ME 360: Modeling, Analysis, and Control of Dynamic Systems

Fall 2024

Section Information

Section 001
Mondays & Wednesdays 8:30 - 10:30 AM
107 GFL

Professor: David Fleming
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Email: dcflem@umich.edu

Section 002
Tuesdays & Thursdays 10:30 AM – 12:30 PM
1005 Dow

Professor: Uduak Inyang-Udoh
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Supporting Instructional Team

GSI – Emma Nottingham – enotting@umich.edu

IA – Benjamin Sison – sisonb@umich.edu

IA – Yuanshao Yang – yuanshao@umich.edu

Prerequisites

You are expected to have knowledge of dynamics and vibrations **(ME 240)** and electrical circuits **(P/A EECS 314)** as well as knowledge of vector calculus, linear algebra, and differential equations.

Course Materials

RECOMMENDED TEXT: William J. Palm III (2021). *System Dynamics (4th Edition)*. McGraw Hill.

- There are multiple hardcopies of this text in the UM Library system as well as online access to the text through the library can be found here (limited to 3 simultaneous users).
- A PDF version of the 3rd Edition can be easily found online. We will post the table of contents of the 4th Edition for reference as the schedule below is based off the 4th Edition chapters.

ALTERNATIVE TEXT: Ramin S. Esfandiari & Bei Lu (2014). Modeling and Analysis of Dynamic Systems *(2nd Edition)*. Taylor and Francis.

- Online access to this text is granted through the UM Library system here (no limit on simultaneous users).
- Although not the primary text for this course, many sections parallel those in the Palm text and have been listed in the schedule below.

Expectations

You should expect that we will start and end each class on time and that we will do our best to prepare the clearest possible lesson plan. In turn, we expect you to attend class to be on time, and to complete all of the required work in the course. We may periodically e-mail you if we note that you are not attending regularly and/or not turning in the required work. Material specific to in-class lessons may appear on any assessments.

We consider this classroom to be a place where you will be treated with respect, and we welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, ability – and other visible and nonvisible differences. All members of this class are expected to contribute to a respectful, welcoming and inclusive environment for every other member of the class. We are dedicated to helping each of you achieve all that you can in this course. It is possible that we may, either in class or smaller interactions, accidentally use language or references that creates offense or discomfort. Should we do so, please contact us and help us understand and avoid making the same mistake again.

“Drop-In Hours” & Piazza

The whole instructional team will be staffing a number of “drop-in” hours throughout the week. These are times in which one or more of the instructional staff will be available to answer any questions you may have about course content relating to class lessons, assignments, assessment preparations, or anything else you would like to discuss. If you would like to come to drop-in hours just to work on your assignments and ask questions of the instructional staff or your peers as they arise, we absolutely encourage you to do so. This is meant to serve as a collaborative and welcoming environment where you can learn from one another.

Below is a table outlining drop-in hours and who staffs them. All drop-in hours will be hosted in the **Findley Learning Center (in GGB)** unless marked as “Virtual” below (crosshatched in color) in which they will be hosted virtually using this link. Note that the room within Findley that we meet is different depending on the day and time.

Start Time	Monday (Findley E)	Tuesday (Findley)	Wednesday (Findley)	Thursday (Findley)	Friday (Findley A)
10:30					
11:00			Fleming		
11:30			(Findley A)		Sison
12:00					
12:30			Yang	Yang	
1:00			(Findley B)	(Findley B)	
1:30		Inyang-Udoh			
2:00		(Findley A)			
2:30					
3:00	Yang			Inyang-Udoh	
3:30				(Vitual)	Nottingham
4:00	Fleming		Nottingham	Nottingham	
4:30			(Findley A)	(Findley A)	
5:00		Sison			
5:30		(Findley F)		Sison	
6:00				(Findley C)	
6:30					

David Fleming
Uduak Inyang-Udoh
Emma Nottingham
Benjamin Sison
Yuanshao Yang

In addition to these drop-in hours, we will be using Piazza for out of class discussion and questions. You should have received an email inviting you to enroll in our course’s Piazza page. On this page you can ask and answer any questions you may have about content or assignments in the class. The system is highly catered to getting you help fast and efficiently from classmates or the whole instructional team. Rather than emailing questions to the instructional team, I encourage you to post your questions on Piazza so that your peers can also benefit from the response. This course’s Piazza page has been linked to Canvas.

