Carleton UNIVERSITY | Department of Systems and Computer Engineering

SYSC 3610
Biomedical Systems, Modeling, and Control
Fall 2023

Instructor

TA name(s)

Course Description and requirements

1) Course description

Properties of linear systems. Linear dynamic models of biomedical systems. Biomedical application of the Laplace transforms. Transfer functions. Block diagram. Frequency and time response. Feedback, control, and stability. Biomedical systems modeling and control.

Includes: Experiential Learning Activity.

Lectures three hours a week, laboratory three hours a week.

http://calendar.carleton.ca/undergrad/courses/SYSC/

2) Prerequisites

MATH 1005 and ((ECOR 1051 and ECOR 1052 and ECOR 1053 and ECOR 1054) or ECOR 1101) and enrolment in Biomedical and Electrical Engineering or Biomedical and Mechanical Engineering, and second-year status in Engineering.

Precludes additional credit for SYSC 3500 or SYSC 3600.

3) Prior Knowledge

Students should have knowledge of:

- Integral calculus (MATH 1004).

- Differential equations (MATH 1005).
- Euler's formula and complex exponential functions, basic mechanics and dynamics, masses, springs, dampers, free body diagrams (ECOR 1053/ECOR 1054/ECOR 1101).
- Basic knowledge of electrical components such as resistors, capacitors, inductors, electrical concepts such as Ohm's law, Kirchhoff's voltage law and Kirchhoff's current law (ECOR 1052).
- Basic programming knowledge for simulations (ECOR 1051/ECOR 1606).
- It would be beneficial to also have knowledge of the Laplace transform although the basics will be taught, as well as nodal analysis and mesh analysis.

4) Course Objectives

Simple mathematical models of the world around us lets us understand how things work and how they will react to different types of input stimuli. This course studies simplified models for mechanical, electrical, fluid, and thermal systems with a focus on biomedical applications and biological systems. For example, the cardiovascular system can be modelled as a fluid system with liquid being pumped through tubes of various dimensions and with various elastic properties. Similarly, the cardiovascular system can also be modelled using electrical circuits with electrical current analogous to fluid flow. As another example, the musculoskeletal system can be modelled as masses, springs, and dampers given the interaction and connections between bones and muscles. As a third example, we can model how medication is absorbed and distributed throughout the body, including the gut, blood stream, and various organs. As a fourth example, we can model a prosthetic limb in terms of mechanical function, electrical function, and sensor capture function.

With simplified mathematical models that approximate the real system, exploratory questions can then be asked. For example, how would the body respond to travelling over a bumpy road given different suspension systems or seat construction? How long would it take a medication to be metabolized by the body and then eliminated through the urinary tract? What sort of control would be needed for a prosthetic leg? If a heart-lung machine were designed, how could the machine be modelled and refined and how would stable control of the heart-lung machine be done for proper operation when attached to a patient?

Modelling of systems is made possible by understanding techniques and tools including the Laplace transform, transfer functions, and block diagrams. How the modelled systems reacts to inputs is done through understanding concepts like the impulse response, step response, and frequency response. Stable control of any modelled system requires understanding feedback loops and target design criteria.

5) Accreditation Units

For more information about Accreditation Units, please visit:

https://engineerscanada.ca/.

The course has 55 AUs divided into:

Math	Natural Science	Complementary Studies	Engineering Science	Engineering Design
			75%	25%

6) Learning outcomes / Graduate Attributes

By the end of this course, students should be able to:

- Understand concepts behind linear systems including causality, superposition, time-invariance, and memory.
- Understand basic dynamic system elements for modeling including resistors, capacitors, inductors, batteries, transformers, masses, springs, dampers, motors, gears, pumps, pipes, flow restrictors, reservoirs, heat masses, etc.
- Model dynamic systems including biological, electrical, mechanical, fluid, and thermal systems.
- Model dynamic systems using linear constant coefficient ordinary differential equations.
- Model dynamic systems using state-space representations with first-order coupled linear constant coefficient ordinary differential equations.
- Model dynamic systems in the Laplace domain and with transfer functions.
- Model dynamic systems using block diagrams and compartment models.
- Develop some common models for some biological systems including muscles, muskoloskeletal, circulatory system, drug absorption, etc.
- Use engineering tools for simulation of dynamic systems.
- Simulate and interpret time responses of dynamic systems including impulse response, step response, and ramp response.
- Determine, plot, and interpret the frequency response of dynamic systems as well as create and use Bode plots.

