Engineering Sciences 53: Fall 2023

Quantitative Physiology as a Foundation for Bioengineering

Meeting time: Monday, Wednesday, Friday 11:15 am -12:30 pm

Note: This course includes an additional weekly 3 hour lab. See canvas for a list of lab section times, how to rank preferences, and your lab placement.

Location: Class lectures: Room 1.402, Allston SEC
Labs: Room LL1.241, Allston SEC

Course description: This course is designed as an introduction to thinking as a bio/biomedical engineer and is recommended for first years and sophomores but open to all students. Simple mathematical models are used to represent key aspects of organ systems function. Core engineering concepts are explored through mechanical and electrical examples within the human body. The primary focus is on quantitative descriptions of organ systems function and control in terms of physical principles and physiologic mechanisms. It includes a foundation in human organ systems physiology, including cardiovascular, pulmonary, and renal systems. Emphasis will be given to understanding the ways in which dysfunction in these systems gives rise to common human disease processes.

Pre-requisite: ES 53 does not have any pre-requisites except some calculus at the high school level.

Co-requisite: We do require physics as a co-requisite. Students must have either taken or be concurrently enrolled in one of the following physics courses at Harvard: PS12a/12b, Physics 15a/15b, AP50a/50b, PS2/PS3. First year students who cannot fit physics into their first semester should talk to the Dr. Moyer about their prior physics background if they would like to enroll.

Texts: **Required texts:**
Human Physiology, Fox, 12th, 13th, **14th Edn**., or 15th Editions (all are acceptable, but the page numbers only line up for the 13th and 14th editions)
Medical Physiology, Boron and Boulpaep, 2017, 3rd Edn. (Available in digital format for free via HOLLIS – no need to buy this textbook unless you'd like a hardcopy)

Head Instructor: Dr. Linsey Moyer, PhD lmoyer@seas.harvard.edu (SEC LL1.240)
Guest Instructor: Prof. Jennifer Lewis, PhD jalewis@seas.harvard.edu
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Course goals and learning objectives:
(1) to provide a basic knowledge of physiology which students can draw upon in pursuing their own areas of interest in bioengineering, systems biology, or other quantitative biomedical sciences
(2) to provide a quantitative introduction to physical principles that play a key role in understanding basic physiology and are particularly important in biomedical engineering
(3) to give students practical laboratory experience in physiological principles, in which they use basic medical and physiologic instrumentation to record real-time data sets of physiologic measurements
(4) to gain fluency in performing basic quantitative visualization and analyses of this data, especially through MATLAB. No prior experience with MATLAB is required prior to enrolling in this course. It is highly recommended to complete the MATLAB bootcamp offered by FAS or the MATLAB onramp.
(5) to provide an introduction to the breadth of research areas and career pathways from visiting faculty and alumni.

Schedule: (Lecture topics may change slightly throughout the course.)

