# UCONN
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## Course and Instructor Information

**Course Title: Special Topics in Mechanical Engineering / Special Topics in Electrical and Systems Engineering**
**Topic: Nonlinear Systems**
**Credits:  3**
**Mode/Format: In person**
**Location: EII 321**
**Time: 11:00 AM – 12:15 PM Tuesday and Thursday, 2024/8/26 - 2024/12/6**
**Prerequisites:** No prerequisites. In particular, ME 3253 Linear Systems Theory is NOT a pre-requisite.

**Professor/Instructor/Facilitator: Chang Liu**
**Pronouns: he/him/his**
**Email: chang_liu@uconn.edu**
**Telephone: (410) 369-6999**
**Office Hours/Availability: TBD in consultation with students**

## Course Materials

**Required textbook:**

Khalil H.K. Nonlinear Systems, Third Edition, Prentice Hall, 2002, ISBN 0-13-067389-7

Please also check the errata for this textbook in the link
https://www.egr.msu.edu/~khalil/NonlinearSystems/

**Required software**: MATLAB. Please follow the instructions on https://software.uconn.edu/software/matlab/ to install.

## Course Description

Nonlinear systems analysis techniques: linearization, bifurcation, nonlinear stability, feedback systems and harmonic balance method. Numerical software for bifurcation analysis and nonlinear stability analysis will also be introduced. Application examples in fluid dynamics will be discussed.

## Course Objectives

Objective 1: By the end of this course, students will be able to theoretically analyze nonlinear systems by characterizing the associated nonlinear solutions and stability. Objective 2: Be able to use numerical software for nonlinear system analysis and apply the numerical software to practical research questions.

## Course Requirements and Grading

**Summary of Course Grading:**

| Course Components | Weight |
|---|---|
| Homework | 50% |
| Project | 50% |

**Homework (50%)**
Homework will mainly contain theoretical questions to test Objective 1 and a small amount of coding questions to test Objective 2. For undergraduate students, one homework with the lowest grade will be automatically dropped and the grade will be averaged based on other homework. For graduate students, grades will be averaged on all homework.

**Course project (50%)**
The course project will mainly test both Objective 1 in theoretical analysis and Objective 2 in applying numerical software to practical research questions. One project proposal (10%) is due in the middle of the semester. The last class will be a final presentation (20%) and the final report (20%) will be due one week after the last class. A list of

suggested projects with references will be provided. All students are welcome to design a project based on existing research projects in a research Lab but need to distinguish the work done within this course project from prior research results in a research Lab. All students will be graded in the same rubric, but undergraduate's course project grades will be curved as $New = 10\sqrt{Old}$.

**Grading Scale:**

| Grade | Letter Grade | GPA |
|---|---|---|
| 93-100 | A | 4.0 |
| 90-92 | A- | 3.7 |
| 87-89 | B+ | 3.3 |
| 83-86 | B | 3.0 |
| 80-82 | B- | 2.7 |
| 77-79 | C+ | 2.3 |
| 73-76 | C | 2.0 |
| 70-72 | C- | 1.7 |
| 67-69 | D+ | 1.3 |
| 63-66 | D | 1.0 |
| 60-62 | D- | 0.7 |
| <60 | F | 0.0 |

**Due Dates and Late Policy**: All course due dates are identified in the course schedule. Deadlines are based on Eastern Time unless otherwise specified. The instructor reserves the right to change dates accordingly as the semester progresses.  All changes will be communicated appropriately. Please feel free to contact me if you need an extension on homework and I will try to accommodate your request. Usually, the due date will be extended for all students if more than one student request an extension. If you do not contact me in advance, expect your grade to be lowered due to lateness (reduced by 25%). HW grade submitted after one week of the due date will be lowered by 50%.

**Weekly Time Commitment:** 6 hours outside of the classroom.

## Course Outline
The tentative outline of the class is below, and they are subject to change based on the progress.

| Dates | Sections in the textbook (Khalil) | Course content |
|---|---|---|
| Week 1 | Chapter 1, Sections 2.1-2.5 | Introduction and linearization |
| Week 2 | Sections 2.6-2.7 and others | Bifurcation analysis |
| Week 3 | https://www.staff.uni-oldenburg.de/hannes.uecker/pde2path/ | Numerical software pde2path for bifurcation and stability analysis |
| Week 4 | Sections 4.1-4.4 | Nonlinear stability I: Lyapunov method |
| Week 5 | Sections 8.1-8.3 | Nonlinear stability II: Region of attraction |
| Week 6 | https://yalmip.github.io/ https://www.cds.caltech.edu/sostools/ | Numerical software YALMIP and SOSTOOLS for finding the Lyapunov function |
| Week 7 Proposal due | Sections 4.8-4.9, Chapter 5 | Feedback systems I: input-output analysis |
| Week 8 | Chapter 6 | Feedback systems II: Passivity |
| Week 9 | Section 7.1 | Feedback systems III: Absolute stability |
| Week 10 | https://doi.org/10.1103/PhysRevE.102.063108 https://doi.org/10.1017/jfm.2021.762 | Application in fluid dynamics I: transition to turbulence in wall-bounded shear flows |
| Week 11 | Section 7.2 | Harmonic balance method |
| Week 12 | https://doi.org/10.3390/fluids7120373 https://doi.org/10.1017/jfm.2022.865 | Application in fluid dynamics II: reduced-order modeling of convection |
| Week 13 | Sections 4.5-4.6 and others | Non-autonomous systems or data-driven modeling (TBD) |
| Week 14 | Final presentation TBD | Final presentation TBD |

