SYDE 683 / NANO 605
Design of MEMS & NEMS

Spring 2023 – v1.0

Session	Location	Time
Lecture	E5-6127	M/W 10:00–11:20 AM

Instructor	Office	Office Hours
Eihab Abdel-Rahman	E7 6422	Walk-in

Course Description:

Micro-Electro-Mechanical Systems (MEMS) drastically reduce the size and cost and improve the performance of sensors and actuators. They are now the technology of choice for novel sensors and actuators. Their footprint is expanding in the display, communications, and haptics industries. Meanwhile, Nano-Electro-Mechanical Systems (NEMS) are coming to their own as the next stage in miniaturization process. The trouble is: it is quite hard to design and fabricate reliable MEMS or NEMS. This course aims to address this challenge.

Course Outcomes:

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

- the methodology to derive / select 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 ability to evaluate the pros and cons of these techniques versus commercial software (COMSOL, ANSYS, and Coventor),
- the effective uses and limitations of each technique.

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 a 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:

There is no textbook for the course. I will post the lectures notes, class recordings, and other course materials to LEARN. You can also use the following books to study for the course:

- *Microsystem Design*, Stephen Senturia, 2001, Springer.
- *MEMS Linear and Nonlinear Statics and Dynamics*, Mohammad I. Younis, 2011, Springer.
- *Understanding MEMS: Principles and Applications*, First Ed., 2015, Luis Castañer.
- *Foundations of MEMS*, Second Ed., Chang Liu, 2012, Prentice Hall.

Evaluation:

The course grade will be assigned as follows:

- Project: 50%
- Final: 50%

Exam problems will test for your ability to model and analyze MEMS/NEMS.
For a student to receive "AUD" credit for this course, they must attend at least 10 weeks of classes, fully participate in, and submit the group project (see below).

Course Project:

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

- Introduction: A high-level summary on the state-of-the-art in modeling and simulation of MEMS & NEMS and recent literature specifically relevant to your device.
- Problem Statement: A concise description of the device, the initial design process, and the analytical tasks.
- Results: A detailed description of your model and the results you obtained.
- 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?

With the exception of the Results section, which is written individually, you will collaborate as a *group* to write, edit, format, and assemble the report.

Class Schedule

Monday	Tuesday	Wednesday	Thursday	Friday
May 8th Lecture Notes # 1 System Modeling	9th	10th Lecture Notes # 2 Elasticity	11th	12th
15th Lecture Notes # 2 Elasticity	16th	17th Lecture Notes # 2 Elasticity	18th	19th
22nd No Class	23rd Lecture Notes # 3A Micro-Structures	24th Lecture Notes # 3B Micro-Structures	25th	26th
29th Lecture Notes # 3C Micro-Structures	30th	31st Lecture Notes # 3C Micro-Structures	June 1st	2nd
5th Lecture Notes # 3D Micro-Structures	6th	7th Lecture Notes # 4A Virtual work	8th	9th
12th Lecture Notes # 4A Virtual work	13th	14th Lecture Notes # 4B Virtual work	15th	16th
19th Lecture Notes # 4B Virtual work	20th	21st Lecture Notes # 4C Variational methods	22nd	23rd
26th Lecture Notes # 4C Variational methods	27th	28th Lecture Notes # 5A Electromechanics	29th	30th
July 3rd No Class	4th	5th Lecture Notes # 5B Electromechanics	6th	7th
10th Lecture Notes # 5C Electromechanics	11th	12th Lecture Notes # 6A Dynamic Systems	13th	14th
17th Lecture Notes # 6B Dynamic Systems	18th	19th Lecture Notes # 6B Dynamic Systems	20th	21st
24th Lecture Notes # 6C Dynamic Systems	25th	26th Lecture Notes # 6C Damping	27th	28th
31st Lecture Notes # 6D Damping	Aug 1st	2nd	3rd	4th

The Fine Print:

- **COVID-19 Considerations**
  There could be a need to make alternate arrangements for in-person course activities. This alternate arrangement could be for a short period of time (e.g., one week) or a more sustained disruption to in-person course activities. In the event of a disruption, all in-person lectures will revert to synchronous, online lectures. Should we be required to move away from regular in-person teaching, the instructor will work with the Department to ensure that students have a fair opportunity to meet course requirements and to be notified of any changes in a timely manner.

  If you are unable to attend an in-person course activity due to emergency self-isolation, please let Professor Abdel-Rahman know as soon as possible (see COIVD-19-Related and Short-Term Absences below).

- **Fair Contingencies for Remote Teaching**
  The course outline presents the instructor's intentions for course assessments, their weights, and due dates in Spring 2023. As best as possible, we will keep to the specified assessments, weights, and dates. To provide contingency for unforeseen circumstances, the instructor reserves the right to modify course topics and/or assessments and/or weight and/or deadlines with due and fair notice to students. In the event of such challenges, the instructor will work with the Department and Faculty to find reasonable and fair solutions that respect rights and workloads of students, staff, and faculty.

- **COVID-19-Related and Short-Term Absences**
  If you declare a COVID-19-related two-day absence or short-term two-day absence and you will miss a graded component of the course, you need to contact Professor Abdel-Rahman as soon as possible. The most likely accommodation will be a two (2) day extension to a deadline / exam date.

- **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).

- **SYDE Comment on Accommodation**
  We respect that our students are independent adult decision-makers, with many opportunities to partake in activities that might be in time conflict with academic deadlines and deliverables. Along with the right to make adult decisions comes the responsibility and accountability for those decisions and any outcomes. The University of Waterloo's policy on accommodation for missed deliverables pertains to verifiable health matters, and highly unfortunate events (for example: family tragedies). The Department of Systems Design Engineering follows University of Waterloo's general policy: students who self-elect to forgo a deliverable receive a "0" for that deliverable. It is preferred practice so that fairness is maintained for members of the same class/course by avoiding preferential treatment.

- **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 graduate Associate Dean. See the following links for information on:
  - Categories of Offenses and Types of Penaltie
  - Guidelines for the Assessment of Penalties
  - Assessment of Unauthorized Collaboration

- **Grievances**
  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.