Control System Theory
EML 5311 Sections CAMP, WEBR, 1FE2, 2FED
Fall 2025, M W F, 6th Period, 12:50 PM – 1:40 PM
NEB 0102

Modifications to this syllabus may be required during the semester. Any changes that are made will be reflected in a posted version of the syllabus and announced in class.

Instructor

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WERT 489
Please contact through the Canvas website https://elearning.ufl.edu
Any emails to ufl email address must include EML 5311 in the subject line

Office Hours

- M W, 2:00 PM – 3:00 PM, WERT 489
- Or via confirmed written appointment
- https://ufl.zoom.us/j/92462496783?pwd=7QyaqhTMNDFcnUiMRxgQJ4Ce46nA1m.1
  (as needed) Zoom Meeting ID: 924 6249 6783 Passcode: 545689

Graduate Student Teaching Assistant (TA)

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Graduate Student Grader

Trivikram Satharasi
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Course Description

Course Catalog: "Analyzing dynamic mechanical engineering control systems. Introduction to classical, digital, and state space techniques. Modeling, stability, transient response, and frequency response. Considers implementation." (Credits: 3)

Course Pre-Requisites

Undergraduate course in control of mechanical engineering systems (e.g., EML 4312) with a minimum grade of B, or instructor permission. You must already be familiar with the following concepts: Laplace transforms, transfer functions, block diagrams, impulse response, step response, first-order systems, second-order systems, poles and zeros, bounded input bounded output stability, reference tracking, disturbance rejection, PID control, the Routh-Hurwitz stability criterion, root locus, Bode plots (drawing and interpreting), the Nyquist criterion, gain and phase margin, and phase lead and phase lag controller design.

Course Objectives

By the end of this course, you should be able to do the following:

- Describe dynamic mechanical engineering systems with linear systems theory, including with linear spaces, linear operators, bases, subspaces, eigenvalues, eigenvectors, canonical forms, linear differential and difference equations, state equations, transfer functions, impulse response, matrix fraction, and polynomial descriptions.

- Analyze linear system descriptions using system-theoretic concepts and state-space methods: causality, controllability, observability, realizations, canonical decomposition, and stability.
- Design control signals for linear systems using state feedback, state observers, and introductory optimal control and estimation techniques.
- Account for control system design tradeoffs.

Materials and Supply Fees

None.

Recommended Textbooks, Software, and Hardware

- Chi-Tsong Chen, "Linear System Theory and Design," Oxford University Press, 4th Ed., ISBN: 9780199959570, 2012
- MATLAB (MathWorks), any recent release.
- Various handout materials provided digitally on Canvas.
- Scientific calculator (not your phone).
- It is important that you have your own laptop/mobile computer. Details are provided at: https://it.ufl.edu/get-help/student-computer-recommendations/ https://www.eng.ufl.edu/students/advising/fall-semester-checklist/computer-requirements/

Alternate (Reference) Textbooks

- João P. Hespanha, "Linear Systems Theory," Princeton University Press, 2nd Ed., ISBN: 9780691179575, 2018
- Panos J. Antsaklis and Anthony N. Michel, "Linear Systems," Birkhäuser; Corrected edition, ISBN: 9780817644345, 2005
- John S. Bay, "Fundamentals of Linear State Space Systems," McGraw-Hill, ISBN: 9780256246391, 1999
- Wilson J. Rugh, "Linear System Theory," Pearson, 2nd Ed., ISBN: 9780134412054, 1995
- Thomas Kailath, "Linear Systems," Prentice-Hall, ISBN: 9780135369616, 1980

Important Dates

- Classes Begin: Aug 21 (Thursday)
- Holidays/Reading Days: Sep 1 (Monday), Oct 17 (Friday), Nov 11 (Tuesday), Nov 24 – 28 (Monday – Friday), Dec 4, 5 (Thursday, Friday)
- Classes End: Dec 3 (Wednesday)
- Classes Canceled:
- Homework dates stated in this syllabus will be confirmed in class
- Exam 1 on the first half of the course can be taken during any 1 hour 50 minutes in Honorlock between 12:30 pm ET on Oct 21 (Tuesday) and 12:29 pm ET on Oct 22 (Wednesday)
- Exam 2 on the second half of the course can be taken during any 2 hours in Honorlock between 12:30 pm ET on Dec 2 (Tuesday) and 12:29 pm ET on Dec 3 (Wednesday)

Requirements for class attendance, make-up exams, assignments, and other work in this course are consistent with university academic policies: https://go.ufl.edu/syllabuspolicies

Attendance Policy

- The class has no attendance policy. Students are expected to attend.
- **Make-up Policy:** Homework / exam absences may be excused with appropriate documentation. See https://care.dso.ufl.edu/instructor-notifications. Note that "Instructors have the right to accept or reject the Instructor Notification."

Class Expectations

- The student is solely responsible for their education. The instructor is the guide to their understanding of the field.

