text, 14 for the title, 12 for subheadings). Please note that larger charts, diagrams, tables, etc. *should* break from the 2-column format and take the entire width of the page. All tables and figures should be numbered and have a descriptive legend. Citations should be in NLM format. A sample LaTeX template will be made available to you, though you may use another document editor (e.g., Microsoft Word) to produce your document if you wish.

If you decide to go with LaTeX, there are many free options available. I have TeXworks installed as an editor with TeXLive on my laptop, and if you'd prefer to work collaboratively online, OverLeaf is an editor that you can use directly in a browser.

The paper should be organized as follows:

- **Abstract** - A brief (1-2 paragraph) description of the paper and its most important results.
- **Introduction** - What is the question that your work is trying to answer. Why is it important?
- **Methods** - This should include a description of your model's geometry and boundary conditions, and should also lay out where you got your physical constants from.
- **Results and Discussion** - Results of the model and your analysis should go here.
- **Conclusions** - A brief recap of your results, and what they have led you to believe - or *not* believe. If your results are inconclusive, *be honest about that*. A well-analyzed failure is preferable to an overhyped mess. If your results suggest future work, either computational or experimental, discuss those possibilities.
- **Works Cited** - Citations should be in NLM format. Your citations should consist primarily (though not necessarily exclusively) of peer reviewed journal articles. If you aren't sure if something is a peer reviewed journal - ask! Citations from the peer reviewed literature usually have a DOI number.

The Appendices should include:

- **Appendix I** - agendas and minutes from weekly group meetings.
- **Appendix II** - a copy of the personal goals statement for each team member detailing what that student wants to get out of the project experience along with a brief (250 words or fewer) statement from each team member discussing what steps that member took during the project to meet those goals.
- **A signed project contract**

Course Content

The chapter indications below refer to Truskey, 2nd edition. The course notes are already arranged in this order.

- Diffusion of mass (Chapters 1, 6, 8.1 - 8.2; skip Diffusion from a point source, 6.8.3, and 6.9)
    - Random Walk
    - Fick's Laws
    - Stokes-Einstein and Wilkie-Chang
    - Steady-state 1D diffusion in Cartesian, cylindrical, and spherical coordinates
    - Unsteady 1D diffusion in a semi-infinite medium
    - Unsteady 1D diffusion in a finite medium
    - Quasi-steady diffusion
- Diffusion and conservation of momentum (Chapters 2, 3, 4.4-4.6; skip 2.8, 3.5)
    - Newtonian and non-Newtonian shear in fluids
    - The Navier-Stokes equation
    - Dimensional analysis
    - Stokes' flow
    - Bernoulli's principle
- Diffusion and Convection (Chapters 3.5-3.6, 4.4-4.6, 7.1-7.3, 7.6, 7.8-7.9)
    - 1D diffusion and convection
    - Short contact time solution
    - Mass transfer coefficients
    - Co- and countercurrent mass transfer
- Diffusion and Reaction (Chapters 6.9, 10)
    - Diffusion- and reaction-limited adsorption
    - Reaction on and convection to a surface
    - Reaction and diffusion in a volume