Grading Policy

Your final grade will be determined by the following breakdown:

	Weighting
Homework Assignments	30%
Exam 1	20%
Exam 2	20%
Final Exam	30%

All assignments and exams will be graded and handed back in a timely manner. If you believe there was a mistake in any of the grading, please write a brief description to us via email explaining the alleged mistake with a copy of the assessment in question. All re-grade submissions must be turned in within a week of originally being returned to you. Although we will not maliciously be looking to deduct points during a re-grade, if a mistake is found that was not deducted for during the first grading, we reserve the right to deduct those points during the re-grade.

Assignments

Ten homework assignments will be set during the term that will be posted and turned in on the course's Canvas site. Homework sets are **due no later than 11:59pm on Friday**, and late homework will NOT be accepted without prior arrangements. The point value equivalent to one homework score for the term will be dropped when calculating the final grade.

You are encouraged to discuss and work on assignments together but the final submission must represent your own understanding of the material. You are not allowed to use solutions from former students' work or copies of solutions that had been made available by any instructor or publisher, or solutions generated by a generative AI tool (i.e. ChatGPT). Violation of this policy will initiate an action to be filed with the Dean's office and the College of Engineering's Honor Council. If you have any questions about this policy, do not hesitate to contact us.

Course Objectives

1. To teach students elementary tools of modeling of mechanical, electrical, fluid, and thermofluid systems.
2. To teach a basic understanding of behavior of first- and second-order linear time-invariant differential equations.
3. To teach basic concepts of Laplace transforms, transfer functions, and frequency response analysis.
4. To introduce the concept of stability and the use of feedback control to actively control system behavior.
5. To provide examples of real-world systems to which modeling and analysis tools are applied (e.g., DC Motor) for the purpose of design.
6. To introduce an appreciation for decision-making skills needed to devise models that adequately represent relevant behaviors yet remain simple.
7. To teach basic concepts in numerical integration and computer simulation of mathematical models.

Learning Outcomes

1. Given a description of a real-world system, make education decisions about how to model it in terms of idealized, lumped elements.
2. Given a simple system containing some combination of mechanical, electrical, and/or thermofluid elements, derive a differential equation describing its input/output behavior.
3. Given a first- or second-order LTI differential equation, predict its step response or free response.
4. Given an LTI differential equation and a sinusoidal input, predict the gain and phase of the steady-state output as a function of input frequency.
5. Given certain desired performance characteristics for a system (such as maximum overshoot), translate specifications into design parameters (such as the dimensions of a spring) necessary to provide those characteristics.
6. Given a physical description of a system and a graphical representation of its time-domain response (step, frequency, etc.), estimate system parameters (i.e. friction or damping coefficient, spring constant).
7. Given a LTI differential equation and an arbitrary input composed of steps, ramps, and other simple functions, set up the solution using Laplace transforms.
8. Describe basic applications of proportional and derivative feedback in control systems to improve performance or stability.
9. Given a system composed of mixed mechanical/electrical/thermofluid components, write the transfer function describing input-output behavior.
10. Given a system with given performance, describe (qualitatively) how behavior can be improved according to specifications, such as overshoot and settling time, using a combination of parameter tuning and feedback control.
11. Describe how changes in parameter values will affect damping ratio and natural frequency for a system, and how these characteristics are manifested in the system's behavior.
12. Implement a mathematical model into commercial simulation software, and use the model to make engineering assessments.

Intended Schedule – Section 001

The following is an *intended schedule* and is subject to changes.