- Cell phones, laptops, etc.: **under no circumstances will disruptions from electronic devices be tolerated. Students are expected to take either handwritten notes with pen/pencil and paper, or electronic notes with stylus and tablet.**
- **Electronic notes must be printed out if used as reference material on examinations.**
- **No Artificial Intelligence (AI):** The learning that takes place in this course requires your unique perspective and human experience. Use of AI would make it harder to evaluate your work. It is not permitted to use any generative AI tools in this course, and the use of AI will be treated as an academic integrity issue.
- Respect and disruption: the instructor and students will be always respectful. Classroom disruption of any kind will not be tolerated.
- **The principles of the Honor Code must be always adhered to.** Individual effort is required on homework assignments, quizzes, and exams. Groups will be treated as individuals for projects. Students are bound by the Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code." On all work submitted for credit, the following statement is either required or implied:

  On my honor, I have neither given nor received unauthorized aid in doing this homework/quiz/report/exam.

  The Conduct Code (https://sccr.dso.ufl.edu/process/student-conduct-code/) specifies behaviors that are in violation of this code and the possible sanctions. You are obligated to report any academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TA.

  Course Zero-Tolerance Policy: *Any* violation or suspected violation of the Honor Code by a student may result in that student receiving a grade of E for the course.

Homework

The purpose of homework is to learn and understand the material. **Students are responsible for performing and understanding the homework problems and solutions on their own.**

Software and Copyrighted Material Use

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing the use of software and the use of copyrighted material. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Exams

All exams are open-book, open-notes, closed-electronic devices except for a scientific calculator (that is **not** your cell phone or laptop)**.**

Honorlock: Consistent with university policy, Honorlock may be used for course assessments and will be confirmed by the instructor. See https://pfs.tnt.aa.ufl.edu/teaching-and-technology-resources/online-proctoring/ for more information.

Students Requiring Accommodations

Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the Disability Resource Center (https://disability.ufl.edu/students/get-started/). Students should share their accommodation letter with their instructor and discuss their access needs as early as possible in the semester.

Commitment to a Positive Learning Environment

The Herbert Wertheim College of Engineering values varied perspectives and lived experiences within our community and is committed to supporting the University's core values.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Coordinator
- HWCOE Human Resources, 352-392-0904, student-support-hr@eng.ufl.edu
- Professor Pam Dickrell, Associate Dean of Student Affairs, 352-392-2177, pld@ ufl.edu

Evaluation of Grades and Grading Policy

Evaluation Mechanism on a Percent Basis

Homeworks (8)	20%
Exam 1	40%
Exam 2	40%

Homework

Students will submit solutions of the homework problems only via the course website. Students who turn in homework before the due date and time will have their homework graded. Not all homework problems may be graded, and a selection of problems may be randomly chosen for grading after the homework due date and time. Submitted homework that is partially- or fully-missing solutions to these chosen problems will not be eligible for full or partial credit for those problems, respectively, even if other non-chosen homework problems were completed. **Grading may be on completeness or on correctness.** However, it is the student's responsibility to check their solutions against posted homework solutions.

Exams

All students are expected to take all exams. If a student is unable to take an exam for unforeseeable reasons, then the other exams will count toward the percentage of the grade that makes up the exams if an appropriate DSO instructor notification is accepted.

Final Grade

Final grades may be calculated by the following table. For example, if a student earns 86.60% (Percent Grade Earned %GE = 86.60) then their grade point will be 3.33 (B+). %GE are rounded to the hundredths decimal place. For example, if a student earns 77.995% (Percent Grade Earned %GE = 77.995) it will be rounded up to 78.00%, and their grade point will be 2.67 (B-). Shifts in the grading table are at the discretion of the instructor.

Table 1. Grading Table. *%GE = Percent Grade Earned.*

Percentage Range	Grade Point
$92.00 \leq \%GE < 100.00 \Longrightarrow A$	4.00
$88.00 \leq \%GE < 92.00 \Longrightarrow A-$	3.67
$85.00 \leq \%GE < 88.00 \Longrightarrow B+$	3.33
$81.00 \leq \%GE < 85.00 \Longrightarrow B$	3.00
$78.00 \leq \%GE < 81.00 \Longrightarrow B-$	2.67
$74.00 \leq \%GE < 78.00 \Longrightarrow C+$	2.33
$71.00 \leq \%GE < 74.00 \Longrightarrow C$	2.00
$67.00 \leq \%GE < 71.00 \Longrightarrow C-$	1.67
$64.00 \leq \%GE < 67.00 \Longrightarrow D+$	1.33
$61.00 \leq \%GE < 64.00 \Longrightarrow D$	1.00
$60.00 \leq \%GE < 61.00 \Longrightarrow D-$	0.67
$00.00 \leq \%GE < 60.00 \Longrightarrow E$	0.00

Grade Corrections

Grade corrections should be submitted promptly in writing within three business days of the grade posting. Include a concise statement of why you believe that there has been an error. The instructor has the final determination in the assigned grade; if a grade change is made, the grade may be lower or higher.

