Department of Mechanical Engineering
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MENG 5314 – Micro Electromechanical Systems (MEMS)
Course Syllabus

Semester / Year	*Spring / 2023*
Catalog Description	*This course introduces the students to principles, modeling, interfacing, and signal conditioning of micro-electro-mechanical systems (MEMS) such as motion sensors and actuators. It also covers basic electronic devices, MEMS resonators, embedded microprocessor systems and control, power transfer components, and mechanism design. The course provides knowledge in the analysis and design of hardware-in-the-loop through simulation and rapid prototyping of real-time closed-loop computer control of electromechanical systems.*
Prerequisites	*ENGR 2302 Dynamics, MATH 3305 or Graduate student standing.*
Section Number	*001*
Instructor Name	*Dr. A. Ibrahim*
Contact Information	*Email: aibrahim@uttyler.edu* *Office: RBN 3008*
Class Type / Instruction Mode / Location	*Mode: F2F* *Location: TBA*
Class Time	*Mo/We 10:10 AM –11:30 AM*
Office Hours	*Mo/We 8:30 AM –10:00 AM*
No. of Credits	*3*
Required Textbook	*MEMS Linear and Nonlinear Statics and Dynamics, Younis, Mohammad I., Springer, New York, 2011.*
Optional References	*NA*
Additional Rules and Requirements	*Programming skills.*
Evaluation Method	***Assignments:*** *30%* ***Midterm Exam:*** *20%* ***Project:*** *30%* ***Final Exam:*** *20%*
Grading Policy / Scale	*Letter grades, scale:* *A: 90 – 100; B: 80 – 89; C: 70 – 79; D: 60 – 69; F: < 60*
Important Events / Dates	***Census date:*** *January 23rd, 2023,* ***Last date to withdraw courses:*** *March 23rd, 2023,* ***Midterm Exam:*** *After Ch4, Week 7 or 8, 2023,* ***Project article and Presentation:*** *Mo/We April 17-19, 2023,* ***Final Exam:*** *As scheduled by UT Tyler.* ***No class:*** *Mo Jan. 16, 2023:* ***Martin Luther*** *King, Jr. Holiday* ***No class:*** *March 13-18* ***Spring Break***
Attendance / Makeup policy / other rules	*Attendance is required / No makeup*
Course Learning Objectives / ABET & PEOs Relation	*By the end of this course, students will be able to:* *1. Describe MEMS and their related design components.* *2. Analyze nonlinear dynamic responses of MEMS devices.*

	3. *Design MEMS resonators and analyze their static and dynamic behaviors.* 4. *Apply analytical and numerical techniques to model and simulate MEMS, considering nonlinear multi-physics interaction and actuation forces.* 5. *Conduct a major project leading to a draft of a publishable level paper.*
Tentative Topics / Course Plans	1. *Introduction to MEMS and their modeling challenges laws of motion.* 2. *Sensing and Actuation in MEMS.* 3. *Elements of Lumped-Parameter Modeling in MEMS.* 4. *Introduction to Nonlinear Dynamics.* 5. *Introduction to Energy Harvesting.* 6. *Continuous Systems: Microbeams.*
University Policies	*https://www.uttyler.edu/academic-affairs/files/syllabus_information_2021.pdf*

Chapter	Title	Topic(s)
Ch1	**Introduction to MEMS and Their Modeling Challenges**	• Introduction to MEMS
Ch2	**Refresher on Linear Vibrations**	• Free Vibration of Single-Degree-of-Freedom Systems • Forced Harmonic Excitation of Single-Degree-of-Freedom Systems • Vibrating MEMS Gyroscopes • Base Excitations of SDOF Systems and Accelerometers Principles • Vibrations of Two-Degree-of-Freedom Systems • Numerical Integration • MEMS Band-Pass Filters
Ch3	**Sensing and Actuation in MEMS**	• Electrothermal Actuation • Piezoelectric Actuation and Detection • Electromagnetic and Magnetic Actuation • Piezoresistive Detection • Electrostatic Actuation and Detection (simple parallel-plate, comb-drive, torsional mirrors) • Resonant Sensors
Ch4	**Elements of Lumped-Parameter Modeling in MEMS**	• Stiffness of Microstructures • Spring-Mass Models
Notes	**Introduction to Energy Harvesting**	• Piezoelectric • Triboelectric • Electromagnetic
Ch5	**Introduction to Nonlinear Dynamics**	• Nondimensionalization • Fixed Points and Linearization • Bifurcations of Fixed Points • Phase Portraits • Nonlinear Oscillations
Ch6	**Continuous Systems: Microbeams**	• Equation of Motion and Boundary Conditions • Natural Frequencies and Mode Shapes • Forced Vibration and Modal Analysis

Important Notes:

- All assignments must be submitted as a single scanned file in pdf format on the due date. **Phone pictures will not be accepted**.
- Late HWs **will not be accepted,** and a **Zero** grade will be offered.
- Projects will be done **individually or with collaborations of two students**. For collaborative projects, the instructor will distribute the students.
- The project's topic should be investigating the static and dynamic behavior of an Energy harvester device of the instructor's choice. However, any idea or suggested project from the student will be welcome after the instructor's approval. It can also be a new idea of a MEMS device of improved performance or desired characteristics.
- The final report should be written in overleaf (https://www.overleaf.com/) in a research article format (10-15 pages).
- You must create an account on overleaf using your UT-Tyler credentials. Later, the instructor will share an Overleaf project template.
- Follow the following link for overleaf tutorials: (https://www.overleaf.com/learn/latex/LaTeX_video_tutorial_for_beginners_(video_1))
- The article should be written in your own words and following the ME writing report guide. The submitted article will be checked for plagiarism. Direct copying from any paper, web or other sources is prohibited and will result in a **Zero grade**.
- The final research article (10-15 pages) is **due before the last week of the semester.**
- The report should be written in a Journal paper format. It shall include:
  - **literature summary** about the topic,
  - **Mathematical model,**
  - **Simulation results** and comparisons with literature results,
  - **Experimental results,** if applicable,
  - **Discussion,**
  - **Summary** and **conclusions**
  - **Recommendations** (research ideas) for future works.
  - **Please refer to the project guidelines on page 4.**
- Students **will present their projects in the last week** of the classes.
- **Please refer to the presentation guidelines on page 5.**
- All **codes** used for generating the reported results **should be submitted** with the final article.

Project Guidelines*		
Week #	**Task**	**Description**
Week 1-3	**Conduct a literature review**	• Read articles about Vibrations Energy Harvesting (understand the concept and working mechanism of Triboelectric and Piezoelectric EH)
Week 4-5	**Introduction writing**	• The introduction requires a review of the literature about the research topic. • Construct it as a descriptive funnel, starting with broad topics and slowly focusing on the work at hand. • Perhaps three to four paragraphs are needed. Start with one paragraph introducing the reader to the general field of study. The subsequent

		paragraphs then describe how an aspect of this field could be improved. • The final paragraph is critical. It clearly states, most likely in the paragraph's first sentence, that the present study will answer an experimental question. The hypothesis is then stated. • Next, briefly describe the approach that was taken to test the hypothesis. Finally, a summary sentence may be added stating how the answer to your question will contribute to the overall field of study.
Week 6-7	**Methods, Setup, Model description**	• Describe the key procedure and technique used in the study. Keep explanations brief and concise. • If a specific experimental design is utilized, describe this design in the second section of this part. • Similarly, if a theoretical or modeling component is utilized, it should also be incorporated in the Methods' initial portion.
Week 8-10	**Results and Discussion**	• The Results section presents the experimental/Simulated data to the reader. • The data should be presented in tables and figures. Introduce each group of tables and figures in a separate paragraph where the overall trends and data points of particular interest are noted. You may want to indicate the placement of a specific table or figure in the text. • Note that each table and figure in the paper must be referred to in the Results section. • Use the results that address your objectives to describe and summarize the most important findings. • identify the most interesting, significant, remarkable findings that were presented in the results • Example of expected results - Resonance Frequency, - Finding the Optimal resistance, - Frequency – Voltage/Power Curves.
Week 11	**Conclusions**	• Again, first, introduce the work and then briefly state the major results. • Then state the major points of the discussion. • Finally, end with a statement of how this work contributes to the overall field of study.
Week 12	**Abstract**	• The abstract should be considered as an independent document. • The first sentence should clearly state the objective of the work. • The subsequent sentences describe how the investigation was carried out. • The following sentences describe the work results with as much precision as possible without being verbose. • The final sentences describe the significance of the results and the impact of this work on the general field of study.
Week 13-14	**Review**	• Review the whole manuscript with proofreading and check everything for final submission.
Week 15	**Submission & Presentation**	• Submit your project in PDF format. • Share access to final overleaf. • Present your article in the class.

* For more guidelines about report writing, please refer to the Report Writing Guide posted on Canvas.

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PowerPoint Presentation Guidelines		
Section	**# of Slides**	**Description**
General Rules	-	• Follow the 5/5/5 rule: no more than five words per line of text, five lines of text per slide, or five text-heavy slides in a row. • Choose readable colors and fonts. • Don't overload your presentation with animations.
Title slide	**1**	• Title of the talk (probably the same as your paper), the names of all group members, the class and university names, and the date the talk is given.
Outline slide	**1**	• List the headings of what you are presenting.
Introduction and Motivation	**3 - 4**	• Explain why your work is impressive. • Place the study in context – how does it relate to / follow from the scientific literature on this subject. If it relates to • Use some pretty visuals (photographs, drawings, etc.) to get the audience excited about the issue and questions you are addressing.
Methods, Setup, Model description	**3 - 5**	• Summarize the design. Show a picture of your organisms and justify why they are appropriate for addressing the questions you are addressing. • Show a picture of your lab setup and/or a model. • Show a diorama of your experimental design (with sample sizes, number of replicates, sampling frequency, etc.). • Mention what parameters you measured, but do not detail the exact procedures used.
Results and Discussion	**4-6**	• Show a photograph (or sketch) that shows an interesting qualitative results. • Then display the results in graphical form, reminding the audience of your hypothesis and stating whether it was supported as you do so. • Use simple, clean, clearly labeled graphs with proper axis labels. • Do not use light colors (yellow, light green, or pink) in your figures. They do not show up well when projected.
Conclusions	**1-2**	• Correctly interpret your results. • Constructively address sources of error and methodological difficulties. • Place your results in context and draw implications from them.