- Become familiar with pole-zero diagrams and relationship to time responses.
- Analyze and understand open-loop and closed-loop dynamic systems.
- Determine the stability of a modeled system.
- Understand basic feedback system models.
- Become familiar with a few classical controllers and preliminary control theory concepts for stable control.

The Canadian Engineering Accreditation Board requires graduates of undergraduate engineering programs to possess 12 attributes. Courses in all four years of our programs evaluate students' progress towards acquiring these attributes. Aggregate data (typically, the data collected in all sections of a course during an academic year) is used for accreditation purposes and to guide improvements to our programs. Some of the assessments used to measure GAs may also contribute to final grades; however, the GA measurements for individual students are not used to determine the student's year-to-year progression through the program or eligibility to graduate.

This following list provides the GAs that will be measured in this course, along with the learning outcomes that are intended to develop abilities related to these attributes.

GA - Indicator	Assessment Tool
1.6.S: Knowledge Base: Developed: Signals and systems	1-16
1.11.S: Knowledge Base: Developed: Biomedical systems	3, 8
2.1: Problem Analysis: Developed: Problem definition	3-8
2.2: Problem Analysis: Developed: Approach to the problem	3-8, 13
2.3: Problem Analysis: Developed: Use of assumptions	3-8
2.4: Problem Analysis: Developed: Interpreting the solution - validity of results	10, 11
5.1: Use of Engineering Tools: Developed: Diagrams and engineering sketches	9-11, 13
5.3: Use of Engineering Tools: Developed: Tools for design, experimentation, simulation, visualization, and analysis	9-11, 13
5.5: Use of Engineering Tools: Developed: Limitations of such tools and the assumptions inherent in their use	9

7) Texts

required, supplementary, other

8) List of Topics

- Basic system properties; fundamental continuous-time signals
- Laplace transform; solutions of ordinary differential equations
- Linear dynamic models of biomedical systems, compartmentalization
- Transfer functions
- State space representations
- Block diagrams, multicompartment models
- Time responses, dynamics of systems
- Frequency response and Bode plots
- Feedback systems and design criteria
- Stability of systems
- Classical control systems: basic properties (P, I, PI, PID)
- Applications of biomedical systems modeling (throughout course)

9) Course Schedule

Topics, (assignments, lab report, project report) due dates, exam/test dates, lab/PA schedule

10) Evaluation and Marking Scheme

All the elements that will contribute to the cumulative grade earned and the overall approximate grade breakdown for the course.

a) Final Exam:

i) Include the following statement

Final exams are for evaluation purpose and will not be returned to students.

ii) Include any exam condition (eg. Closed-book, type of calculator …) and requirement (eg. Minimum grade on final exam to pass the course)

iii) Final exam weight [Fall 2022/Winter 2023/Summer 2023]

1 - In any course that assigns less than 50% to a proctored final exam, the professor will notify the department of the revised grading scheme with a description of how the marking scheme ensures that the final grade is reflective of each individual student's abilities and understandings.

2 - The proctored exam (except where an exception has been granted) will be worth a minimum of 25% of the final grade.

3 - A minimum of 50% of the final grade will be justifiably based on individual student work

iv) Deferred Final Examinations

Students who are unable to write the final examination because of a serious illness/emergency or other circumstances beyond their control may apply for accommodation by contact the Registrar's office. Consult the Section 4.3 of the University Calendar (https://calendar.carleton.ca/undergrad/regulations/academicregulationsoftheuniversity/examinations/)

c) Additional requirement(s):

Please consult Section 5 of the undergraduate regulations (https://calendar.carleton.ca/undergrad/regulations/academicregulationsoftheuniversity/grading/)

If additional requirements beyond the cumulative grade earned in the course (for example, a requirement that students complete/pass certain assignments, examinations, lab, project components, or attend a minimal number of lab/PA sessions in order to pass the course), this should be clearly identified in the course outline.

d) Exam format and e-proctoring statement

Engineering Courses shall have on campus and proctored final examinations. The final exam may be in electronic format (ie. Student will

write the exam on campus and use either their computer or a university-owned computer).