Week	Lesson	Date	Day	Topic	Palm (4e)	Esfandiari & Lu (3e)	Assigned	Due (Fridays @ 11:59 PM)
1	1,2	8/26	M	Introduction, Terminology, & ODEs	Ch. 1.1-1.5		-	-
	2,3	8/28	W	Linearization & Analytical Solutions to ODEs	Ch. 2.1-2.2	Ch. 2.2 & 4.6	-	-
2	-	9/2	M	University Break - No Classes	-	-	HW1	-
	4	9/4	W	Laplace Transforms	Ch 2.3-2.4, 2.7	Ch. 2.3	-	-
3	5	9/9	M	Laplace Transforms & Transfer Functions	Ch. 2.5-2.6	Ch. 4.3	HW2	-
	6	9/11	W	Rigid Body Modeling	Ch. 3.1-3.3	Ch. 5.2-5.3	-	HW1
4	7	9/16	M	Rigid Body Modeling	Ch. 3.3-3.5	Ch. 5.4-5.5	HW3	-
	8	9/18	W	Mechanical Systems	Ch. 4.1-4.3	Ch. 5.1	-	HW2
5	9	9/23	M	Mechanical Systems	Ch. 4.4-4.6	Ch. 5.1	HW4	-
	10	9/25	W	State Space Representation of Differential Equations	Ch . 5.1-5.3	Ch. 4.2-4.4	-	HW3
6	11	9/30	M	State Space Representation of Differential Equations	Ch. 5.3-5.6	Ch. 4.2-4.4	HW5	-
	12	10/2	W	Electrical Models	Ch. 6.1-6.3	Ch. 6.1-6.2, 6.5	-	HW4
7	13	10/7	M	Electromechanical Systems	Ch. 6.3-6.5	Ch. 6.3-6.5	-	-
	-	**10/9**	**W**	**Exam 1 (Loc. TBA)**	-	-	-	-
8	-	10/14	M	University Break - No Classes	-	-	-	-
	14	10/16	W	Electromechanical Systems	Ch. 6.5-6.8	Ch. 6.4-6.7	HW6	HW5
9	15	10/21	M	Time Domain - 1st & 2nd Order Systems	Ch. 8.1-8.2	Ch. 8.2-8.3	-	-
	16	10/23	W	Time Domain Response	Ch. 8.3-8.5	Ch. 8.2-8.3	HW7	HW6
10	17	10/28	M	Time Domain Response	Ch. 8.3-8.5	Ch. 8.2-8.3	-	-
	18	10/30	W	Frequency Responses	Ch. 9.1	Ch. 8.4	HW8	HW7
11	19	11/4	M	Frequency Responses	Ch. 9.2	Ch. 8.4	-	-
	20	11/6	W	Bode Plots & Filtering	Ch. 9.3-9.4	Ch. 8.4	HW9	HW8
12	21	11/11	M	Frequency Response & System ID	Ch. 9.5-9.8	Ch. 10.2	-	-
	-	**11/13**	**W**	**Exam 2 (Loc. TBA)**	-	-	-	-
13	22	11/15	M	Control Systems	Ch. 10.1-10.2	Ch. 10.3	-	-
	23	11/20	W	Control Systems	Ch. 10.3-10.4	Ch. 10.4	HW10	HW9
14	24	11/25	M	Control Systems	Ch. 10.5-10.7	Ch. 10.4	-	-
	-	11/27	W	University Break - No Classes	-	-	-	-
15	25	12/2	M	Control Systems	Ch. 10.5-10.7	Ch. 10.4	-	HW10
	26	12/4	W	Thermal/Fluid Systems	Ch. 7	Ch. 7	-	-
16	27	12/9	M	Last Day Wrap-Up				
16	-	**12/11**	**W**	**Final Exam (Cumulative) 1:30 - 3:30 PM (Loc. TBD)**	-	-	-	-

Intended Schedule – Section 002

The following is an *intended schedule* and is subject to changes.

