Université d'Ottawa
Faculté de génie

Département de
génie mécanique

uOttawa

University of Ottawa
Faculty of Engineering

Department of
Mechanical Engineering

MCG 3305: Biomedical Systems Dynamics

Fall 2018
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Instructor: Dr. Davide Spinello
email: dspinell@uottawa.ca
office: CBY A612
phone: 613.562.5800 ext. 2460
office hours: Take an appointment by email

Teaching Assistants:
Kristina Kupferschmidt
email: kkuff042@uottawa.ca
Farzan Soleymani
email: fsole078@uottawa.ca

Lectures: HGN 302
Monday 14:30 - 15:50
Thursday 16:00 - 17:20

Tutorial: Thursday 8:00 - 9:50
STE 2060 (Computer room)
STE 2052 (Computer room)

Course Outline

Modeling of mechanical, fluid, thermal and biomedical systems using a lumped parameter approach. Concepts of through and across variables in systems. Block diagrams for system representation. Linearization and solution of system equations. Transient and frequency response of biomedical systems.

Marks

Graded components

Exams There is one mid-term exam and the final exam, both in class. If a student cannot attend an exam due to a **medical condition certified by a doctor**, the instructor must be notified in advance. Unexcused absence from an exam will result in a grade of 0 for that exam.

The date of the of the mid-term exam could be changed within the first week of class to accommodate specific exigences of the students that have to be evaluated by the instructor.

Mid-term exam (24%) Mon, October 29 (During lecture time)

Final exam (60%) TBD

Homework assignments (6%) Homework assignments are individual and they are instrumental to prepare for exams, as they cover in an advanced way topics addressed in class.

Project (10%) The project is based on the Arduino microcontroller. Part of the evaluation will be on a written report, and part on an oral presentation with demonstration. Arduino devices will be provided by the instructors; however students are allowed to use their personal ones if preferred.

Course grade calculation

Marks from homework assignments, project, and mid-term exam determine the semester mark S, computed as follows:

Mid-term exam	60%
Homework assignments	20%
Project 20%	
Total of semester (S)	100%

This mark will be combined with the final exam mark F in the following way:

$$0.6F + 0.4S$$

If $F < 55\%$, regardless of the mark of the semester S the overall course grade will be F.

Reading and tutorial material

At the beginning of the course the students are assumed to be familiar with the theory of ordinary differential equations, Laplace transforms, and Newtonian mechanics of particles and rigid bodies as covered in MCG2108. You are strongly encouraged to review the related material from pre-requisite courses.

Textbook (required): Ogata, K.: *Modern control engineering - Fifth edition*. Prentice Hall, 2009

Textboox (available from the library, not required): M. Kutz, Editor: Biomedical engineering and design handbook. Fundamentals. Vol.1. Second Edition. McGraw Hill. Link to uOttawa library online resource (maximum 5 concurrent users).

Scientific articles:

1. A. V. Hill, 1938: The heat of shortening and the dynamic constants of muscle. *Proceedings of thhe Royal Society of London B*, **126** 136-195. DOI~10.1098/rspb.1938.0050.
2. B. Feng, R. Z. Gan, 2004: Lumped parametric model of the human ear for sound transmission. *Biomechanics and Modeling Mechanobiology* **3** 33–47 DOI~10.1007/s10237-004-0044-9
3. S. A. Ben-Haim, G. M. Saidelt, 1990: Mathematical Model of Chest Wall Mechanics: A Phenomenological Approach. *Annals of Biomedical Engineering*, **18** 37-56.
4. F. P. Primiano Jr, 1982: Theoretical analysis of chest wall mechanics. *Journal of Biomechanics*, **15**(12) 919-931.
5. P. T. Macklem, D. M. Macklem, A. De Troyer, 1983: A model of inspiratory muscle mechanics. *Journal of Applied Physiology*, **55**(2) 547-557.
6. C.-P. Chou, B. Hannaford, 1996: Measurement and modeling of McKibben pneumatic artificial muscles, *IEEE Transactions in Robotics and Automation,* **12**(1) 90-102.
7. A. Shitzer, L. A. Stroschein, R. R. Gonzalez, K. B. Pandolf, 1996: Lumped-parameter tissue temperature-blood perfusion model of a cold-stressed fingertip, *Journal of Applied Physiology,* **80**(5) 1829-1834.
8. O. O. Ley, C. C. Deshpande, B. B. Prapamcham, M. M. Naghavi, 2008: Lumped Parameter Thermal Model for the Study of Vascular Reactivity in the Fingertip, *ASME Journal of Biomechanical Engineering,* **130**(3) 031012-031012-13.

