

Cleveland State University
Department of Electrical Engineering and Computer Science

EEC 646/746: Dynamics and Control of MEMS

Catalog Data: Dynamics and Control of MEMS(4 credits)
Prerequisites: EEC510: Linear systems and EEC440: Control Systems

Required Textbook: Stephen D. Senturia, *Microsystem Design*, Kluwer Academic Press, 2001. ISBN: 0-7923-7246-8

- Reference books:**
- Chang Liu, *Foundations of MEMS*, Prentice Hall, 2006.
 - Nadim Maluf, *An Introduction to Microelectromechanical Systems Engineering*, Artech House Publishers, 2000.
 - Tai-Ran Hsu, *MEMS & Microsystems: Design, Manufacture, and Nanoscale Engineering*, 2nd Edition, John Wiley & Sons Inc., 2008.
 - E. B. Magrab et al., *An Engineer's guide to Matlab*, 3rd edition, Prentice Hall, 2010.

Instructor: Dr. Lili Dong, Associate Professor of Electrical Engineering,
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Content: This course provides a comprehensive overview of MEMS technique and MEMS control. Topics include MEMS fabrication processes, MEMS sensors and actuators, Dynamic modeling of MEMS, control, signal processing, and electronics for MEMS, and case studies of MEMS devices.

- Objectives:** After taking this course, students should be able to
- Understand MEMS fabrication techniques;
 - Develop dynamics models for MEMS devices;
 - Analyze typical MEMS actuators and sensors;
 - Design control systems for typical MEMS devices.

Course Outline:
Week Topics Required Reading Assignment

Week	Topics	Required Reading	Assignment
		Syllabus	
1	Introduction to MEMS Syllabus	Lecture 1	Homework 1 posted
		S. D. Senturia 1.1-1.4, 2.2, 2.3	
2	Silicon as a material for MEMS	Lecture 2	Project 1 posted
		S. D. Senturia 3.1, 3.2, 3.3	
3	Pattern Transfer and MEMS fabrication process	Lecture 3	Homework 1 due
		Lecture 4	Homework 2 posted
		S. D. Senturia 4.1, 4.2, 4.3, 4.4	
4	MEMS fabrication process and process integrations	Lecture 5	

		Lecture 6	
5	Lumped models:equivalent circuits	Lecture 7	Homework 2 due
		Lecture 8	Homework 3 posted
		S. D. Senturia 5.1, 5.2, 5.3, 5.4, 5.5	
6	Capacitive sensors and electrostatic actuators	Lecture 9	Project 1 due
		Lecture 10	Project 2 posted
		S. D. Senturia 6.1, 6.2	
7	Linear and nonlinear dynamic systems	Lecture 11	Homework 3 due
		Lecture 12	Homework 4 posted
		S. D. Senturia 7.1, 7.2, 7.3	
8	8 Linear elasticity, thin film stress, Large deformation, axially loaded beams	Lecture 13	
		Lecture 14	
		S. D. Senturia 8.1, 8.2, 8.3, 8.4, 8.5	
9	Spring break		
10	beam bending and residue stress	Lecture 15	Homework 4 due
		S. D. Senturia 9.1, 9.2, 9.3, 9.6,9.8	Homework 5 posted
11	11 Elastic energy and principle of virtual work	Lecture 16	Project 2 due
	Information literacy skills (supplemental lecture)	Information literacy Powerpoint Slides S. D. Senturia 10.1, 10.2, 10.3	Project 3 posted
12	Feedback systems	Lecture 17	Homework 5 due
		S. D. Senturia 15.1, 15.2, 15.3	Homework 6 posted
		Damping conditions (supplemental materials)	
13	Resonators and Oscillators	Lecture 18	
	Uncertainty and robustness	Lecture 19	
		S. D. Senturia 15.5	
14	Micro-accelerometers and pressure sensors	Lecture 20	Homework 6 due
		Lecture 21	Homework 7 posted
		S. D. Senturia 19.1, 19.2, 19.3, 18.1, 18.2, 18.3	
15	MEMS gyroscopes	Lecture 22	
		S. D. Senturia 21.1, 21.2, 21.3	
16	MEMS gyroscopes (continued)	Lecture 23	Homework 7 due
		MEMS papers by Dr. Dong	Project 3 due
		(Supplemental materials)	

Grading:

Projects 60%
Homework 40%

Grading Scale:

A..... 93-100
A minus..... 90-92
B plus.....87-89
B..... 84-86
B minus..... 80-83
C 60-79
F..... <60

Instructional Activities:

This course utilizes the Blackboard course management system

<https://bblearn.csuohio.edu/MACAuth/login.jsp>

You need your CSU ID and password to log in Blackboard. If you have problems of using Blackboard, contact the technician in IS &T center at CSU (<http://www.csuohio.edu/ist/ist>) immediately. The course instructor will communicate with students via a variety of interactive tools including Discussions and Announcement in Blackboard, and emails. Students in this course are required to log in Blackboard regularly (at least once a week) to access the course content, to participate in class discussions, and to download and submit course assignments. All the course materials are included in the "Learning Module" (on the course webpage) in Blackboard.

