16:125:573: Kinetics, Thermodynamics and Transport in Biomedicine, Spring 2025

Instructor:
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Class Meetings:
- Lecture, Mondays and Wednesdays, BME126 (Webex meeting as needed), 3:50-5:10 PM
- Office Hours, Tuesdays, 10:30 - 11:30 AM or by prior appointment

The course is electronically administered through Canvas (canvas.rutgers.edu). The class meetings will be held during regular class times in person. Lectures can also be viewed asynchronously through Canvas Modules. Lecture notes, example problems and any additional supplemental material will be available through Canvas. If you are having problems accessing the course materials, please contact Dr. Zahn immediately.

The goal of this course is to introduce students to advanced concepts in Transport Phenomena; especially as applied to biomedical problems and physiological modeling. Of particular interest are concepts which have analogous applications in many diverse engineering fields.

Grading:

- Grades are based on 1) Homework (10%) 2) In class quizzes (70%) 3) Final Project (optional) (20%)

Text Books:

G.A. Truskey, F. Yuan, D.F. Katz, "Transport Phenomena in Biological Systems 2nd Ed" Pearson Education, 2009.
R.F. Probstein, "Physiochemical Hydrodynamics 2nd Ed" Wiley Interscience, 2003.
R.B. Byrd, W.E. Stewart, and E.N. Lightfoot, "Transport Phenomena" John Wiley and Sons, 1960.
Y.C. Fung "Biomechanics Mechanical Properties of Living Tissues 2nd Ed" Springer, 1993.
R. L. Fournier "Basic Transport Phenomena in Biomedical Engineering 2nd Ed" Taylor and Francis 2007.
M.M. Denn, "Process Fluid Mechanics" Prentice Hall, 1980
L.G. Leal "Laminar Flow and Convective Transport Processes. Scaling Principles and Asymptotic Analysis" Butterworth Heinemann, 1992.

I will also be using other textbook chapters and resources and the text developed by Dr. Troy Shinbrot in the BME department. Appropriate material will be posted online on Canvas in the handouts section

Exams: There will be two exams given throughout the semester. Any student who feels the exams are 'unfair' or 'hard' are welcome to complete one of the transport exams Dr. Zahn took while in graduate school as a substitute for their exam grade.

Final Project: An optional final project applying course material to a particular biomedical Device/Biotransport problem is offered. If you choose not to complete a final project each exam will be weighted 10% more.

The final project report consists of a written report related to transport phenomena discussed in class (preferably with biomedical relevance but not an absolute requirement). Details will be forthcoming in the semester.

The purpose of the project is for you to explore ideas/topics discussed in class in further detail. It is expected to have a detailed **quantitative modeling** (and possibly computational simulation) component to your description.

Course Policy: Transport phenomena utilizes a large amount of applied mathematics. Successful understanding requires developing both physical insight to approach problems and validate solutions as well as

the use of vector and tensor notation, linear algebra, and especially solving partial differential equations. One area where students have struggle with this course is in applied mathematics.

Course preparation is essential.

Lectures will also be available as Canvas Modules by clicking on the Modules tab on the Canvas Course site. The streams will display lecture slides each of which have been dictated. Some of the slides contain a fair amount of mathematics being derived and the dictation can be dry; but I recommend you follow along with the lectures taking notes, so you understand the derivation process.

Teaching following the COVID pandemic.
The course is intended to be taught in person because I believe it is more effective than online course teaching (there are numerous studies to support this). However, the health and well-being of everyone in the class (as well as all members of the University community) is one of my top concerns.

If you feel unwell and have flu-like/COVID symptoms (Cough, Fever, Fatigue, Sore throat, difficulty breathing, loss of taste or smell) do not come to campus or to class. Please email me and let me know and we will make arrangements to accommodate you. Recorded lectures will be available from Canvas along with other course materials and/or we can set up a virtual meeting in the classroom. Please also make arrangements to obtain a COVID tests as soon as possible. Students who test positive for COVID-19 should contact Student Health directly (848-932-7402) to report the case and seek guidance.

If I develop symptoms then the course will move to a synchronous remote format through webex until the symptoms resolve and I have a negative COVID test.

If there are technology problems during remote sessions (inability to connect to webex, slow bandwidth etc.) I ask for patience and if I am unable to connect please stay in the webex room unless you receive an email from me. Please note that all lectures are made available as dictated powerpoint presentations.

Since circumstances are constantly changing communication is key and I ask for your patience and understanding and I will do my best to accommodate your concerns as well. If you have any questions or concerns please contact me.

Disclaimer: Dr. Zahn reserves the right to change the syllabus or any course policies at any time, depending on student preparation, particular areas of interest, or in order to achieve the learning objectives for the course. Students will be informed of any changes to the syllabus prior to their implementation.

