SYDE 683 / NANO 702
Design of MEMS & NEMS

Spring 2021 – v 1.0

Instructor: Eihab Abdel-Rahman
Lectures: Tuesdays & Thursdays 11:00AM–12:20PM (EDT)

- in-person: room E5 - 6008
- online Zoom

Recordings will be available on Learn after class.
Office Hours: We will schedule office hours online as needed.

Course Description:

Micro-Electro-Mechanical Systems (MEMS) drastically reduce the size and cost and improve the performance of sensors and actuators. They are the dominant technology in pressure sensors and accelerometers. They have an expanding footprint in the display, navigation, and haptics industries. They are also facilitating the introduction of new classes of devices and new applications. Nano-Electro-Mechanical Systems (NEMS) are also emerging as the next stage in miniaturization. The trouble is: it is quite hard to design and fabricate reliable MEMS let alone NEMS. This course aims to address this challenge.

Course Outcomes:

The course provides a rigorous grounding in the theory and practice of MEMS & NEMS design. It will enable you to build MEMS by *design* rather than by *trial and error*. It will also give you the analytical tools to explore the possibilities of NEMS. Specifically, you will master:

- the methodology to select, derive, and use MEMS & NEMS models as design tools,
- the basic concepts required to construct your own lumped-mass models,
- the use of reduced-order models in MEMS & NEMS design,
- the advantages and disadvantages of these techniques versus commercial software (COMSOL, ANSYS, and Coventor),
- the most effective uses and limitations of each modeling approach.

We will adopt a hands-on approach and examine these topics within the framework of a major course project. Throughout the term, you will work as group applying the concepts you learn in class to this year's design project and report back to class about your progress and findings. This learning process will culminate in a group report detailing your findings and conclusions.

Textbook:

- "*Understanding MEMS: Principles and Applications*," First Edition, 2015, Luis Castañer.
- Lectures notes, recordings, and other course materials will be posted to LEARN.

References:

- "*Microsystem Design*," Stephen Senturia, 2001, Springer.
- "*MEMS and Microsystems: Design, Manufacture, and Nanoscale Engineering*," Second Ed., Tai-Ran Hsu, 2008, John Wiley & Sons.
- "*MEMS Linear and Nonlinear Statics and Dynamics*," Mohammad I. Younis, 2011, Springer.
- "*Foundations of MEMS*," Second Ed., Chang Liu, 2012, Prentice Hall.

Evaluation:

The course grade will be assigned as follows:

	SYDE 683	NANO 702
Project:	50%	N.A.
Final:	50%	100%

Exams are takehome. I will post the exam to Learn and you will have 48 hours to sovle it and return the anwer to me. They will test for your ability to model and analyze MEMS. Submit your exams and projects as PDF files sent to my email.

Course Project:

We will start the project in the third week by introducing the proposed actuator. Each of you will select a modeling & simulation technique to perform tasks: static, eigenvalue, and dynamic analyses of the actuator. Each week, you will report back on your progress and compare your results in class. The tasks will build-up incrementally to allow you, during the last two weeks of the term, to write a group report covering:

- Introduction: A summary of the state-of-the-art on modeling and simulation of MEMS and recent literature relevant to your MEMS device.
- Problem Statement: description of the device, initial design process, and the analytical tasks.
- Results: The detailed analytical results each of you found.
- Discussion: Comparison of the similarities and differences among your results and those available in the literature.
- Conclusions: Which modeling & simulation techniques work best for what types of analytical tasks? What is the value proposition for each modeling technique? What are your recommendations for a second generation actuator design?

Class Schedule

Monday	Tuesday	Wednesday	Thursday	Friday
May 10th	11th Lecture Notes # 1 Sec: 1.1–1.4, 1.6, 1.7	12th	13th No class Instructor on Holiday	14th
17th	18th Lecture Notes # 2 Sec: 2.1–2.5, 2.7, 2.11	19th	20th Lecture Notes # 2 Sec: 2.1–2.5, 2.7, 2.11	21st
24th	25th Lecture Notes # 3 Sec: 3.1–3.6	26th	27th Lecture Notes # 4 Sec: 3.6–3.9	28th
31st	June 1st Lecture Notes # 5 Sec: 3.11	2nd	3rd Lecture Notes # 5 Sec: 3.11	4th
7th	8th Lecture Notes # 6 Sec: 3.12–3.14	9th	10th Lecture Notes # 7 Virtual work	11th
14th	15th Lecture Notes # 7 Virtual work	16th	17th Lecture Notes # 8 Virtual work	18th
21st	22nd Lecture Notes # 8 Virtual work	23rd	24th Lecture Notes # 9 Variational methods	25th
28th	29th Lecture Notes # 9 Variational methods	30th	July 1st No Class	2nd
5th	6th Lecture Notes # 10 Sec: 3.12–3.14	7th	8th Lecture Notes # 11 Sec. 4.1–4.3, 4.6–4.8	9th
12th	13th Lecture Notes # 12 Sec. 5.1 & 3.10	14th	15th Lecture Notes # 13 Circuit Models	16th
19th	20th Lecture Notes # 14 Sec. 5.2–5.14	21st	22nd Lecture Notes # 15 Sec. 6.1–6.3	23rd
26th	27th Lecture Notes # 16 Sec. 6.4–6.5	28th	29th Lecture Notes # 17 Sec. 6.6–6.7	30th
Aug 2nd	3rd Lecture Notes # 18 Nonlinear MEMS	4th	5th Lecture Notes # 18 Nonlinear MEMS	6th

The Fine Print:

We are currently facing unusual and challenging times with a pandemic and its consequences. The instructor reserves the right to modify course topics and/or assessments with due notice. In the event of further challenges, the instructor will work with the Department to find reasonable and fair solutions.

- **Academic Integrity**
  In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility.

  In exams, students are expected to work individually and submit their own original work. Under Policy 71, the instructor may have follow-up conversations with individual students to ensure that the work submitted was completed on their own. Any follow up will be conducted remotely (e.g., MS Teams, Zoom, phone). Permissions is hereby provided for collaboration on the course project.

- **Discipline**
  A student is expected to know what constitutes academic integrity, to avoid committing an academic offense, and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offense, or who needs help in learning how to avoid offenses (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate Associate Dean.

  For information on categories of offenses and types of penalties see Policy 71.

  For typical penalties see Guidelines for the Assessment of Penalties.

- **Grievance**
  A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance; see Policy 70 - Section 4. When in doubt, please contact the undergraduate administrative assistant for provide further assistance.

- **Appeals**
  A decision made or a penalty imposed under Policy 70, other than a petition, or Policy 71 may be appealed, if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72.

- **AccessAbility Services**
  AccessAbility Services is the University's centralized office for the provision of academic accommodations for students with a known or unknown disability, illness, or condition. They are located in Needles Hall, Room 1401. The service collaborates with academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodation, please register with them at the beginning of the academic term.

- **Compassionate Accommodation**
  If you are facing challenges that are affecting more than one course, contact the Associate Chair - Graduate Studies or the Graduate Administrative Coordinator. They will review your case and coordinate a reasonable and fair plan in consultation with appropriate others (e.g. instructors, Department Chair, AccessAbility Services, Engineering Counselling services, Registrar's Office).