#		Date	Module	Topic	Lab Held (Th)	What's due
1	W	6-Sep	Overview	Overview		
2	F	8-Sep	EP	Cell membrane biophysics; and chemical gradients	Lab 0: MATLAB	
3	M	11-Sep	EP	Nernst potential, membrane potential, driving voltages		PS0
4	W	13-Sep	EP	Action potentials; Hodgkin-Huxley intro		
5	F	15-Sep	EP	Hodgkin-Huxley model	Lab 1: EMG part 1	Lab 0
6	M	18-Sep	Muscle	Muscle anatomy and neural innervation		PS1
7	W	20-Sep	Muscle	Muscle contraction, tetany		
8	F	22-Sep	Muscle	Force, length, power; Hill's model	Lab 2: EMG part 2	Lab1
9	M	25-Sep	Muscle	Cardiac muscle; Cardiac action potentials		PS2
10	W	27-Sep	Cardiac	Electrical properties of the heart; contraction, cardiac cycle		
11	F	29-Sep	Cardiac	Blood Pressure and electromechanical pumping		Lab 2
12	M	2-Oct	Guest	Faculty & alum introductions		PS3
13	W	4-Oct	Guest	Faculty & alum introductions		
14	F	6-Oct	Quiz 1	Quiz 1	Lab 3: ECG and your heart	
	M	9-Oct		NO CLASS – Indigenous People's Day		
15	W	11-Oct	Cardiac	Pressure volume dynamics; Wigger's Diagram		
16	F	13-Oct	Cardiac	Heart problems, blood	Lab 4: Pulse, Blood pressure,	Lab 3
17	M	16-Oct	Vascular	Blood; Vascular anatomy and function		PS4
18	W	18-Oct	Vascular	Hemodynamics and vascular resistance		
19	F	20-Oct	Vascular	Blood flow problems; cardiovascular diseases		Lab 4
20	M	23-Oct	Vascular	Hemoglobin, gas transport; partial pressures		PS5
21	W	25-Oct	Guest	Applications in Quantitative Pediatric Cardiology		
22	F	27-Oct	Pulmonary	Pulmonary anatomy and circulation	Lab 5: Lung volumes and flow	
23	M	30-Oct	Pulmonary	Mechanics of ventilation, lung volumes and pressure		PS6
24	W	1-Nov	Pulmonary	Gas transport and physics, pulmonary anatomy		
25	F	3-Nov	Guest	Faculty & alum introductions	Lab 6: Respiration	Lab 5
26	M	6-Nov	Quiz 2	Quiz 2		Quiz 2
27	W	8-Nov	Pulmonary	Oxygen consumption modeling		
28	F	10-Nov	pulmonary	Pulmonary diseases		Lab 6
29	M	13-Nov	Renal	Filtration and solute exchange		PS7
30	W	15-Nov	Renal	Modeling renal function		
31	F	17-Nov	Renal	Modeling renal function II	Lab 7: Renal filtration	
32	M	20-Nov	Renal	Renal diseases/conditions		PS8
	W	22-Nov		NO CLASS - Thanksgiving		
	F	24-Nov		NO CLASS - Thanksgiving		Lab 7
33	M	27-Nov	Renal	Faculty & alum introductions		
34	W	29-Nov	Guest	Jennifer Lewis (Renal Vascular interaction)		PS 9
35	F	1-Dec	Guest	Jennifer Lewis – Bioprinting and Assembly		
36	M	4-Dec	Quiz 3	Quiz 3		Quiz 3
	TBD	TBD		Final Presentations		Presentation

Policies and Expectations:

In this class, you will take an active part in the learning process. In some ways, this may make the course more challenging; however, we hope this approach will make the course much more fun and interesting as well. Because of the interactive nature of this course, we highly encourage attendance. Participation will be necessary for you to completely achieve the course goals. It is your job to come prepared to class, ask questions, participate, and take notes. If we write something on the board you should also write it down. We encourage you to attend office hours and meet with the teaching staff and peers to stay on top of your assignments.

The tenets of our approach to the classroom:

- *Adopt a Humanistic Approach to Science and Engineering*
- *Recognize that the Culture of Science Is Shifting Toward Collaboration and Inclusion*
- *Understand that Experiences, Perspectives, Personalities, and Worldviews Vary*
- *Realize that People Are Imperfect and Make Mistakes*
- *Take Appropriate Steps to Make Amends If You Make a Mistake*
- *Adopt a Mindset of Continuous Growth and Improvement*

Diversity and Inclusion – We, the instructional team including Dr. Moyer, and the teaching assistants would like to create a learning environment for our students that supports a diversity of thoughts, perspectives and experiences, and honors your identities (including race, gender, class, sexuality, religion, ability, etc.) To help accomplish this:

- If you have a name and/or set of pronouns that differ from those that appear in your official Harvard records, please let us know.
- As a participant in course discussions and lab groups you should also strive to honor the diversity of your classmates.
- We (like many people) are still in the process of learning about diverse perspectives and identities. If something was said in class (by anyone) that made you feel uncomfortable, please talk to us about it.
- You can also submit anonymous feedback (which will lead to us making a general announcement to the class, if necessary, to address your concerns). If you prefer to speak with someone outside of the course, the SEAS Committee on Diversity, Inclusion, and Belonging is an excellent resource.
- If you are struggling for any reason in this course, please reach out to us. The instructional team want to be a resource for you.

Faculty and alumni panels - While this course is not an overview of biomedical engineering it does provide an introduction to the breadth of research areas and career pathways from our guests who visit. Throughout the course we will invite faculty from bioengineering to give short overviews of their research. Alumni will be invited to share their experiences along their career paths. The students will be in charge of introducing the faculty members or alums. Attendance at these meetings will be part of the participation grade. These visits are a valuable feature of this course and provide students with introductions to faculty and alumni.

Problem sets – Problem sets will cover the quantitative aspects of the physiology covered during lecture and from the text(s). Students may choose to consult with one another on problem sets and share general strategies, but each student's problem set must represent his/her/their own work. Copying from one another is not permitted. Please submit your problem set by uploading a PDF version to Canvas by the designated time on its respective due date. Each problem set will cover material from the text and the 3-4 lectures preceding the deadline (e.g. P set 2 covers the 18th, 20th, and 22nd material and is due on Tuesday the 26th).