Lec	Date	Subject	Problem Sets	Reading
	01/22	Introduction		
1	01/27	Lecture 1: Introduction/Vector and Tensor Operations Divergence Theorem (Math Stuff)		BSL Appendix A
2	01/29	Lecture 2: Viscosity/Rheological Properties of Fluids i.e., why can't I get the ketchup out of the bottle?		Truskey 76-82 Truskey 102-105 Shinbrot Chapter 9
3	02/03	Lecture 3: Momentum Shell Balances I "Easy Problems" (Newtonian Fluids, Bingham Plastics)		Truskey 55-119 Fournier 115-129 BSL 51-56
4	02/05	Lecture 4: Momentum Shell Balances II "Hard Problems" (Power Law Fluids, Casson Equation)	HW 1 due	Fung 72-82 Kundu 797-801
5	02/10	Lecture 5: Conservation Laws (Mass, Momentum) Hurray for the Divergence Theorem!!		Probstein 9-51 Truskey 120-134 Leal 11-69 Kundu 839-841
6	02/12	Lecture 6: Conservation Laws (Mass again? Convection Diffusion Equation)	HW 2 Due	Truskey 346-350
7	02/17	Lecture 7: Math Review PDEs, Bessel's Equation, (What the Heck is a Bessel Function??) Euler Equation		
8	02/19	Lecture 8: Unidirectional Flow in Tubes, Ducts, Conduits. Transient solutions	HW 3 Due	Truskey 134-145,
	02/24	Let's Catch our Breath!		
9	02/26	Lecture 9: Pulsatile Flow in Tube	HW 4 Due	Leal 71-117 Truskey 215-227 Shinbrot Chapter 4 Kundu 809-814
10	03/03	Lecture 10: Flow in Elastic Tubes (Arterial Flow) Pulse Wave Velocity		Shinbrot Chapter 3 Kundu 803-809
11	03/05	Lecture 11: Lumped Parameter Cardiovascular models: 2-3 element Windkessel Model	HW 5 Due	Elad and Einav
	03/10	Let's Catch our Breath! Exam Review!		
	03/12	Exam 1		
	03/17	Spring Break No Classes		
	03/19	Spring Break No Classes		
12	03/24	Lecture 12: Interfacial Boundary Conditions Law of Laplace Pulmonary physiology Plateau Rayleigh Instability (why do water streams break up into droplets?)		Leal 197-274 Shinbrot Chapter 2
13	03/26	Lecture 13: Low Reynolds number flow Flow Around Sphere	HW 6 Due	Denn 248-254
14	03/31	Lecture 14: Bernoulli Equation and Potential Flow		Truskey 177-187
15	04/02	Lecture 15: Boundary Layer Theory Flow Separation Entrance Effects Watch	HW 7 Due	Truskey 187-197
16	04/07	Lecture 16: Interstitial Flow Darcy's Law, Starling's Law		Truskey 399-434
17	04/09	Lecture 17: Semi-Infinite Domains, Similarity Solutions Flow from a moving plate One Dimensional Unsteady Diffusion Diffusion from an infinite Source Diffusion from a Sphere	HW 8 Due	Truskey 300-318
18	04/14	Lecture 18: Mass Transport with convective flow (Taylor Aris Dispersion, Compartmental analysis, Microdialysis		Truskey 346-352 Truskey 383-393 Probstein 82-95
19	04/16	Lecture 19 Transport with Reaction, Thiele Modulus Krogh Tissue Cylinder	HW 9 Due	Truskey 497-507 Truskey 637-646
	04/21	Let's Catch our Breath!		
20	04/23	Lecture 20: Ionic Transport, Nernst-Planck Equation Electrolyte Transport Hodgkin Huxley Model Cell Physiology and Biosensors	HW 10 Due	Truskey 357-359
21	04/28	Lecture 21: Electrokinetics, Electrophoresis		Probstein 26-29 Probstein 195-197
	04/30	Let's Catch our Breath one last time!! Exam Review!	HW 11 Due	
	05/05	Exam 2		

Academic Integrity Policy

Rutgers University takes academic integrity very seriously. By enrolling in this course, you assume responsibility for familiarizing yourself with the Academic Integrity Policy and the possible penalties, including suspension and expulsion, for violating the policy.
As per the policy, all suspected violations will be reported to the Office of Student Conduct.
Academic dishonesty includes (but is not limited to):

- Cheating
- Plagiarism (using the work of others as your own)
- Aiding other students in committing a violation or allowing other students to use your work
- Failure to cite sources correctly
- Fabrication
- Using another person's ideas or words without attribution
- Reusing previous assignments
- Unauthorized collaboration
- Sabotaging another student's work

If you are in doubt about what does and does not constitute academic dishonesty, please consult Dr. Zahn

Adherence to academic integrity principles is important to ensure that:

- All student work is fairly evaluated and no student has an inappropriate advantage over others.
- The academic and ethical development of all students is fostered.
- The reputation of the University for integrity, ethics, scholarship, and professionalism is maintained and enhanced.

