MECH 410K/550C: Advanced Mechatronics

2020-2021 Term 2

Objectives

Learn how to analyze and design mechatronic devices, e.g., sensors, actuators, and motors. Maxwell's equations in quasi-static regimes. Interaction between the fields and materials via polarization and magnetization. Magnetic circuits. Force densities and Maxwell stress tensors. Energy method for electromagnetic forces and torque. Applications to electromagnetic sensors, voice coil actuators, reluctance actuators, electrostatic actuators, permanent-magnet synchronous motors, and piezoelectric actuators. Control systems for motors and piezoelectric actuators (course vector: 3-0-0).

Contact Information

- Instructor: Dr. Minkyun Noh (mnoh@mech.ubc.ca)

Office Hours

- Time: TBD (1 hour/week)
- Location: On-line via Zoom

Prerequisites

Courses on vector calculus, differential equations, and introductory electromagnetic fields. For example, MATH 254 (taught as part of MECH 222), MATH 258 (taught as part of MECH 221), PHYS 158, and MECH 358, or equivalents.

Lectures

There will be 26 lectures including two in-class quizzes. Live (synchronous) lectures will be delivered via CANVAS – Zoom. The lectures will be recorded for use by students enrolled in this course, but these recordings will not be used beyond the current section of the course. Please be aware that student participation, such as when asking questions in class, will be captured as part of these recordings. Lecture notes will be posted on CANVAS.

- Time: Tuesdays/Thursdays (9:30 am – 11:00 am)
- Location: CANVAS – Zoom
- Requirement: Computer and internet access. (Optional: microphone and camera)

References

There is no required textbook. Below is the list of selected reference books relevant to the course.

- T. A. Lipo, *Introduction to AC Machine Design*. Piscataway, NJ: IEEE Press, 2017. (link)
- G. Schweitzer and E. H. Maslen, *Magnetic Bearings.* Berlin, Heidelberg: Springer-Verlag, 2009. (link)
- A. Chiba *et al.*, *Magnetic Bearings and Bearingless Drives.* Amsterdam, The Netherlands: Elsevier-Newnes, 2005. (link)
- H. A. Haus and J. R. Melcher, *Electromagnetic Fields and Energy*. Englewood Cliffs, NJ: Prentice-Hall, 1989. (link)

- H. H. Woodson and J. R. Melcher, *Electromechanical Dynamics – Part I: Discrete Systems*. Malabar, FL: Krieger Pub. Co., 1990. (link)
- H. H. Woodson and J. R. Melcher, *Electromechanical Dynamics – Part II: Fields, Forces, and Motion.* Malabar, FL: Krieger Pub. Co., 1985. (link)
- J. R. Melcher, *Continuum Electromechanics*. Cambridge, MA: MIT Press, 1981. (link)

Homework

There will be 8 problem sets. Each problem set will be posted on CANVAS following the schedule table below. The due date is a week after. Late submission will incur score deduction of 10% per day. There will be an additional design problem assignment to the students registered for the graduate version.

Quizzes

Quizzes will be taken during 1.5 hours at the lecture schedule T in Vancouver time. Students in different time zone can request an alternative schedule T_{new} such that $T - 24$ hours $< T_{new} < T$. Quiz problems will be uploaded to CANVAS – Assignments as PDF files. Students can download the files only during their scheduled quizzes. After the quizzes, students will scan and upload their solutions to CANVAS – Assignments during 0.5 hour. The quizzes are open-book and open-note. It is highly recommended to prepare 2-3 pages of summary notes to refer to, instead of flipping through the lecture notes and textbooks.

- Quiz 1: Feb 9th during the lecture time (or alternative schedule).
- Quiz 2: Mar 23th during the lecture time (or alternative schedule).
- Requirement: Computer and internet access. Scanner or equivalent.

Final Exam

Final Exam will be taken during 3 hours at the schedule T in Vancouver time (TBD). Students in different time zone can request an alternative schedule T_{new} such that $T - 24$ hours $< T_{new} < T$. Final Exam problems will be uploaded to CANVAS – Assignments as a PDF file. Students can download the file only during their schedules exam. After the exam, students will scan and upload their solutions to CANVAS – Assignments during 0.5 hour. The exam is open-book and open-note. It is highly recommended to prepare 2-3 pages of summary notes to refer to, instead of flipping through the lecture notes and textbooks.

- Final Exam: TBD
- Requirement: Computer and internet access. Scanner or equivalent.

Grading

Students pass this course based on their final course mark. A weighted average examination grade of at least 50% is not required. The "examination grade" includes scores from the quizzes, homework, and final exam done individually.

- Quiz 1 (25%) + Quiz 2 (25%) + Homework (20%) + Final Exam (30%)

Policies and Resources to Support Student Success

UBC provides resources to support student learning and to maintain healthy lifestyles but recognizes that sometimes crises arise and so there are additional resources to access including those for survivors of sexual violence. UBC values respect for the

person and ideas of all members of the academic community. Harassment and discrimination are not tolerated nor is suppression of academic freedom. UBC provides appropriate accommodation for students with disabilities and for religious and cultural observances. UBC values academic honesty and students are expected to acknowledge the ideas generated by others and to uphold the highest academic standards in all of their actions. Details of the policies and how to access support are available at https://senate.ubc.ca/policies-resources-support-student-success

Schedule Table

Week	Date	Lecture	HW
1	Jan 5	Introduction, Maxwell's equations, Quasi-static approximation	
	Jan 7	Potentials, Superposition Integrals	
2	Jan 12	Perfect conductors in electro-quasi-static (EQS) systems,	1
	Jan 14	Electrodes and capacitance, Example: electrostatic microphone	
3	Jan 19	Perfect conductors in magneto-quasi-static (MQS) systems,	2
	Jan 21	Windings and inductance, Example: metal detector	
4	Jan 26	Method of images	3
	Jan 28	Example: eddy-current sensor	
5	Feb 2	Multi-region homogeneous boundary value problems	4
	Feb 4	Inhomogeneous boundary value problems	
6	Feb 9	**Quiz 1**	
	Feb 11	Polarization	
7	Feb 16	**Midterm Break**	
	Feb 18		
8	Feb 23	Example: electret microphone	5
	Feb 25	Magnetization, Magnetic circuits	
9	Mar 2	Permanent magnet: magnetization current vs. magnetic charge	6
	Mar 4	Example: voice coil actuator	
10	Mar 9	MQS/EQS force densities	7
	Mar 11	MQS/EQS Maxwell stress tensor	
11	Mar 16	MQS /EQS force via energy method	8
	Mar 18	Example: reluctance actuators, electrostatic actuators	
12	Mar 23	**Quiz 2**	
	Mar 25	Permanent-magnet synchronous motors (PMSM)	
13	Mar 30	PMSM control systems	
	Apr 1	Piezoelectricity	
14	Apr 6	Piezoelectric actuator control systems	
	Apr 8	Case study: magnetically-levitated motor systems	