PURDUE UNIVERSITY®

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Course Information

- **ECE602, Lumped Linear Systems (Online Section)**
- **Term:** Spring 2024
- **Instructional Modality:**
  - Asynchronous online; no required in-person meetings. All course materials, including recorded lectures, are available in the Brightspace course.
- **Course credit hours:** 3
- **Prerequisites (if any)**:
  - It is expected that you are familiar with the Laplace transform and ordinary differential equations. Knowledge of undergraduate feedback control is not strictly needed for most topics, but will definitely increase your appreciation of some of the topics covered in this course.
  - Knowledge of linear algebra is **needed.** Although officially Purdue's MATH 511 is listed as a co-prerequisite of this course, in practice, students who took MATH 511 and this course in the same semester often found it challenging as the pace of the two courses may not be fully synchronized. Some references that can help you freshen up on linear algebra include:
    - *Linear Algebra and Its Applications*, 4th ed., G. Strang, 2006.
    - *Introduction to Linear Algebra*, 4th ed., G. Strang, Wellesley-Cambridge Press, 2009.

Instructor and TA Contact Information

- **Instructor:** Jianghai Hu, jianghai@purdue.edu
  - **Office hours:** Monday 4-5pm EST, to be held virtually at https://purdue.webex.com/meet/jianghai
- **TA:** Junyi Chai, chai28@purdue.edu
  - **Office hours:** Thursday 1:30-2:30pm EST, to be held virtually at https://purdue-edu.zoom.us/j/6696395358
- Office hours may change in the semester. For in-person meetings, email for appointments.

Online Discussion Forum

A Piazza forum for this course has been set up at https://piazza.com/purdue/spring2024/ece60200epeonline. You are highly encouraged to post questions and start discussions on anything related to the course on the forum. If you prefer, your posts can be anonymous or private to the instructor only. The instructor will try to respond to your questions timely. Other students are also welcome to chime in for the help.
Note that there is a separate Piazza forum for the on-campus section of ECE 602. Please **do not use the on-campus section's forum** as the contents of the two sections are different.

Course Description

This course introduces the fundamentals of modern control theory for linear dynamical systems. The course adopts the state-space method that builds upon the classical transfer function methods covered in undergraduate feedback control courses. The state-space framework is used in modeling and controller design for systems arising in many engineering and non-engineering disciplines.

Audience

This course is designed for students from Electrical Engineering, Mechanical Engineering, Aeronautical and Astronautical Engineering, Civil Engineering, and Biomedical Engineering…to name a few.

Learning Resources, Technology & Texts

Textbook

No required textbooks for this course. The lectures are mostly based on instructor's own notes. However, the following may be useful references:

- C.-T. Chen, "Linear System Theory and Design," Oxford University Press, Fourth edition, 2013
- S. H. Zak, "**Systems and Control**," Oxford University Press, 2003
- P. J. Antsaklis and A. N. Michel, "**A Linear Systems Primer**," Birkhauser Boston, 2007
- T. Kailath, "Linear Systems," Prentice Hall, 1980
- W. J. Rugh, "Linear System Theory," Pearson, Second edition, 1995

Linked titles above are available online through the Purdue Libraries.

Required Computational Tools

You will need access to **MATLAB®** for this course. You can access MATLAB through the Purdue University MATLAB Portal.

Learning Outcomes

After completing this course, you will be able to:

- Construct models for dynamical systems arising in various applications, such as: mechanical, electrical, pneumatic, hydraulic, economic, and biological systems
- Recognize various properties of given linear systems, such as: stability, controllability, observability, stabilizability, and detectability
- Design controllers so that a system satisfies given performance specifications
- Test and validate the controller design using simulation tools, such as MATLAB and Simulink

