Syllabus - ECE 240: INTRODUCTION TO LINEAR DYNAMICAL SYSTEMS

Lecture: TuTh 11:40 AM – 1:15 PM at PhysSciences 136
Dates: September 25, 2025 – December 5, 2025

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Office Hours: Thursday, 4:30-5:30pm at E2-547B
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Course Overview

A linear dynamical system is a mathematical model of a physical process that can be described either by a set of first-order differential equations in continuous time or by a set of first-order difference (recursion) equations in discrete time. Generally, these systems can be written in the compact form:

$$\frac{dx(t)}{dt} = Ax(t) + Bu(t), \quad x_{k+1} = Ax_k + Bu_k$$
$$y(t) = Cx(t) + Du(t), \quad y_k = Cx_k + Du_k.$$

The study of these linear systems has many applications in aerospace, robotics, communications, economics, power grids, and many modern engineering systems. Problems are often cast as *design* (altering inputs to achieve desired outputs) and *estimation* (processing measurements to infer states).

Prerequisites

- Exposure to Linear Algebra and Differential Equations is required (AM 147).
- Background in circuits (ECE 101), controls (ECE 154/241), signals and systems (ECE 103), or dynamics (PHYS 5/6, ECE 10) is useful but not required.

Learning Outcomes

By the end of this course, students will be able to:

1. Demonstrate knowledge of linear dynamical systems and the underlying linear algebra.
2. Understand, apply, and implement software solutions for Least Squares, Least Norm, and Nonlinear Least Squares problems.
3. Understand the Matrix Exponential and its use in analyzing dynamical systems.
4. Understand the Singular Value Decomposition (SVD) and its applications.
5. Understand the concepts of controllability and observability and their role in system analysis and design.
6. Apply linear dynamical systems to areas such as robotic control, navigation, communications, and power systems.

Tentative Lecture Schedule

Week	Topics
1	Introduction, course overview, engineering examples; review of linear algebra (1): vectors/matrices, linear functions, range and null space, linear independence, rank, orthogonality, vector spaces and subspaces
2	Review of linear algebra (2): inner products and norms, basic matrix factorizations, eigenvalues and eigenvectors, positive definiteness and quadratic forms, and block matrix manipulations
3	LU/QR factorizations; least-squares (LS)
4	Multi-objective LS; least-norm solutions of underdetermined equations; recursive estimation
5	LS fitting; LS via QR factorization; review and preparation for Midterm
6	Midterm exam; Nonlinear LS via Gauss-Newton method
7	Eigenvectors and diagonalization; symmetric matrices
8	Ellipsoids; matrix norms
9	Singular Value Decomposition (SVD) and its applications
10	Controllability and observability; state estimation
11	Additional advanced topics; course wrap-up and Final Exam

Course Resources

- Lecture notes/slides (posted on Canvas)
- Optional references:
  - *Lecture Notes for Stanford EE263* by Stephen Boyd
  - *Linear Systems Theory (2nd Edition)* by Joao Hespanha
  - *Linear Algebra and its Applications* by Gilbert Strang
  - *Introduction to Applied Linear Algebra* by Stephen Boyd and Lieven Vandenberghe

Coursework and Grading

- Homework: 30%
- Midterm (Oct 28th, in-class): 40%
- Final (take-home): 30%

Final grades will be assigned as follows: A^+ for 93–100, A for 86–92, A^- for 80–85, B^+ for 75–79, B for 70–74, C for 65–69, D for 60–64, and *Fail* for below 60. A grade of *Satisfactory (S)* is equivalent to a grade of B or better.

Software

MATLAB will be the primary software tool. Alternatives such as Octave or Python may be used, but official support is limited.

Policies

Late Policy: No late homework accepted without prior arrangement under exceptional circumstances.

Academic Integrity: Independent work is required. Collaboration is encouraged at the conceptual level, but direct copying of solutions is prohibited. Academic misconduct will result in disciplinary action.

AI Tool Usage:

- AI tools may be used to clarify concepts and improve writing.
- AI tools may not be used to generate solutions to homework or exams.
- Use of AI on midterm/final exams is strictly prohibited.

DRC Support

UC Santa Cruz is committed to supporting students with disabilities. Students requiring accommodations should contact the DRC and provide the Accommodation Authorization Letter within the first two weeks. Contact DRC: drc@ucsc.edu, (831) 459-2089.

Acknowledgments

This course builds upon the *Introduction to Linear Dynamical Systems sequence (EE263 and EE363)* offered at Stanford University. Lecture notes are adapted from the published materials of Professor Stephen Boyd (Fall 2007) and Sanjay Lall (Fall 2025). I would also like to acknowledge Professor Steve McGuire and Professor Gabe Elkaim at UCSC for generously sharing their teaching materials.