TEXAS A&M UNIVERSITY
DEPARTMENT OF MECHANICAL ENGINEERING
FALL 2023

MEEN 434/634 Dynamics and Modeling of Mechatronic Systems

Mechatronic interactions in lumped-parameter and continuum systems. Review of integral and differential electromagnetic laws, including motions. Lumped elements and dynamic equations of motion. Linear and nonlinear actuators and transducers. Field transformation and moving media. Electromagnetic force densities and stress tensors. Three credit hours (3-0).

Instructor:

Won-jong Kim, Ph.D.
Associate Professor
223 MEOB
(979)845-3645, phone
wjkim@tamu.edu, e-mail
http://alum.mit.edu/www/wjkim, webpage

TA:

Mr. Boliang Meng
boliangm@tamu.edu, e-mail

Lectures:

TR 8:00 AM–9:15 AM at 204 JCAIN

Office Hours: (Refer to OfficeHours.pdf at Canvas for the details.)

Dr. Kim:	T 4:00 PM–6:00 PM ONLINE, or by appointment. The ZOOM meeting ID and passcode are posted at Canvas.
Mr. Meng:	F 3:00 PM–4:00 PM ONLINE, or by appointment. The ZOOM meeting ID and passcode are posted at Canvas.

Textbooks (required):

- H. H. Woodson and J. R. Melcher, *Electromechanical Dynamics*, Parts 1 and 2, Krieger, 1990. Posted on the course website.
- H. A. Haus and J. R. Melcher, *Electromagnetic Fields and Energy*, Prentice Hall, 1989. Posted on the course website.

Reference:

- J. R. Melcher, *Continuum Electromechanics*, MIT Press, 1981. Posted on the course website.

On-Line Course Materials:

A course website is being established at canvas.tamu.edu. You should be able to access the website if you are registered for the course. All course-related material you will need, e.g. textbooks, homework sets, solutions, and other useful materials will be placed there.

Prerequisite: MEEN 364

- Dynamic systems and controls (MEEN 364)
- Differential equations, complex variables, and vector calculus (MATH 308 and 251)
- Freshman electromagnetics (PHYS 207/208)

MATH 308, MATH 251, and PHYS 207/208 are prerequisite to MEEN 364. I expect you to be familiar with the following topics.

Dynamic Systems and Controls:

- Drawing free body diagrams
- Writing equations of motion
- Finding transfer function
- Simple controller design (PID, etc.)
- System stability

Differential Equations, Complex Variables, and Vector Calculus:

- Solving differential equations using Laplace transform
- Exposure to partial differential equations (in heat transfer, fluidics, or waves, etc.)
- Elementary complex variables (poles and zeros, Euler equation, etc.)
- Vector algebra (multiplication of vectors and matrices, matrix inversion, determinant, etc.)
- Vector calculus (gradient, divergence, curl, Laplacian, line integral, surface integral, volume integral, etc.)

Electromagnetics:

- Basic knowledge of Maxwell's equations, Coulomb's law, Ohm's law, Faraday's law, Biot-Savart law, and Ampere's law
- Calculating electric and magnetic fields and forces for very elementary geometries such as point charges and current-carrying lines

Course Objectives:

- Understand dynamics and modeling of lumped-parameter and continuum electromechanical systems.
- Analyze and design linear and nonlinear actuators and transducers as crucial elements in electromechanical systems.

Course Learning Outcomes:

Upon successful completion of this course, you will be able to:

- Understand and model mechanical-electrical interactions with dynamics and electromagnetics principles using lumped elements.
- Determine force using force-energy and force-coenergy relations in lumped electromechanical systems.
- Analyze and model magnetic circuits. This will enable you to design linear and nonlinear actuators including voice-coil actuators, electromagnets, etc.
- Analyze and design rotary and linear DC and AC motors.
- Understand dynamics of mechatronic systems.
- Calculate force using Maxwell stress tensor in stationary and moving continuum media.
- Understand dynamics of electromechanical continua and derive equations of motion of magnetizable elastic strings/membranes under the influence of time-varying field.

Applications:

Conventional linear/rotary motor design/analysis, sensor/actuator modeling and characterization, magnetic bearing/levitation, electromagnetic launcher, specialty (piezoelectric, magnetostrictive, magnetoelastic, electrostatic, electrochemical, ionic etc.) actuators and sensors, and so forth.