Week	Lesson	Date	Day	Topic	Palm (4e)	Esfandiari & Lu (3e)	Assigned	Due (Fridays @ 11:59 PM)
1	1	8/27	Tu	Introduction, Terminology, & ODEs	Ch. 1.1-1.5	-	-	-
	2	8/29	Th	Linearization & Analytical Solutions to ODEs	Ch. 2.1-2.2	Ch. 2.2 & 4.6	-	-
2	3	9/3	Tu	Laplace Transforms	Ch 2.3-2.4, 2.7	Ch. 2.3	HW1	-
	4	9/5	Th	Laplace Transforms & Transfer Functions	Ch. 2.5-2.6	Ch. 4.3	-	-
3	5	9/10	Tu	Rigid Body Modeling	Ch. 3.1-3.3	Ch. 5.2-5.3	HW2	-
	6	9/12	Th	Rigid Body Modeling	Ch. 3.3-3.5	Ch. 5.4-5.5	-	HW1
4	7	9/17	Tu	Mechanical Systems	Ch. 4.1-4.3	Ch. 5.1	HW3	-
	8	9/19	Th	Mechanical Systems	Ch. 4.4-4.6	Ch. 5.1	-	HW2
5	9	9/24	Tu	State Space Representation of Differential Equations	Ch . 5.1-5.3	Ch. 4.2-4.4	HW4	-
	10	9/26	Th	State Space Representation of Differential Equations	Ch. 5.3-5.6	Ch. 4.2-4.4	-	HW3
6	11	10/1	Tu	Electrical Models	Ch. 6.1-6.3	Ch. 6.1-6.2, 6.5	HW5	-
	12	10/3	Th	Electromechanical Systems	Ch. 6.3-6.5	Ch. 6.3-6.5	-	HW4
7	-	10/9	**W**	**Exam 1 (5-7PM in 1013 DOW)**	-	-	-	-
	13	10/10	Th	Electromechanical Systems	Ch. 6.5-6.8	Ch. 6.4-6.7	-	-
8	-	10/12	Tu	University Break - No Classes	-	-	-	-
	14	10/17	Th	Time Domain - 1st & 2nd Order Systems	Ch. 8.1-8.2	Ch. 8.2-8.3	HW6	HW5
9	15	10/19	Tu	Time Domain Response	Ch. 8.3-8.5	Ch. 8.2-8.3	-	-
	16	10/24	Th	Time Domain Response	Ch. 8.3-8.5	Ch. 8.2-8.3	HW7	HW6
10	17	10/26	Tu	Frequency Responses	Ch. 9.1	Ch. 8.4	-	-
	18	10/31	Th	Frequency Responses	Ch. 9.2	Ch. 8.4	HW8	HW7
11	19	11/2	Tu	Bode Plots & Filtering	Ch. 9.3-9.4	Ch. 8.4	-	-
	20	11/7	Th	Frequency Response & System ID	Ch. 9.5-9.8	Ch. 10.2	HW9	HW8
12	**-**	**11/13**	**W**	**Exam 2 (6-8PM in Chrysler Auditorium)**	-	-	-	-
	21	11/14	Th	Control Systems	Ch. 10.1-10.2	Ch. 10.3	-	-
13	22	11/19	Tu	Control Systems	Ch. 10.3-10.4	Ch. 10.4	-	-
	23	11/21	Th	Control Systems	Ch. 10.5-10.7	Ch. 10.4	HW10	HW9
14	24	11/26	Tu	Control Systems	Ch. 10.5-10.7	Ch. 10.4	-	-
	-	11/28	Th	University Break - No Classes	-	-	-	-
15	25	12/3	Tu	Thermal/Fluid Systems	Ch. 7	Ch. 7	-	-
	26	12/5	Th	Last Day Wrap-Up	-	-	-	HW10
16	-	**12/16**	**M**	**Final Exam (Cumulative) 4:00PM - 6:00 PM (Loc. TBD)**	-	-	-	-