Assignments

Assessment Type	Description	% of Final Grade
FunWork	We're sure that these assignments will be a source of fun for you – thus, we have named them "FunWork" instead of your everyday, basic "homework." FunWork is assigned roughly biweekly and may involve MATLAB programming.	30%
Midterm Exam 1 & Midterm Exam 2	Each midterm exam will test your understanding of the course material. The midterms will be available to online access for 48 hours (see the schedule below), but you will only have 1.5 hours to complete the exam once you have started.	40% (20% each)
Final Exam	The final exam will be comprehensive. The final exam will be available to online access for 72 hours (see the schedule below), but you will only have 2.5 hours to complete the final exam once you have started.	30%

Note: The exams will be conducted via Examity, an online exam proctoring platform. More details will be announced prior to the first exam (Midterm 1).

Grading Scale

Final grades will be awarded as follows. Note that these only serve as a rough guideline and could be revised subject to the instructor's perceived level of performance of the whole class.

95% - 100%	A+
85% - 95%	A
81% - 85%	A-
77% - 81%	B+
70% - 77%	B
66% - 70%	B-
62% - 66%	C+

62% - 66%	C+
57% - 62%	C
53% - 57%	C-
48% - 53%	D+
45% - 48%	D
40% - 45%	D-
<40%	F

Course Schedule

Weeks	Module	Assignments and Exams
Weeks 1 & 2 January 8-21	Welcome and Introduction 1. Systems 2. State Variables 3. State-Space Models 4. State-Space Models vs. Transfer Functions	**FunWork 1** • Due Date: Sunday, January 21 at 11:59 PM ET (1/22 at 04:59 UTC)
Weeks 3 & 4 January 22-February 4	5. Linear Algebra Review 6. Functions of Square Matrices 7. Matrix Exponential 8. Solutions of Continuous-Time Autonomous LTI Systems	**FunWork 2** • Due Date: Sunday, February 4 at 11:59 PM ET (2/5 at 04:59 UTC)
Weeks 5 & 6 February 5-18	9. Solutions of Discrete-Time Autonomous LTI Systems 10. Solutions of Autonomous LTV Systems 11. Stability of Continuous-Time Linear Systems 12. Stability of Discrete-Time Linear Systems	**FunWork 3** • Due Date: Sunday, February 18 at 11:59 PM ET (2/19 at 04:59 UTC)
Weeks 7 & 8 February 19-March 3	13. Stability of Nonlinear Systems Around Equilibrium Points 14. Solutions of Controlled Continuous-Time LTI Systems 15. Solutions of Controlled Discrete-Time LTI Systems	**Midterm 1** • Exam Opens: Friday, February 23 at 08:00 AM ET (13:00 UTC) • Exam Due Date: Sunday, February 25 at 07:59 AM ET (12:59 UTC)
Weeks 9 & 10 March 4-24 **Note that due to Spring Break (3/11-15), Weeks 9 & 10 span 3 calendar weeks.**	16. Solving Continuous-Time Dynamical Systems Numerically 17. Quadratic Forms 18. Lyapunov Stability Theory 19. Reachability and Controllability of Discrete-Time LTI Systems	**FunWork 4** • Due Date: Sunday, March 10 at 11:59 PM ET (3/11 at 03:59 UTC)

Weeks	Module	Assignments and Exams
Weeks 11 & 12 March 25-April 7	20. Controllability of Continuous-Time LTI Systems 21. Separating the Controllable Part from the Uncontrollable Part of a Given System 22. Observability of Continuous-Time LTI Systems 23. State-Space Realizations of Transfer Functions	**FunWork 5** • Due Date: Sunday, March 31 at 11:59 PM ET (4/1 at 03:59 UTC) **Midterm 2** • Exam Opens: Friday, April 5 at 08:00 AM ET (12:00 UTC) • Exam Due: Sunday, April 7 at 07:59 AM ET (11:59 UTC)
Weeks 13 & 14 April 8-21	24. Bounded-Input Bounded-Output (BIBO) Stability 25. Canonical Forms of Single-Input-Single-Output (SISO) Systems 26. State Feedback Control	**FunWork 6** • Due Date: Sunday, April 14 at 11:59 PM ET (4/17 at 03:59 UTC)
Week 15 April 22-28	27. State Observer Design 28. Observer-Based Feedback Controller 29. Linear Quadratic Regulation (LQR) Problems (additional module for your knowledge, but material not covered on Final Exam)	**FunWork 7** • Due Date: Sunday, April 28 at 11:59 PM ET (4/30 at 03:59 UTC)
Final Exam Week April 29-May 4		**Final Exam** • Exam Opens: Monday, April 29 at 8 AM ET (12:00 UTC) • Exam Due Date: Thursday, May 2 7:59 AM ET (11:59 UTC)