Grading:

- Two in-class exams for 25% each
- Final exam for 40%
- Homework for 10% total

There will be nine or ten homework sets. You will usually be given 10 days to work on each homework set. Each homework set is due at 11:59 PM on its designated due date and should be submitted on Canvas electronically. *No late homework will be accepted***.**

Exams:

- First in-class exam: Thursday, October 12.
- Second in-class exam: Thursday, November 16.
- Final exam: 1:00 PM–3:00 PM, Friday, December 8, 2023. Comprehensive. Covers all class materials.

All exams are closed-book, closed-note. A formula sheet will be provided for each exam.

Policy on Grading Complaints:

If you feel a mistake was made in grading any material, please first contact the person doing the grading within a week after the graded paper is distributed. If you are not satisfied with the resolution of the matter then talk to me. *After the one-week discussion period, we will not review your exams or change grades.* Make your complaint to me in writing and via e-mail. Be specific about your complaints. Please note I do not negotiate my partial-credit policy with students.

Tentative Grading Policy:

- A: greater than 80%
- B: greater than 60% and less than 80%
- C: greater than 40% and less than 60%
- D, F: less than 40%

Absences:

Work missed due to absences will only be excused for University-approved activities in accordance with TEXAS A&M UNIVERSITY STUDENT RULES (see https://student-rules.tamu.edu/rule07). Specific arrangements for make-up work in such instances will be handled on a case-by-case basis. In accordance with recent changes to Rule 7, please be aware that in this class any "injury or illness that is too severe or contagious for the student to attend class" will require "a medical confirmation note from his or her medical provider" (see Rule 7.3.2.1). Also refer to Rule 7.2.2.6 in regard to job interviews.

The university views class attendance and participation as an individual student responsibility. Students are expected to attend class and to complete all assignments. Please refer to Student Rule 7 in its

entirety for information about excused absences, including definitions, and related documentation and timelines.

Students will be excused from attending class on the day of a graded activity or when attendance contributes to a student's grade, for the reasons stated in Student Rule 7, or other reason deemed appropriate by the instructor. Please refer to Student Rule 7 in its entirety for information about makeup work, including definitions, and related documentation and timelines.

Absences related to Title IX of the Education Amendments of 1972 may necessitate a period of more than 30 days for make-up work, and the timeframe for make-up work should be agreed upon by the student and instructor" (Student Rule 7, Section 7.4.1).

"The instructor is under no obligation to provide an opportunity for the student to make up work missed because of an unexcused absence" (Student Rule 7, Section 7.4.2). Students who request an excused absence are expected to uphold the Aggie Honor Code and Student Conduct Code. (See Student Rule 24.)

To Earn Graduate Credit:

MEEN 434/634 is a stacked course. University policy FS.18.033 requires that more rigorous activities be provided for graduate students to ensure work at the graduate level. To earn the MEEN 634 credit, you are expected to perform one of the following (in the descending order of preference):

- Design a new actuator or sensor applying the principles covered in this course.
- Analyze an existing actuator or sensor applying the principles covered in this course.
- Summarize and criticize in the context of this course the contributions of at least three research papers authored by others.

I strongly recommend that you relate this activity to your own graduate research. You should submit a *type-written* report by 11:59 PM on Thursday, November 30, 2023. The report should not exceed 10 single-spaced pages with 12-point fonts. I will be glad to offer my guidance regarding this activity, and you are encouraged to speak with me early in the semester.

Academic Integrity Statement and Policy:

"An Aggie does not lie, cheat or steal, or tolerate those who do."

"Texas A&M University students are responsible for authenticating all work submitted to an instructor. If asked, students must be able to produce proof that the item submitted is indeed the work of that student. Students must keep appropriate records at all times. The inability to authenticate one's work, should the instructor request it, may be sufficient grounds to initiate an academic misconduct case" (Section 20.1.2.3, Student Rule 20).

You can learn more about the Aggie Honor System Office Rules and Procedures, academic integrity, and your rights and responsibilities at aggiehonor.tamu.edu.

On all course work, assignments, and examinations at Texas A&M University, the following Honor Pledge shall be preprinted and signed by the student:

"On my honor, as an Aggie, I have neither given nor received unauthorized aid on this academic work."