Course Schedule, Approximately by Lecture Number (1/3 Linear Algebra, 1/3 Analysis, 1/3 Control Design)

1	Aug 22	Course Introduction, Introduction to Systems	Ch. 1, 2.1, 2.2
2	Aug 25	Linearity, Linear Systems, Linearization	Ch. 2.3, 2.4
3	Aug 27	Linearization, Newton's Method, Discrete-Time Linear Systems	Ch. 2.4, 2.8
4	Aug 29	Convolution, Impulse Response in Continuous and Discrete Time	Ch. 2.2, 2.3
5	Sep 3	Fundamental Property of LTI Systems, Fields, Vector Spaces	Ch. 2.3, 3.2
Approximate End of Coverage for Homework 1			
6	Sep 5	Dimension, Basis, Norm, Normalization	Ch. 3.2
7	Sep 8	Banach Space, Hilbert Space	Ch. 3.2
Homework 1 Due Sep 8 (Monday), 11:59 PM			
8	Sep 10	Projection, Projection Theorem, Orthonormalization, Linear Transformation	Ch. 3.3
Approximate End of Coverage for Homework 2			
9	Sep 12	Linear Operators, Change of Basis, Range, Nullspace	Ch. 3.3
10	Sep 15	Rank-Nullity Theorem, Invertibility, Operator Norms, Linear Equations	Ch. 3.3
Homework 2 Due Sep 15 (Monday), 11:59 PM			
11	Sep 17	Linear Equations, Eigenvalues	Ch. 3.3, 3.4
Approximate End of Coverage for Homework 3			
12	Sep 19	Eigenvectors	Ch. 3.4
13	Sep 22	Cayley-Hamilton Theorem, Algebraic Multiplicity, Geometric Multiplicity	Ch. 3.6
Homework 3 Due Sep 22 (Monday), 11:59 PM			
14	Sep 24	Generalized Eigenvectors, Jordan Canonical Form	Ch. 3.5
15	Sep 26	Singular Value Decomposition, Quadratic Forms, Functions of Matrices	Ch. 3.10, 3.9
16	Sep 29	Matrix Exponential, Solution to Linear System Dynamics	Ch. 4.2, 4.5
Approximate End of Coverage for Homework 4			
17	Oct 1	State Transition Matrix	Ch. 4.6
18	Oct 3	State Transition Matrix, Stability	Ch. 4.7, 4.8
Homework 4 Due Oct 3 (Friday), 11:59 PM			
19	Oct 6	BIBO Stability, Lyapunov Stability, Asymptotic Stability	Ch. 5.2, 5.4
Approximate End of Coverage for Homework 5			
20	Oct 8	Stability of Discrete-Time and Time-Varying Linear Systems	Ch. 5.3, 5.6
21	Oct 10	Stability Examples, Lyapunov Functions	Ch. 5.5
End of Coverage for Exam 1			
22	Oct 13	Controllability	Ch. 6.2
Homework 5 Due Oct 13 (Monday), 11:59 PM			
23	Oct 15	Controllability	Ch. 6.2
24	Oct 20	Controllability Properties, Observability	Ch. 6.2, 6.3
Exam 1 Available Oct 21, 22			
25	Oct 22	Observability	Ch. 6.3
26	Oct 24	Controllability and Observability for Linear Time-Varying Systems	Ch. 6.8
Approximate End of Coverage for Homework 6			
27	Oct 27	Kalman Decompositions	Ch. 6.4
28	Oct 29	System Realizations	Ch. 7
Homework 6 Due Oct 29 (Wednesday), 11:59 PM			
29	Oct 31	Canonical Realizations, Minimal Realization	Ch. 7
30	Nov 3	Output Feedback, State Feedback, Eigenvalue Assignment	Ch. 8.2
31	Nov 5	Fixed Controllable Modes, Stabilizability, Two Degree of Freedom Control	Ch. 9.3
32	Nov 7	Tracking Accuracy, Disturbance Rejection, Integral Control	Ch. 8.3, 9.3
33	Nov 10	State Observers, Fixed Observable Modes, Detectability	Ch. 8.4

Approximate End of Coverage for Homework 7

34	Nov 12	Disturbance Estimators, Reduced-Order Observers	Ch. 8.4
35	Nov 14	Separation Principle	Ch. 8.5
36	Nov 17	Internal Model Principle, Control Trade-offs, Loop Shaping	

Homework 7 Due Nov 17 (Monday), 11:59 PM

37	Nov 19	Linear Quadratic Regulator	
38	Nov 21	Linear Quadratic Regulator	

Approximate End of Coverage for Homework 8

39	Nov 21	Kalman Filter, Linear Quadratic Gaussian Control	

End of Coverage for Exam 2

Homework 8 Due Nov 30 (Sunday), 11:59 PM

Exam 2 Available Dec 2, 3