Attendance Policy

When conflicts or absences can be anticipated, such as for many University-sponsored activities and religious observations, the student should inform the instructor of the situation as far in advance as possible. For unanticipated or emergency absences when advance notification to the instructor is not possible, the student should contact the instructor as soon as possible by email or phone. When the student is unable to make direct contact with the instructor and is unable to leave word with the instructor's department because of circumstances beyond the student's control, and in cases falling under excused absence regulations, the student or the student's representative should contact or go to the Office of the Dean of Students (ODOS) website to complete appropriate forms for instructor notification. Under academic regulations, excused absences may be granted by ODOS for cases of grief/bereavement, military service, jury duty, parenting leave, or emergent or urgent care medical care.

Academic Integrity

Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing integrity@purdue.edu or by calling 765-494-8778. While information may be submitted anonymously, the more information is submitted the greater the opportunity for the university to investigate the concern. More details are available on our course Brightspace under University Policies.

Nondiscrimination Statement

Purdue University is committed to maintaining a community that recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. A hyperlink to Purdue's full Nondiscrimination Policy Statement is included in our course Brightspace under University Policies.

Accessibility

Purdue University strives to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247.

Mental Health/Wellness Statement

If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try WellTrack**.** Sign in and find information and tools at your fingertips, available to you at any time.

If you need support and information about options and resources, please contact or see the Office of the Dean of Students. Call 765-494-1747. Hours of operation are M-F, 8 am- 5 pm.

If you find yourself struggling to find a healthy balance between academics, social life, stress, etc., sign up for free one-on-one virtual or in-person sessions with a Purdue Wellness Coach at RecWell. Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is free and can be done on BoilerConnect.

If you're struggling and need mental health services: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office on the second floor of the Purdue University Student Health Center (PUSH) during business hours. The CAPS website also offers resources specific to situations such as COVID-19.

Additional Wellness Resources

TaskHuman offers private, real-time, on-demand, 1-on-1 video calls with wellness coaches covering over 800+ topics such as anxiety, mindfulness, reducing stress, clean eating, time management, in- home workouts, relationship tensions, financial issues, spiritual guidance and many more. You can access these wellness coaches from around the world 24/7. The College of Engineering has an exclusive agreement with TaskHuman which gives you **FREE and UNLIMITED** access to these resources. Over 3,200 calls have been made by College of Engineering people so far with an average satisfaction rating of 4.89/5.

Learn more here: https://engineering.purdue.edu/ECE/TaskHuman.

DOWNLOAD TASKHUMAN:

1. Scan the QR Code to download the TaskHuman App or download the TaskHumanApp directly from the App Store or Google Play Store.
2. Create an account.
3. Go to Setting and tap on "Check for Discounts."
4. Insert your code: purdue63

Basic Needs Security

Any student who faces challenges securing their food or housing and believes this may affect their performance in the course is urged to contact the Dean of Students for support. There is no appointment needed and Student Support Services is available to serve students 8 a.m.-5 p.m. Monday through Friday. Considering the significant disruptions caused by the current global crisis as it relates to COVID-19, students may submit requests for emergency assistance from the Critical Need Fund.

Emergency Preparation

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructors or TAs via email or phone. You are expected to read your @purdue.edu email on a frequent basis.