Arduino web resources:

- Arduino Starter Kit Manual by M. McRoberts. Usage is permitted under Creative Commons Attribution-NonCommercial-NoDerivs 3.0 Unported (see https://creativecommons.org/licenses/by-nc-nd/3.0/). Available in pdf version from Virtual Cammpus. Web link: https://archive.org/details/ArduinoStarterKitManual
- Arduino web resources:
  - General: http://playground.arduino.cc//Main/ManualsAndCurriculum
  - Projects: http://playground.arduino.cc/projects/ideas

Matlab:

- Tutorial: https://matlabacademy.mathworks.com/
- Control systems: https://www.mathworks.com/academia/student_center/tutorials/controls-tutorial-launchpad.html

Tentative lectures schedule

Lecture	Reading	Topic	Suggested problems
1: Th, Sep 6	2-2	Introductory concepts. Transfer functions and impulse-response function.	
2: Mo, Sep 10	2-2; 2-3	Transfer functions and impulse-response function. Block diagrams and basic operations.	B-2-1; B-2-2; B-2-4
3: Th, Sep 13	2-4; 2-5	Modeling in state space. State-space representation of scalar differential equation systems.	B-2-8; B-2-9; B-2-10; B-2-11; B-2-12
4: Mo, Sep 17	3-2;	Modeling of mechanical systems.	
5: Th, Sep 20	3-2; 2-7	Modeling of mechanical systems. Linearization of nonlinear mathematical models.	B-2-13; B-2-14
6: Mo, Sep 24	3-2	Modeling of mechanical systems.	B-3-1; B-3-2; B-3-3; B-3-4; B-3-6
7: Th, Sep 27	Notes; Ref. 1	Lumped parameter model of skeletal muscles (Hill's model)	
8: Mo, Oct 1	3-3	Modeling of electrical systems.	B-3-7; B-3-8; B-3-9; B-3-13
9: Th, Oct 4	Problem B-3-13	Servomotor analysis	
10: Th, Oct 11	4-3; Ref. 6	Pneumatic systems; McKibben model of pneumatic artificial muscles.	A-4-4, B-4-3
11: Mo, Oct 15	2-3; 4-3	PID controllers transfer functions. Pneumatic controller devices.	
12: Th, Oct 18	4-3	Pneumatic controller devices.	A-4-5; B-4-3; B-4-4
	Oct 21 - Oct 27	*Study week*	
13: Mo, Oct 29		**Mid-term exam**[1] The exam is scheduled in the lecture room, with the same duration as the lecture.	
14: Th, Nov 1	Ref. 2	Lumped parameters model of the human auditory system.	
15: Mo, Nov 5	Kutz: Chapter 3	Circulatory system.	
16: Th, Nov 8	Ref. 3, 4	Respiratory system: models of chest wall mechanics.	
17: Mo, Nov 12	4-5; Refs. 7 and 8	Thermal systems. Lumped parameter model of cold stressed fingertip, and vascular reactivity in the fingertip.	A-4-10, A-4-11, B-4-12
18: Th, Nov 15	5-2	Transient response of first order systems.	
19: Mo, Nov 19	5-2	Transient response of first order systems.	
20: Th, Nov 22	5-2	Transient response of first order systems.	A-5-1, B-5-1
21: Mo, Nov 26	5-3	Transient response analysis of second order systems.	
22: Th, Nov 29	5-3	Transient response analysis of second order systems.	
23: Mo, Dec 3	5-3	Transient response analysis of second order systems.	A-5-5, A-5-7, A-5-9, A-5-14, B-5-2, B-5-3, B-5-4, B-5-5, B-5-6,B-5-10, B-5-11.
24: We[2] Dec 5	5-3	Second-order systems and transient response specifications.	B-5-12, B-5-15, B-5-16, B-5-18, B-5-19

[1] The midterm exam will cover topics lectured up to lecture 10 (remind: this is a *tentative* lecture schedule).
[2] Monday schedule to make up for Thanksgiving day.

