

# ASEN 5014 Linear Control Systems

## Fall 2017 Syllabus

Lecture: AERO 114 TTh, 2:30-3:45 pm  
Final Exam: No Final Exam (See Course Grading)

## Instructional Team

Instructor:  
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Office/Hours: TBD

## Text

Required: *Modern Control Theory (3rd Ed.)*, William Brogan, Prentice-Hall, 1991.

## Web Site

<https://canvas.colorado.edu/>

All class material, lecture recordings, assignments and solution sets will be distributed on the course web site.

Students are encouraged to use the Discussions thread on the course web site to ask questions and clarifications about assignments. Students should answer each other's questions when appropriate. The instructor will monitor the discussion threads daily.

## Prerequisites

APPM 2380 (Ordinary Differential Equations) or equivalent, senior or graduate standing.

## Overview

This course will present methods for the analysis and design of feedback control for linear dynamic systems. The course includes elements of Linear System Theory, State Space Control Theory, and State Space Control Design.

## Course Grading

Homework:	15%
Exam 1:	25%
Exam 2:	25%
Project:	35%

Homework: Includes theoretical proofs, analysis, and simulation. Group work is encouraged, although individual understanding will be necessary to do well on exams.

Exams: Two take-home exams will be given during the semester (roughly 1/3 and 3/4 through the semester). Exams will require the use of a computer with matrix algebra software such as Matlab. Make up exams must be arranged at least two weeks in advance.

Projects: Analysis and control of a complex linear dynamical system using all the tools and techniques described in class.

## Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the [Honor Code](#). Violations of the Honor Code may include but are not limited to: plagiarism (including use of paper writing services or technology [such as essay bots]), cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty.

All incidents of academic misconduct will be reported to Student Conduct & Conflict Resolution: [honor@colorado.edu](mailto:honor@colorado.edu), 303-492-5550. Students found responsible for violating the [Honor Code](#) will be assigned resolution outcomes from the Student Conduct & Conflict Resolution as well as be subject to academic sanctions from the faculty member. Visit [Honor Code](#) for more information on the academic integrity policy.

## Classroom Behavior

Students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote, or online. Failure to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation, or political philosophy.

For more information, see the [classroom behavior policy](#), the [Student Code of Conduct](#), and the [Office of Institutional Equity and Compliance](#).

## Requirements for Infectious Diseases

Members of the CU Boulder community and visitors to campus must follow university, department, and building health and safety requirements and all public health orders to reduce the risk of spreading infectious diseases.

The CU Boulder campus is currently mask optional. However, if masks are again required in classrooms, students who fail to adhere to masking requirements will be asked to leave class. Students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct & Conflict Resolution. Students who require accommodation because a disability prevents them from fulfilling safety measures related to infectious disease will be asked to follow the steps in the “Accommodation for Disabilities” statement on this syllabus.

For those who feel ill and think you might have COVID-19 or if you have tested positive for COVID-19, please stay home and follow the [further guidance of the Public Health Office](#). For those who have been in close contact with someone who has COVID-19 but do not have any symptoms and have not tested positive for COVID-19, you do not need to stay home.

## Accommodation for Disabilities, Temporary Medical Conditions, and Medical Isolation

[Disability Services](#) determines accommodations based on documented disabilities in the academic environment. If you qualify for accommodations because of a disability, submit your accommodation letter from Disability Services to your faculty member in a timely manner so your needs can be addressed. Contact Disability Services at 303-492-8671 or [dsinfo@colorado.edu](mailto:dsinfo@colorado.edu) for further assistance.

If you have a temporary medical condition or required medical isolation for which you require accommodation, notify the instructor and your lab group for the section you will miss. See [Temporary Medical Conditions](#) on the Disability Services website for additional information.

## Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

## Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. University policy prohibits [protected-class](#) discrimination and harassment, sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, and related retaliation by or against members of our community on- and off-campus. These behaviors harm individuals and our community. The Office of Institutional Equity and Compliance (OIEC) addresses these concerns, and individuals who believe they have been subjected to misconduct can contact OIEC at 303-492-2127 or email [cureport@colorado.edu](mailto:cureport@colorado.edu). Information about university policies, [reporting options](#), and support resources can be found on the [OIEC website](#).