Signature of Student

Americans with Disabilities Act (ADA) Policy:

Texas A&M University is committed to providing equitable access to learning opportunities for all students. If you experience barriers to your education due to a disability or think you may have a disability, please contact Disability Resources in the Student Services Building or at (979) 845-1637 or visit disability.tamu.edu. Disabilities may include, but are not limited to attentional, learning, mental health, sensory, physical, or chronic health conditions. All students are encouraged to discuss their disability related needs with Disability Resources and their instructors as soon as possible.

Title IX and Statement on Limits to Confidentiality:

Texas A&M University is committed to fostering a learning environment that is safe and productive for all. University policies and federal and state laws prohibit gender-based discrimination and sexual harassment, including sexual assault, sexual exploitation, domestic violence, dating violence, and stalking.

With the exception of some medical and mental health providers, all university employees (including full and part-time faculty, staff, paid graduate assistants, student workers, etc.) are Mandatory Reporters and must report to the Title IX Office if the employee experiences, observes, or becomes aware of an incident that meets the following conditions (see University Rule 08.01.01.M1):

- The incident is reasonably believed to be discrimination or harassment.
- The incident is alleged to have been committed by or against a person who, at the time of the incident, was (1) a student enrolled at the University or (2) an employee of the University.

Mandatory Reporters must file a report regardless of how the information comes to their attention – including but not limited to face-to-face conversations, a written class assignment or paper, class discussion, email, text, or social media post. Although Mandatory Reporters must file a report, in most instances, you will be able to control how the report is handled, including whether or not to pursue a formal investigation. The University's goal is to make sure you are aware of the range of options available to you and to ensure access to the resources you need.

Students wishing to discuss concerns in a confidential setting are encouraged to make an appointment with Counseling and Psychological Services (CAPS).

Students can learn more about filing a report, accessing supportive resources, and navigating the Title IX investigation and resolution process on the University's Title IX webpage.

Statement on Mental Health and Wellness:

Texas A&M University recognizes that mental health and wellness are critical factors that influence a student's academic success and overall wellbeing. Students are encouraged to engage in proper self-care by utilizing the resources and services available from Counseling & Psychological Services (CAPS). Students who need someone to talk to can call the TAMU Helpline (979-845-2700) from 4:00 p.m. to 8:00 a.m. weekdays and 24 hours on weekends. 24-hour emergency help is also available through the National Suicide Prevention Hotline (800-273-8255) or at suicidepreventionlifeline.org.

COVID Statement:

To help protect Aggieland and stop the spread of COVID-19, Texas A&M University urges students to be vaccinated and to wear masks in classrooms and all other academic facilities on campus, including labs. Doing so exemplifies the Aggie Core Values of respect, leadership, integrity, and selfless

service by putting community concerns above individual preferences. COVID-19 vaccines and masking — regardless of vaccination status — have been shown to be safe and effective at reducing spread to others, infection, hospitalization, and death.

Schedule:

Following is a tentative schedule. The pace will be adjusted as the semester progresses.

Week	Contents
1	Overview of the course, review of vector calculus, review of electric field theory
2	Review of magnetic field theory, quasistatic approximations
3	Constitutive laws, energy conservation, force-energy relations
4	Coenergy, force-coenergy relations, magnetic circuits
5	Energy conversion cycles, systems with multiple terminals, variable-reluctance actuators
6	Permanent magnets, coupled mechanical and electromagnetic systems
7	Static equilibria, linearization about static equilibria
8	Dynamic equilibria and linearized dynamics, active stabilization, magnetic levitation example
9	Field transformations, conduction conservative laws, field transformation examples
10	DC Machines, magnetic diffusion
11	Magnetic diffusion in sinusoidal steady state and in convective media, charge relaxation
12	Quasistatic stress tensor, stress tensor examples
13	One-dimensional elastic continua, dynamics of electromechanical continua
14	Electromechanical dynamics with convection, introduction to continuum electromechanics

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Fall 2023

Instructor: Prof. Won-jong Kim

Questionnaire

Name: For Credit / Audit

Email address:

Phone number (optional):

TAMU ID:

TAMU Department:

Are you a senior, a master's student, or a doctoral student?

Advisor (if applicable):

Have you taken MEEN 364 (or equivalent)?	Yes.	No.
Have you taken MATH 308 and 251 (or equivalent)?	Yes.	No.
Have you taken junior-level Electromagnetic Field Theory? (such as either PHYS 304 or ECEN 322, which is not pre-requisite, though.)	Yes.	No.

What would you like to learn from this course?

Will the course material be useful for your research? If so, please tell me about your research briefly.