CEAB Graduate Attributes Continual Improvement Process (GAPIC)

The Canadian Engineering Accreditation Board (CEAB) is the organization that accredits engineering programs in Canada. CEAB has introduced as a requirement for accredited programs the Continuous Curriculum Improvement Process, which according to the EGAD project web page (https://egad.engineering.queensu.ca/) is "An iterative process of review that enables ready identification of strengths, limitations, gaps and redundancies within a program." The process is implemented by measuring a list of 12 Graduate Attributes defined by CEAB, which are generic characteristics, expected to be exhibited by graduates of Canadian engineering schools. Given the generic nature of GAs (so that they apply to all engineering programs), measurements are made with respect to Indicators, which specialize the GAs to the specific program. The list of GAs and related indicators for Mechanical Engineering and for Biomedical Mechanical Engineering can be found in this document: http://by.genie.uottawa.ca/~spinello/accreditation_resources/MCG_MGB_indicators.pdf.

The following set of indicators pertain to this course. According to CEAB requirements, indicators can be assessed at three levels: Introductory (I), Developed (D), Advanced (A):

Graduate Attribute 1: Knowledge base for engineering (Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.)

- 1b: Apply relevant Natural Science knowledge (Anatomy, Chemistry, Physics)
- 1c: Apply general engineering knowledge
- 1d: Apply mechanical engineering knowledge

Graduate Attribute 2: Problem analysis (An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.)

- 2a: Identify and characterize an engineering problem
- 2b: Formulate a solution plan (methodology) for an engineering problem

Graduate Attribute 5: Use of Engineering Tools (An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.)

- 5b: Use engineering tools

Learning outcomes are measurable outputs linked to Indicators as indicated below. By the end of the course, students are expected to acquire the following learning outcomes:

- Apply fundamental concepts from thermo-mechanics and electromagnetism to model mechanical and biomedical systems (GA 1)
- Use Matlab to model and simulate mechanical and biomedical systems (GA 5)
- Basic understanding and capability to operate and program an Arduino microcontroller device (GA 5)
- Identify and apply relevant problem solving methodologies (GA2)

Plagiarism

Academic fraud is an act by a student that may result in a false evaluation (including papers, tests, examinations, etc.). It is not tolerated by the University. Any person found guilty of academic fraud will be subject to severe sanctions.

Here are some examples of academic fraud:

- Plagiarism or cheating of any kind;
- Present research data that has been falsified;
- Submit a work for which you are not the author, in whole or part;
- Submit the same piece of work for more than one course without the written consent of the professors concerned.

Please consult this webpage: it contains regulations and tool to help you avoid plagiarism. An individual who commits or attempts to commit academic fraud, or who is an accomplice, will be penalized. Here are some examples of possible sanctions:

- Receive an "F" for the work or in the course in question;
- Imposition of additional requirements (from 3 to 30 credits) to the program of study;
- Suspension or expulsion from the Faculty.

You can refer to the regulations on this webpage.

Student services

Academic Writing Help Centre

At the AWHC you will learn how to identify, correct and ultimately avoid errors in your writing and become an autonomous writer. In working with our Writing Advisors, you will be able to acquire the abilities, strategies and writing tools that will enable you to:

- Master the written language of your choice
- Expand your critical thinking abilities
- Develop your argumentation skills
- Learn what the expectations are for academic writing

Career services

Career Services offers various services and a career development program to enable you to recognize and enhance the employability skills you need in today's world of work.

Counselling service

There are many reasons to take advantage of the Counselling Service. We offer:

- Personal counselling
- Career counselling
- Study skills counselling

Access service

The Access Service acts as intermediary between students, their faculty and other University offices to ensure that the special needs of these students are addressed and that the best possible learning conditions are being offered.

Note that the University of Ottawa is affiliated with AERO and ACE services for the adaptation of accessible academic materials for students with perceptual disabilities. If you have any questions, please contact the Accessibility Librarian (Email: libadapt@uottawa.ca) or the Access Services for textbooks.