## Calendar and/or Class Meeting Schedule
11:00 AM – 12:15 PM Tuesday and Thursday at EII 321, 2024/8/26 - 2024/12/6

## AI Policy
You are welcome to use AI writing tools such as ChatGPT on most assignments (I'll alert you when you can't) but whenever you use them, you must include an acknowledgement statement that briefly shares that and how you used them. For example, "I used ChatGPT when I was struck at the start and retained substantial parts of what it produced, including X and Y ideas and most of the wording in paragraphs 3 and 4" or "After I wrote my first 2 paragraphs, I used

GPT-3 playground to extend the text for another 200 words but then edited…" Please also note that all large language models still tend to make up incorrect facts and fake citations. You will be responsible for any inaccurate, biased, offensive, or otherwise unethical content you submit, regardless of whether it originally comes from you or an AI tool.

## Evaluation of Course Experience

Students will be given an opportunity to provide feedback on their course experience and instruction using the University's standard procedures, which are administered by the Office of Institutional Research and Effectiveness (OIRE). The University of Connecticut is dedicated to supporting and enhancing teaching effectiveness and student learning using a variety of methods. The Student Evaluation of Teaching (SET) is just one tool used to help faculty enhance their teaching. The SET is used for both formative (self-improvement) and summative (evaluation) purposes. Additional informal formative surveys and other feedback instruments may be administered within the course.

## Academic Integrity

Cheating of any kind on examinations and/or plagiarism of homework is strictly prohibited. Students may work together on homework but submitted work should be your own. Any student work that is found to be in violation of the university policy regarding academic misconduct will be assigned a grade of zero. Read and understand The UConn Student Code of Conduct Academic, Scholarly, and Professional Integrity and Misconduct Policy..

## How to Succeed in this Course

All students can succeed in this course and we are here to help you along the way.  Please do not hesitate to ask questions or attend office hours.  All questions are important here.  Success in this course program depends heavily on your personal health and well-being.  Recognize that stress is an expected part of the college experience, and it often can be compounded by unexpected setbacks or life changes outside the classroom. Your teaching assistants and I strongly encourage you to reframe challenges as an unavoidable pathway to success. Reflect on your role in taking care of yourself throughout the semester, before the demands of exams and projects reach their peak.  Please feel free to reach out to me about any difficulty you may be having that may impact your performance in your courses or campus life as soon as it occurs and before it becomes too overwhelming.  In addition to your academic advisor, I strongly encourage you to contact the many other support services on campus that stand ready to assist you.

## Accommodations for Illness or Extended Absences

Please stay home if you are feeling ill and please go home if you are in class and start to feel ill.  If illness prevents you from attending class, it is your responsibility to notify me as soon as possible. You do not need to disclose the nature of your illness, however, you will need to work with me to determine how you will complete coursework during your absence. If life circumstances are affecting your ability to focus on courses and your UConn experience, students can email the Dean of Students at dos@uconn.edu to request support.  Regional campus students should email the Student Services staff at their home campus to request support and faculty notification.

## Students with Disabilities

The University of Connecticut is committed to protecting the rights of individuals with disabilities and assuring that the learning environment is accessible.  Students who require accommodations should contact the Center for Students with Disabilities, Wilbur Cross Building Room 204, (860) 486-2020 or http://csd.uconn.edu/.

## Resources for Students Experiencing Distress

The University of Connecticut is committed to supporting students in their mental health, their psychological and social well-being, and their connection to their academic experience and overall wellness. The University believes that academic, personal, and professional development can flourish only when each member of our community is assured equitable access to mental health services. The University aims to make access to mental health attainable while fostering a community reflecting equity and diversity and understands that good mental health may lead to personal and professional growth, greater self-awareness, increased social engagement, enhanced academic success, and campus and community involvement.

Students who feel they may benefit from speaking with a mental health professional can find support and resources through the **Student Health and Wellness-Mental Health** (SHaW-MH) office. Through SHaW-MH, students can make an appointment with a mental health professional and engage in confidential conversations or seek recommendations or referrals for any mental health or psychological concern.

Mental health services are included as part of the university's student health insurance plan and also partially funded through university fees. If you do not have UConn's student health insurance plan, most major insurance plans are also accepted. Students can visit the **Student Health and Wellness-Mental Health located in Storrs on the main campus in the Arjona Building, 4th Floor,** or contact the office at **(860) 486-4705, or https://studenthealth.uconn.edu/** for services or questions**.**