Key points for this course:

I have seen a dramatic uptick in academic integrity violations in the past few years and I am well versed in reporting cases to the office of student conduct. I am not 'out to get' students but academic integrity violations will not be tolerated.

On homework assignments, students may collaborate on homework in groups of up to but not exceeding three people. **Collaboration and Discussion is encouraged. Cheating is not!!!**

There is a fine line between collaboration and discussion of ideas and cheating. DO NOT CROSS OVER IT!

All homework writeups, and exams are to reflect your own work. You are not to copy solutions from classmates, or use/copy web materials (solutions from other university courses, course hero, chegg, generative AI, etc.) in solving problems.

If you have trouble with a homework assignment feel free to consult your classmates and you should come to office hours to ask your questions to me. But when you go to writeup homework you need to work independently.

Generative AI is strictly prohibited in this course. This includes written documents (i.e., final project writeup), mathematical derivations and problem solving, generating (Matlab) code and graphing.

Cheating will result in a 0 grade on an assignment. Repeat offenders will be given a grade of F in the class.

- Each student is expected to submit his/her homework independently, as an individual
- The collaboration is allowed to work together to a solution(s), not to ease the work load or responsibility for each student
- Authorized (i.e. acceptable) collaboration includes: 1) interpretation of the assignment instructions, 2) concepts involved in the assignment, 3) approaches to completing the assignment.
- Anything beyond this constitutes unauthorized aid and violates the academic integrity policy.
- The assignment should not be a compilation of solutions from different students – each student should do all of the work on their own.
- If you collaborate, please include the names of your collaborators after your name at the top of the submitted assignment.

- Including a student's name indicates that he/she contributed to the collaboration; including a student's name and/or providing your answers to a student when that student did not contribute is a violation of academic integrity.
- If you have trouble with a homework assignment feel free to consult your classmates and you should come to office hours to ask your questions to me
- During exams you must not communicate with others.
- It is unethical to receive a score / grade using work produced by another person (who may or may not be a student in this class).
- All Exams and Homework assignments will require students to sign an Honor pledge (see below) or will not be graded.

Honor pledge: On each assessment you will be required to re-affirm the university honor pledge: "*On my honor, I have neither received nor given any unauthorized assistance on this examination / assignment*". The academic integrity policy also states that "*Students are also encouraged to help educate fellow students about academic integrity and to bring all alleged violations of academic integrity they encounter to the attention of the appropriate authorities*". i.e. if you are aware of or suspect that other students are violating the academic integrity policy, you should inform the instructor, anonymously if you prefer.

The University's full statement on academic integrity, is available at http://nbacademicintegrity.rutgers.edu/home/academic-integrity-policy/. Students are expected to adhere to the Policy on Academic Integrity.

II Violations of Academic Integrity
Various ways in which academic integrity can be violated are described below. The comments and examples within each section provide explanations and illustrative material, but do not exhaust the scope of possible violations. For context and specific details, the University Code of Student Conduct as well as the Student Judicial Affairs website should be consulted.

A. Cheating
Cheating is the use of impermissible and/or unacknowledged materials, information, or study aids in any academic activity. Using books, notes, calculators, conversations with others, etc. when their use is restricted or forbidden, constitutes cheating. Similarly, students may not request others (including commercial term paper companies) to conduct research or prepare any work for them. Students may not submit identical work, or portions thereof, for credit or honors more than once without prior approval of the instructor to whom the work is being submitted for the second or subsequent time.

B. Fabrication
Fabrication is the falsification or invention of any information or citation in an academic work. "Invented" information may not be used in any laboratory report or other academic work without authorization from the instructor. It is improper, for example, to analyze one sample in an experiment and "invent" data based on that single experiment for several more required analyses. Students must also acknowledge the actual source from which cited information was obtained. A student should not, for example, reproduce a quotation from a book review and claim that the quotation was obtained from the book itself.

C. Plagiarism
Plagiarism is the representation of the words or ideas of another as one's own in any academic work. To avoid plagiarism, every direct quotation must be identified by quotation marks, or by appropriate indentation, and must be cited properly according to the accepted format for the particular discipline. Acknowledgment is also required when material from any source is paraphrased or summarized in whole or in part in one's own words. To acknowledge a paraphrase properly, one might state: to paraphrase Plato's comment... and conclude with a footnote or appropriate citation to identify the exact reference. A footnote acknowledging only a directly quoted statement does not suffice to notify the reader of any preceding or succeeding paraphrased material. Information that is common knowledge, such as names of leaders of prominent nations, basic scientific laws, etc, need not be cited; however, the sources of all facts or information obtained in reading or research that are not common knowledge among students in the course must be acknowledged. In addition to materials specifically cited in the text, other materials that contribute to one's general understanding of the subject may be acknowledged in the bibliography.