If you intend to have the electronic format exam, then it must use an e-proctoring option provided by the university and the following note must be added to the course outline:

e-Proctoring: Please note that tests and examinations in this course will use a remote proctoring service provided by Scheduling and Examination Services. You can find more information at https://carleton.ca/ses/e-proctoring/.

e) Self-Declaration form and Deferred Term work

Calendar language (Section 4.4 https://calendar.carleton.ca/undergrad/regulations/academicregulationsoftheuniversity/examinations/#deferred-term-work):

Students who claim illness, injury or other extraordinary circumstances beyond their control as a reason for missed term work are held responsible for immediately informing the instructor concerned and for making alternate arrangements with the instructor and in all cases this must occur no later than three (3) days after the term work was due. The alternate arrangement must be made before the last day of classes in the term as published in the academic schedule.

Instructors can require (or not) the student to submit the self-declaration form. Include the following statement if you require the student to submit a completed self-declaration form:

Consult with the instructor no later then 3 days after any missed course work or midterm examination.

or

Contact the instructor with the completed self-declaration form no later than 3 days after the date/deadline of term work including test/midterm, labs, assignments.

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Advising and Counselling services

a) Engineering Academic Advising

The Engineering Academic Support Service : https://carleton.ca/engineering-design/current-students/undergrad-academic-support/ assists undergraduate engineering students with course selection, registration, and learning support from first-year through to graduation.

Academic Advisors Contact : https://carleton.ca/engineering-design/current-students/undergrad-academic-support/undergraduate-advisors/

b) Student Mental Health Service

As a University student you may experience a range of mental health challenges that significantly impact your academic success and overall well-being. Carleton's Wellness Services Navigator https://wellness.carleton.ca/navigator/ is designed to help students connect with mental health and wellness resources. If you need to talk to someone, please reach out for assistance: https://carleton.ca/health/emergencies-and-crisis/.

Learning and Working Environment

The University and all members of the University community share responsibility for ensuring that the University's educational, work and living environments are free from discrimination and harassment. Should you have concerns about harassment or discrimination relating to your age, ancestry, citizenship, colour, creed (religion), disability, ethnic origin, family status, gender expression, gender identity, marital status, place of origin, race, sex (including pregnancy), or sexual orientation, please contact the Department of Equity and Inclusive Communities at equity@carleton.ca

We will strive to create an environment of mutual respect for all through equity, diversity, and inclusion within this course. The space which we work in will be safe for everyone. Please be considerate of everyone's personal beliefs, choices, and opinions.

Academic Integrity and Plagiarism

a) Please consult the Faculty of Engineering and Design information page about the Academic Integrity policy and our procedures: https://carleton.ca/engineering-design/current-students/fed-academic-integrity Violations of the Academic Integrity

Policy will result in the assignment of a penalty such as reduced grades, the assignment of an F in a course, a suspension or, expulsion.

b) One of the main objectives of the Academic Integrity Policy is to ensure that the work you submit is your own. As a result, it is important to write your own solutions when studying and preparing with other students and to avoid plagiarism in your submissions. The University Academic Integrity Policy defines plagiarism as “presenting, whether intentionally or not, the ideas, expression of ideas or work of others as one’s own.” This includes reproducing or paraphrasing portions of someone else’s published or unpublished material, regardless of the source, and presenting these as one’s own without proper citation or reference to the original source.

Examples of violations of the policy include, but are not limited to:
· any submission prepared in whole or in part, by someone else;

· using another’s data or research findings without appropriate acknowledgement;

· submitting a computer program developed in whole or in part by someone else, with or without modifications, as one’s own;

· failing to acknowledge sources of information through the use of proper citations when using another’s work and/or failing to use quotations marks; and

· unless explicitly permitted by the instructor in a specific course, the use of generative AI and similar tools to produce assessed content (such as text, code, equations, images, summaries, videos, etc.).

Academic Accommodations

You may need special arrangements to meet your academic obligations during the term. For an accommodation request the processes are as follows:

Pregnancy obligation: write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For accommodation regarding a formally-scheduled final exam, you must complete the Pregnancy Accommodation Form (click here).

Religious obligation: write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details click here.

Academic Accommodations for Students with Disabilities: The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic

medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or pmc@carleton.ca for a formal evaluation. If you are already registered with the PMC, contact your PMC coordinator to send me your Letter of Accommodation at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). After requesting accommodation from PMC, meet with me to ensure accommodation arrangements are made. Please consult the PMC website for the deadline to request accommodations for the formally-scheduled exam (if applicable).

Survivors of Sexual Violence: As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: https://carleton.ca/equity/sexual-assault-support-services

Accommodation for Student Activities: Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation will be provided to students who compete or perform at the national or international level. Write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf