

BIOE 420: Introduction to Biological Control Systems

Fall 2026, Mon/Wed/Fri: 11:00-11:50, 2100 Sidney Lu Mech Eng Bldg

Course Info

3 Undergraduate credit hours

3 weekly 50-minute lectures, 3.0 hrs/wk

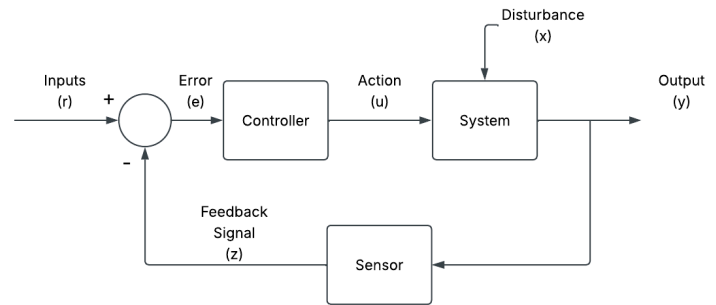
Instructor: Eliot Bethke, PhD

bethke2@illinois.edu

3126 Everitt Lab

Office Hours

TBD (starting week 2) or by appointment



Canvas Site:

<https://canvas.illinois.edu/courses/72206>

Required Materials

Physiological Control Systems: Analysis, Simulation, and Estimation. Michael C. K. Khoo, v2.

Available Free Online through library (must be on campus or VPN):

<https://onlinelibrary-wiley-com.proxy2.library.illinois.edu/doi/book/10.1002/9781119058786>

Students are also required to obtain an Arduino Uno R4 Minima by week of Sept. 7, along with a USB cable to interface to a computer using MATLAB. See canvas site for more details. The Arduino Uno will be used in Arduino exercises turned in during the semester.

Supplementary Texts

- Nise. Control Systems Engineering, 6th Ed. John Wiley and Sons, Inc. 2011.
- K. Ogata. Modern Control Engineering. 3rd ed. Prentice Hall, 1997.
- Feedback Systems: An introduction for scientists and engineers. Astrom and Murray. Online. https://fbswiki.org/wiki/index.php/Main_Page

Course Objectives

At the end of the course, the student should be able to:

- Translate a problem statement about a physiological system into various forms for understanding its behavior, including: block diagrams, Differential equations, Laplace, Fourier analysis, and state space.
- Understand and be able to apply analytical tools for understanding the behavior of a system, including impulse and frequency response, bode plots, and phase diagrams.
- Be able to assess stability of a linear system. Be able to design a stable controller of a linear system.
- Be able to use system identification principles to characterize an unknown system.
- Demonstrate understanding of tools to deal with nonlinear systems often encountered in biology.
- Be competent in applying the systems analysis tools in MATLAB to understand complex, high-order systems.

Course Overview

The Bioengineer is faced with complex, personalized physiology for each patient and medical condition that healthcare may encounter. However, the capabilities to measure and interact with that physiology are reaching new levels through minimally invasive and sensitive detectors along with targeted therapeutic agents and internet connected devices. This course will give students the tools that they need to understand homeostatic systems in the body, characterize them mathematically, and enable simulation and control of those systems. In addition, the student will learn to design controllers to impact the system to restore homeostasis when pathology has disrupted it. Students will explore control through theory, written assignments, MATLAB tools, and simulations. Students will complete a project, designing and characterizing a physiological control system for a realistic medical condition.

Homeworks

Weekly homework assignments will be given that require the students to demonstrate the concepts learned during the reading and lecture portions of the course. Not all problems will be graded. Solutions will be made available for all problems, and it is the student's responsibility to ensure that all problems were understood. Note: Students may discuss homework problems with other students in the class but should write up solutions independently with their own work. Assignments will be due through Canvas. Please read the instructions carefully and ask questions if items are not clear. Students must ensure that the uploads are clearly readable and adjust their scanning app as needed.

Final Project

The course will also include a project. Working in teams, the students will design a controller to meet a specified need for controlling a physiological system. Students will analyze the system, simulate its behavior, perform system identification and controller design, and analyze the performance of their solution. The course project takes the place of a final exam and should demonstrate the application of the concepts learned in the course from the controller design to analysis of performance.

Quizzes and Exams

Several short quizzes will be given, unannounced, on several occasions to test understanding of lecture material and assigned reading. There will be no excused absences for quizzes but the three lowest quiz grades will be dropped. The course will also consist of three midterm exams.

Approximate Contact Hours for Topics

Topic	Hours (est)	Example from Biology
Differential equations to transforms	6	Cardiovascular system, muscle spindle
Time domain methods	2	Biorhythm tracking and filtering
State space	2	Respiratory tidal volume
Frequency analysis	5	Lung mechanics
Stability	5	Pupillary light reflex
System Identification	6	Functional brain imaging, blood glucose regulation
Design of control systems and model-based control	6	Muscle position, control of respiration
Adaptive control in biology	2	Arterial pCO ₂ buffering
Nonlinear systems	6	Molecular networks
<i>TOTAL</i>	<i>40</i>	

Grading Breakdown

Exam 1	10%
Exam 2	10%
Exam 3	10%
Homework	15%
Quizzes	15%
Arduino exercises	5%
Final project	25%
Class participation	10%

Grading Scale

A	≥ 90%
B	80 - 89.9%
C	70 - 79.9%
D	60 - 69.9%
F	< 60%

Academic Integrity

The University of Illinois at Urbana-Champaign Student Code should also be considered as a part of this syllabus. Students should pay particular attention to Article 1, Part 4: Academic Integrity. Read the Code at the following URL: <http://studentcode.illinois.edu/>.

Academic dishonesty may result in a failing grade. Every student is expected to review and abide by the Academic Integrity Policy: <https://studentcode.illinois.edu/article1/part4/1-401/>. Ignorance is not an excuse for any academic dishonesty. It is your responsibility to read this policy to avoid any misunderstanding. Do not hesitate to ask the instructor(s) if you are ever in doubt about what constitutes plagiarism, cheating, or any other breach of academic integrity.

This Course's Policy on Use of Generative AI (GenAI or AI)

What do I mean by "GenAI / AI":

AI is a broad term encompassing many different models and technologies which operate on a wide variety of media including image and video, audio, text, and even mathematical proofs. The most relevant tools to this course are LLMs including (but not limited to) OpenAI's ChatGPT, Anthropic's Claude, Microsoft's CoPilot, Google's Gemini, and AI agents which utilize LLMs including (but not limited to) Manus, OpenClaw, Devin, and others. These tools can be used to generate code, formulae, and writing, which are the types of output which will be used to evaluate you in this course.

What am I NOT allowed to use AI for?

You are not allowed to use AI tools to generate text, code, formulae, or images which answer questions given on any homework, quizzes, or exams that will contribute to your grade. Your work must be your own, as your degree will not be awarded to your AI, nor do I assume you wish your future paychecks to be paid to your AI.

What can I use AI tools for in this course?

AI tools are ubiquitous. I do not possess tools to police your AI usage, nor do I wish to spend my time investigating you for potentially using AI tools. Below is a list of commonly accepted uses for AI which are generally considered ethical as long as you cite the usage where appropriate:

- Generate additional problems, study guides, or summaries to provide supplemental learning outside of this course
- Light usage to clean up language/grammar, especially if English is not your first or primary language
- Troubleshoot code you wrote which does not run properly and you cannot fix with assistance from peers/instructors
- Providing starting points for basic research such as identifying keywords or terminology to help with identifying primary literature in databases like PubMed, Arxiv, Scopus, etc.

If you do use AI tools in these or similar capacities in any way that modifies or affects the materials you submit, you should properly [cite the use of the tool using the APA recommended format](#).

Expectations and promises related to AI

At the end of the day, this course and the materials provided are intended to challenge you to think through and navigate each stage of the problem solving process. Manually working through these curated problem sets and projects requires you to reflect on previous learning, and to recognize patterns of problems and problem solving common in bioengineering. Applying techniques to simplify, reduce, and solve those problems on your own given the information provided reinforces deeper, more complex cognitive skills that enable more expert reflection on the result and will enhance your understanding of the potential impacts of solving that problem. The use or overreliance on AI can short-circuit this process if you do not already have enough expertise, tricking you into thinking you're learning the same deeper ideas.

By using AI to generate your submitted work, you are doing the following things:

1. Taking a short-cut to achieve fast, easy results which may hurt your long-term learning
2. Risking becoming dependent on private, for-profit tools to accomplish certain tasks
3. Cheapening the value of the degree you are seeking, and
4. Violating my trust and expectation of you

Likewise, it would be unfair of me to not offer you an expectation of myself. By taking this course, you can trust that:

- I will properly cite and disclose any usage of AI tools used to refine any materials presented to you in this course
- I will NEVER use AI to grade your assignments or provide feedback
- The content and answers I provide you in this course are derived from years of hard work and experience which I will happily share to help you if I can
- I will not accuse you of using AI unless you go out of your way to make it blatant and do not cite it as requested

Additional Expectations

1. The student will consider the readings as required material and may be tested on items not covered during lecture. Readings are important at the start of the course, but then lecture material becomes the main source of information as the course progresses.
2. Not all homework problems will be graded. Students are expected to study the solution sets to ensure that they have understood all of the problems assigned.
3. Ethics and Integrity: Students are expected to uphold the highest ethical standards, be honest, and practice academic integrity. This includes doing original work and citing sources used. Group discussions with classmates (only those currently enrolled in the course) about course content and homework is encouraged. However, all work submitted by you must be your own work. No discussion is allowed on exam problems. Please see the academic integrity statement at the University's policy on academic integrity, found in the Code of Policies and Regulations Applying to All Students under Article 1, Part 4: Academic Integrity and Procedure.
4. Working on course material with students or AI other agents who are not students that are currently enrolled in the course is prohibited. Also, using course materials from previous semesters is prohibited. This is cheating as defined in the student code and is a violation of academic integrity.

5. There will be no excused absences for quizzes, but the lowest three quiz grades will be dropped.
6. Homework is due by the start of class on the due date, unless otherwise noted. Homework not turned in on time will be accepted until 1 pm the following day at a 50% penalty. You must email the homework to me: bethke2@illinois.edu as a pdf file by the 1 pm deadline to receive any credit. The work must be in a logical order and clear what works pertains to which problem of the homework.
7. Students will be expected to track their grade and verify its accuracy by frequently checking the grades on the Canvas site, as appropriate.

Attendance

Your attendance at all scheduled classes is mandatory and essential for success in the course. However, circumstances occasionally occur where you may need to miss a class.

1. **Planned Absences:** If you need to miss class or an exam for a religious observance, an athletic commitment, graduate school interview or some other planned reason, you must notify the instructor and reach an agreement on plans to make up any missed work (exams) prior to the date, otherwise, the absence will be unexcused and you will receive a zero on the exam. Homework must be turned in early (before the deadline) if you will be absent on the day it is due. The lowest three quiz grades will be dropped to accommodate missed quizzes, no make-up for missed quizzes will be provided.
2. **Serious Illness/ Family Emergency:** If you are seriously ill or experiencing a family emergency and are unable to attend class or complete an assignment, inform Dr Sutton by email. If you need an extension on your homework due to a serious illness or family emergency, arrangements must be made with Dr. Bethke BEFORE the homework due date. Late homework cannot be accepted for any reason once the answer key is posted.

Mental Health

Significant stress, mood changes, excessive worry, substance/alcohol misuse or interferences in eating or sleep can have an impact on academic performance, social development, and emotional wellbeing. The University of Illinois offers a variety of confidential services including individual and group counseling, crisis intervention, psychiatric services, and specialized screenings which are covered through the Student Health Fee. If you or someone you know experiences any of the above mental health concerns, it is strongly encouraged to contact or visit any of the University's resources provided below. Getting help is a smart and courageous thing to do for yourself and for those who care about you.

- Counseling Center (217) 333-3704
- McKinley Health Center (217) 333-2700
- National Suicide Prevention Lifeline (800) 273-8255
- Rosecrance Crisis Line (217) 359-4141 (available 24/7, 365 days a year)

If you are in immediate danger, call 911.

Community of Care

As members of the Illinois community, we each have a responsibility to express care and concern for one another. If you come across a classmate whose behavior concerns you, whether in regard to their well-being or yours, we encourage you to refer this behavior to the Connie Frank CARE Center (formerly the Student Assistance Center) in the Office of the Dean of Students. You may do so by calling 217-333-0050 or by submitting an online referral. Based on your report, staff in the Connie Frank CARE Center will reach out to offer support and assistance.

Further, as a Community of Care, we want to support you in your overall wellness. We know that students sometimes face challenges that can impact academic performance (examples include mental health concerns, food insecurity, homelessness, personal emergencies). Should you find that you are managing such a challenge and that it is interfering with your coursework, you are encouraged to contact the Connie Frank CARE Center (formerly the Student Assistance Center) in the Office of the Dean of Students for support and referrals to campus and/or community resources.

Students with Disabilities

To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor as soon as possible and provide the instructor with a Letter of Academic Accommodations from Disability Resources and Educational Services (DRES). To ensure that disability-related concerns are properly addressed from the beginning, students with disabilities who require assistance to participate in this class should apply for services with DRES and see the instructor as soon as possible. If you need accommodations for any sort of disability, please speak to me after class, or make an appointment to see me or see me during my office hours. DRES provides students with academic accommodations, access, and support services. To contact DRES, you may visit 1207 S. Oak St., Champaign, call 217-333-1970, e-mail disability@illinois.edu or visit the DRES website at <http://www.disability.illinois.edu/>. Disruptive Behavior Behavior that persistently or grossly interferes with classroom activities is considered disruptive behavior and may be subject to disciplinary action. Such behavior inhibits other students' ability to learn and an instructor's ability to teach. A student responsible for disruptive behavior may be required to leave class pending discussion and resolution of the problem and may be reported to the Office for Student Conflict Resolution (<https://conflictresolution.illinois.edu>; conflictresolution@illinois.edu; 333-3680) for disciplinary action.

Emergency Response Recommendations

Emergency response recommendations and campus building floor plans can be found at the following website: <https://police.illinois.edu/em/run-hide-fight/>. I encourage you to review this website within the first 10 days of class.

Religious Observances

Illinois law requires the University to reasonably accommodate its students' religious beliefs, observances, and practices in regard to admissions, class attendance, and the scheduling of examinations and work requirements. In order to best facilitate planning and communication between students and faculty, students should make requests for absence letters as early as possible in the semester in which the request applies.

Sexual Misconduct Reporting Obligation

The University of Illinois is committed to combating sexual misconduct. Faculty and staff members are required to report any instances of sexual misconduct to the University's Title IX and Disability Office. In turn, an individual with the Title IX and Disability Office will provide information about rights and options, including accommodations, support services, the campus disciplinary process, and law enforcement options.

A list of the designated University employees who, as counselors, confidential advisors, and medical professionals, do not have this reporting responsibility and can maintain confidentiality, can be found here: wecare.illinois.edu/resources/students/#confidential.

Other information about resources and reporting is available here: wecare.illinois.edu.