Student learning requirement:

Email Account: An email account is mandatory for this course. Throughout the semester, course-related information may be *distributed to the students' email addresses listed on campus net*. Students are expected to check their emails regularly (at least once a week for course update). Please note that Email is primarily used as a communication tool between instructor and students in this course. Students are required to submit their assignment to Blackboard. The course instructor will **NOT ACCEPT any submission of course assignments through emails**.

Internet Access: Students in this course are required to have access to high-speed internet and a computer in order to have a successful experience in this online course. The students are required to have up-to-date versions of web browsers such as Internet Explorer, Firefox, and Google Chrome. The online-course is not appropriate for a student who has no or limited (such as dial-up) internet access.

File Storage: Students in the course are required to have a file storage/retrieval media (such as a computer hard disk, USB flash drive, or a memory card) for the purpose of saving students' own work completed in this course. Students are required to make backups regularly to safeguard their own data.

Scanner Access: Students in this course are required to have access to a scanner. Students may be required to scan their completed assignment into pdf file format, and submit it to Blackboard. The online course is not appropriate for a student who has no scanner access.

Software: Students in this course are required to have access to the following software in order to complete this course successfully: Web browser and Plugins (such as Internet Explorer and Firefox), Adobe Reader, CutePDF Writer, Microsoft Word, Microsoft Powerpoint, and Matlab/Simulink (student version). Students are required to have basic knowledge of using Matlab/Simulink to complete course assignments. Please note: The computer lab in Fenn Hall (first floor) is equipped with the latest version of Matlab/Simulink that you could use for free. Or you can purchase Matlab/Simulink (student version) from CSU's book store. To download the free CutePDF Writer and install it in your own computer, you may visit <http://www.cutepdf.com/>

Homework:

Homework is a major learning tool in this course. Students are required to submit their homework NO LATER THAN DUE DATE. Students are required to complete homework problems independently. Academic cheating and plagiarism will result in a grade of ZERO and disciplinary actions. Students are required to save their homework in .pdf or .doc file format when submitting via Blackboard.

Projects:

Students are expected to complete three projects before the end of this semester. For the first project, students are required to design and draw fabrication steps (or process flow) for producing two MEMS devices. For the second project, students are required to conduct computer simulations using Matlab/Simulink, and produce and analyze simulation results for an electrostatic actuator. For the third project, students are required to conduct literature review about the control systems for a specific MEMS sensor or actuator and write a project report based on their findings. Every student has to complete his/her project independently. Academic cheating and plagiarism will result in a grade of ZERO and disciplinary actions. Students are required to save their project reports in .pdf or .doc file format when submitting via Blackboard.

Academic Honesty Policy:

According to the graduate catalog of CSU

(http://catalog.csuohio.edu/content.php?catoid=14&navoid=1203&hl=%22Plagiarism%22&returnto=search#Plagiarism_Policy),

“Plagiarism is the act of presenting, as one’s own the ideas, opinions, writings, or work of another person without appropriate scholarly attribution. This act is a form of academic dishonesty and is a serious incident of academic misconduct.”

The plagiarism in electrical engineering is particularly explained in details in the following slides:

<https://www.csuohio.edu/engineering/sites/csuhio.edu.engineering/files/Plagiarism.pdf>

The penalties for ethical infractions, which “include but are not limited to cheating, plagiarism, and tampering with graded material”, are listed in the following document.

(<https://www.csuohio.edu/engineering/sites/csuhio.edu.engineering/files/Ethics%20Policy.pdf>)

From the above PDF file, the following penalties will be imposed for all minor infractions.

1. The student will receive an F (or zero) on the assignment that is related to the offense.
2. The instructor who discovers the offense will write a letter to the student documenting the infraction. The instructor will send a copy of the letter to the Department Chair, and place a copy in the student’s file in the department office.

The instructor who discovers the offense is responsible to check the student’s file

before taking action in order to determine if the offense is a repeat offense. If the offense is a repeat offense, then the infraction is, by definition, a major infraction.

3. The student will lose all department funding.

- Resources:** The textbook, reference books, CSU library (<http://library.csuohio.edu/>), and the course materials posted on Blackboard are major course resources.
- Others:** All the class materials will be uploaded to the “Learning Module” in Blackboard system. All important notices will be announced in Blackboard as well.

Please note: The course outline is subject to change during the semester.

All assignments (including homework and projects) are due by 11:30pm (Cleveland, OH Local Time) on their due dates unless otherwise noted.