TEXAS A&M UNIVERSITY
DEPARTMENT OF MECHANICAL ENGINEERING
SPRING 2023

MEEN 431 Advanced System Dynamics and Controls

Unified framework for modeling, analysis, synthesis, design and simulation of mechanical systems with energy exchange across multiple domains; study of mechanical, electrical, hydraulic and thermal subsystems; Newtonian mechanics, rigid body dynamics, multiple degrees of freedom vibrations and control system design. Three credit hours (3-0).

Instructor:

Won-jong Kim, Ph.D.
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http://alum.mit.edu/www/wjkim, webpage

TA:

TBA

Grader:

TBA

Lectures:

MWF 11:30 AM–12:20 PM at 204 JCAIN

Office Hours:

Dr. Kim:	M 5:00–6:00 PM and R 4:30–5:30 PM ONLINE, or by appointment. The ZOOM meeting ID and passcode are posted in OfficeHours.pdf at Canvas.
Grader:	by appointment.

Textbooks (required):

- D. W. Childs, *Dynamics in Engineering Practice*, 11th Ed., CRC Press, 2015.
- G. F. Franklin, J. D. Powell, and A. Emami-Naeini, *Feedback Control of Dynamics Systems*, 8th Ed., Prentice Hall, 2018 (4th–7th Ed. OK).

References:

- J. L. Meriam and L. G. Kraige, *Engineering Mechanics Dynamics*, 6th Ed., Wiley, 2007.
- B. T. Kulakowski, J. F. Gardner, and J. L. Shearer, *Dynamic Modeling and Control of Engineering Systems*, 3rd Ed., Cambridge, 2007. Click on the Online Access link near the end of https://catalog.library.tamu.edu/Record/in00003828641
- W. T. Thomson and M. D. Dahleh, *Theory of Vibrations with Applications*, 5th Ed., Prentice Hall, 1998.

All references can be checked out for four hours from the Reserved Books Desk at Evans Library.

On-Line Course Material:

A course web page is being established at canvas.tamu.edu. You should be able to access the web page if you are registered for the course. All course-related material you will need, e.g. supplementary notes and examples, homework sets, solutions, and other useful materials will be placed on Canvas. You may also refer to wonjongkim.tamu.edu/MEEN364 for additional materials on classical control.

Learning Outcomes and Course Objectives:

To build upon the fundamentals of analytical dynamics and feedback control to:

- Understand the phenomenon of vibration
- Understand limitations of feedback and controller design
- Prediction of dynamics behavior of mechanical systems by analytical methods and computer simulation
- Synthesize/design mechanical systems to achieve desired performance goals

Prerequisites:

- MEEN 364, *Dynamic Systems and Controls*
- Working familiarity with Matlab/Simulink or Python is expected.

Grading:

- Mid-term exams for 50% total
- Final exam for 40%
- Homework for 10% total

Exams:

There will be two mid-term exams. The comprehensive final exam will be held as scheduled in the University Schedule of Classes.

- Exam 1: in-class, TBA
- Exam 2: in-class, TBA
- Final exam: 10:30 AM–12:30 PM, Tuesday, May 9, 2023.

Homework:

There will be about a dozen homework sets. Each homework set is due 11:59 PM on its designated due date and should be submitted on Canvas electronically. ***No late homework will be accepted.*** All written work must be clear and professionally done with the necessary steps leading to the solution clearly marked. Homework solutions will be made available on the course web site. Only part of the homework problems will be selected randomly for grading. The intention of the homework assignments is to check for the work of the individual. Each student is required to turn in their solutions to the homework assignments. However, students are allowed to form groups or consult other students to discuss the problems.

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 work 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.

Grading Policy:

- A: greater than 90%
- B: greater than 80%
- C: greater than 70%
- D: greater than 60%
- F: less than 60%

Schedule:

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

Week	Contents
	Multi-DOF Systems
1	Review—DOF, planar kinematics, FBD, Newtonian mechanics, EOM, 1-DOF vibrations
2	Multi-DOF vibrations, free and forced vibrations, modal analysis
	Dynamics and System Modeling
3	Rotation transformations, Euler angles, rotating-frame formula
4	Rigid-body kinematics, angular momentum, inertia matrix
5	Rigid-body kinetics, work-energy principle
6	Lagrangian mechanics
7	Modeling of interconnected systems, energy exchange across multiple domains
8	Causalities, constitutive laws, derivation of state equations
	Advanced Controls
9	Review—Transfer function, performance specifications, Routh stability criterion
10	Controller design, integrator anti-windup
11	Sensitivity, feedback, and stability
12	PID autotuning, frequency response, loop-shaping design of compensators
13	State-space design, pole placement, state feedback, state observers
14	Nyquist stability criterion, ideal Bode characteristics

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.)

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.