Laboratory assignments - Students will work in small groups (3 students per group) on laboratory exercises and reports. Except for the first two labs, one report is submitted per group of students but must be a collaborative effort. All students are expected to attend their lab section and work with peers to collect the required data. Each student must contribute to the

group's laboratory report both in the writing and the MATLAB analysis. Different groups may choose to consult with one another, but copying from one another is not permitted. Written reports should include a thorough presentation & visualization of experimental results. One report should be submitted through Canvas per group of students in PDF format. Please check out the additional lab report guide and past example (see Canvas). Check Canvas for due dates which are roughly one week after the lab is held.

Quizzes – Three quizzes will cover lecture material, laboratory material, and problems similar to those found in your problem sets. To study it is recommended to review 1) handouts and learning objectives 2) problem sets, 3) past quizzes (see Canvas). These quizzes will be held during normal lecture time (75 minutes). You are allowed to bring the following to each of the three quizzes:

- One-sided single page of notes allowed. (One equation sheet will already be given to you and will be available on Canvas)
- Bring pencils and calculators (and extra batteries or an extra calculator)

Final Project - Throughout ES53, we learn about our familiar but mysterious, intricate but simple, delicate but robust body. For the final project students will dig deeper into one specific clinical issue of their choosing. You'll use some engineering and creativity to try to design a new medical intervention. For this assignment, you will work in teams of four to:

1. Understand the pathophysiology of a particular disease/clinical issue
2. Research available treatment options and identify gaps (shortcomings of current medical interventions)
3. Propose a medical solution to treat the disease or address complication(s)
4. Write up your proposed design with supporting background information
5. Pitch your idea to a group of engineers - your classmates!

The final project presentations will occur in person during the scheduled final exam period. The College will set this date and time.

Academic Honesty – All students are expected to maintain an environment of academic integrity. Students are expected to collaborate but any and all cheating will result in a zero grade for that assignment. Repeated violations of academic integrity may result in dismissal from the course or failure of the course. All students must avoid engaging in any activities (e.g ChatGPT) that would dishonestly improve their results, or improve or hurt the results of other learners. To that end students are not permitted to share course materials via website, via email, photocopying, or by any other means. Always remember that if you need help with any part of the coursework you are always encouraged and welcome to talk to the instructors or any of the teaching fellows.

Late Work Policy - If P-sets or lab reports are turned in late (past the date set in canvas for P-sets and past your specific due date/time for labs) then 20% of the grade for that assignment will be deducted. If the assignment is turned in more than 12 hours late then 60% of the grade for that assignment will be deducted. If you turn in an assignment more than 48 hours late no points or credit will be given for that assignment. All members will receive a reduction in their grade for late lab assignments.

Tentative Grading Breakdown:

Problem Set Assignments	20%*
Lab Reports	20%
Quizzes	40%
Final Project Presentation	15%
Participation	5%

**One p-set may be dropped*

QRD statement: ES 53 is a quantitative physiology course wherein several body systems are modeled using math and physics to explain and predict physiological phenomena. Students learn computational methods for analyzing and processing real physiological signals from their bodies using MATLAB and also compare limitations of both the models and the real data. A background in high school calculus is expected but no prior coding experience is required.

Generative Artificial Intelligence statement: We expect that all work students submit for this course will be their own, or through collaborative work with other students. In instances when collaborative work is assigned, we expect for the assignment to list all team members who participated. We specifically forbid the use of ChatGPT or any other generative artificial intelligence (AI) tools for any problem sets, quizzes, or labs. Violations of this policy will be considered academic misconduct.

Please note that the A.I. policy for this course reflects our specific goals. We fully understand that different courses in the College will have a wide range of policies based on the particular goals of those courses, and we hope that you'll reach out to us if—at any point—you're unclear about what our policy is or why.

We want to make sure you have access to as much support as possible and that you are sure what that support is, and where to find it. Here are some of the people, places, and other resources you can (and should!) reach out to:

- Us! Our course will have regular office hours, and you should come to those at any stage of completion of your problem sets or labs.
- Your peers – we encourage collaboration and peer to peer learning.
- Our Canvas site has many links to MATLAB help as well as a guide created by past TFs!
- Your textbooks, including the free online Physiology text available via HOLLIS.
- MATLAB online help: https://www.mathworks.com/help/matlab/