Please know that faculty and graduate instructors have a responsibility to inform OIEC when they are made aware of incidents related to these policies regardless of when or where something occurred. This is to ensure that individuals impacted receive an outreach from OIEC about their options for addressing a concern and the support resources available. To learn more about reporting and support resources for a variety of issues, visit [Don't Ignore It](#).

## Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance.

See the [campus policy regarding religious observances](#) for full details.

## Mental Health and Wellness

The University of Colorado Boulder is committed to the well-being of all students. If you are struggling with personal stressors, mental health or substance use concerns that are impacting academic or daily life, please contact [Counseling and Psychiatric Services \(CAPS\)](#) located in C4C or call (303) 492-2277, 24/7.

Free and unlimited telehealth is also available through [Academic Live Care](#). The Academic Live Care site also provides information about additional wellness services on campus that are available to students.

## Course Purpose and Learning Objectives

After taking this course, you should be able to

1. Construct state space models from differential equations and transfer functions.
2. Apply the concepts of linear independence, span, subspace, dimension, and basis to a vector space.
3. Test a mapping from one vector space to another for linearity, apply a change of basis, construct the matrix of a mapping.
4. Use concepts of column space, row space, right null space and left null space to characterize solutions of linear equations. Calculate least squares approximate or minimal solutions.
5. Spectrally decompose a generic linear operator using eigenspaces. Apply this to the solution of homogeneous state space equations to determine natural modes.
6. Use a modal basis to derive the general solution to state space equations using the Cayley-Hamilton theorem.
7. Characterize the Lyapunov stability properties of state space systems, relate these to eigenvalues of the state matrix.
8. Understand the tests for complete controllability and observability, apply them to find controllable and unobservable subspaces.
9. Design observers to reconstruct internal states.
10. Design state feedback controllers to achieve prescribed closed loop poles, and understand when and why complete pole assignment is possible.
11. Use linear-quadratic optimization to design control systems.
12. Understand limitations of pole placement/optimization theory due to unmodeled dynamics.
13. Use MATLAB as an aid in solving numerical problems associated with the above concepts, simulating system responses, and computing state feedback/optimal controllers.

## **Course Outline**

## ASEN 5014 Spring 2024 Schedule

Week	Dates	Tuesday	Thursday	Reading
1	15-Jan	Introduction	State Space Models	Ch. 1-4
2	22-Jan	Model Conversion	Vector Spaces	Ch. 5.1-5.5
3	29-Jan	Dimension and Basis	Ortho-normalization	Ch. 5.6-5.8
4	5-Feb	Subspaces	Linear Mappings	Ch. 5.9-5.11
5	12-Feb	Linear Mappings	Mapping Subspaces	
6	19-Feb	Linear Equation Solutions	Least Squares Solutions	Ch. 6.1-6.9
7	26-Feb	Eigenspaces (Exam 1 assigned)	Matrix Exponential	Ch. 7
8	4-Mar	Eigen-decomposition (Exam 1 due)	Jordan and Modal Form	Ch. 9.1-9.4
9	11-Mar	Real Modal Form	Lyapunov Stability	Ch. 9.6-9.7, 9.10
10	18-Mar	BIBO Stability	Controllability	Ch. 10.1 - 10.6
11	25-Mar		Spring Break - NO CLASS	
12	1-Apr	Controllability	State Variable Feedback	Ch. 11.1-11.5, 8.4-8.5, 13.1-13.4
13	8-Apr	Observability	Observer Design (Exam 2 assigned)	Ch. 11.7, 12.1-12.5, 13.6
14	15-Apr	State Variable Control Design	State Variable Control Design (Exam 2 due)	Ch. 13.7 - 13.8
15	22-Apr	Disturbance Rejection	Optimal Control	Ch. 14.1-14.3, 14.7
16	29-Apr	Robustness	Various Topics	

**Exam 1 material**

**Exam 2 material**

**NO FINAL EXAM**