Math 415: Applied Dynamical Systems, Chaos, and Modeling FA23

General Course Information

Generic Math 415 Course Description

An introduction to nonlinear dynamical systems including stability, bifurcations and chaos. The course will give underlying mathematical ideas but emphasize applications from many scientific fields.

Prerequisites: MATH 376, (MATH 234 and 319), (MATH 234 and 320), (MATH 234 and 340), (MATH 234 and 341) or (MATH 234 and 375) or graduate or professional standing or member of the Pre-Masters Mathematics (Visiting International) program.

Course website: https://canvas.wisc.edu/courses/363934

Course Designations and Attributes

Breadth – Natural Science
Level – Advanced
L&S Credit – Counts as Liberal Arts and Science credit in L&S

Credit Hours

This *3-credit class* meets for *three 50-minute class periods* each week over the fall semester and carries the expectation that students will work on course learning activities (reading, writing, problem sets, studying, etc.) for about *2 hours* out of the classroom *for every class period*. This syllabus includes additional information about meeting times and expectations for student work.

Instructor

Dr Thomas Chandler (he/him), tgchandler@wisc.edu, https://people.math.wisc.edu/~tgchandler/

Availability: The instructor will be available at the following times/places:

- Office Hours: T 12:30pm – 2:00pm (virtual, zoom), F 1:00pm – 2:00pm (in-person, Math Learning Center at Table 1, access from B224 or B1-level in Van Vleck).
- Extra (in-person or virtual) instructor office hours can be arranged on request. Please contact the instructor via Canvas or email to arrange.
- Contributing to Q&A on Piazza, predominantly on Monday and Wednesday evenings.

Class Instructional Mode, Time, and Location

Class	Date & Time	Location
415-001	MWF 9:55am – 10:45am	Social Sciences 6240 (in person)

There will be a total of 42 classes with no classes during thanksgiving recess (11/23 – 11/26).

Other Course Information

Required Textbook, Software, & Other Course Materials

Required Textbook: This course will follow the second edition of *Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering* by Steven Strogatz.

Software: MATLAB (MATrix LABoratory) will be used by the instructor for several demonstrations. UW students have institutional access to MATLAB, see https://software.wisc.edu/cgi-bin/ssl/csl.cgi (UW login required). Learning and using MATLAB is highly recommended, but is not required for this course; however, assessed homework may require reading, understanding, and writing algorithms in MATLAB-like syntax. Alternatives to MATLAB (e.g. Python and Mathematica) may also be useful to students.

Other: Handwritten class notes, as well as homework and midterm solutions, will be posted on Canvas.

Course Website, Learning Management System & Digital Instructional Tools

- All course material, homework, announcements, and grades will be uploaded onto Canvas (https://canvas.wisc.edu/courses/363934).
- All virtual contact (e.g. virtual office hours) shall be on Zoom. A link can be found on the Canvas website (https://canvas.wisc.edu/courses/363934/external_tools/14065).
- Questions of general interest related to the course should be posted and discussed on the course Piazza site (https://piazza.com/wisc/fall2023/fa23math415001) or brought to the office hours. The course instructor will be regularly contributing to posts on Piazza.
- All other questions should be sent to the instructor directly via email.

Examination

There will be three (in-person) exams for this course: two midterms and a final exam. These exams shall be closed book and no communication with anyone (in or out of the class) is allowed during the exams. All the exams are cumulative with no make-up exams. Further information about each exam will be given closer to the time. *By signing up to this course, you are agreeing to take the exams at the following (Madison, WI) times:*

Exam	Date & Time	Location
Midterm 1 Exam	4th October, Evening Exam	To be announced
Midterm 2 Exam	1st November, Evening Exam	To be announced
Final Exam	21st December 2:45 PM – 4:45 PM	To be announced

Please inform the instructor of any problems sitting these exams as soon as possible.

Exam Proctoring: Exam proctoring will be required for this course. Failure to use the proctoring service assigned will results in a zero on the exam. Further details will be given before each exam.

Grading

This course will be assessed via weekly problem sheets (cumulative, with the two lowest scores being dropped), one in-person midterm exam, and a final in-person exam. The scales given below may be decreased (but never increased) to allow for grade curving.

Weighting: 35% Homework Assignments, 15% Midterm 1, 15% Midterm 2, 35% Final Exam

Tentative Grading Scales: 0-59 F, 60-69 D, 70-78 C, 79-81 BC, 82-88 B, 89-91 AB, 92-100 A

Assessed Homework: Problem Sheets

A weekly problem sheet will be posted on Canvas focused on the content presented in the corresponding week's classes. Each sheet will require students to read pages out of the textbook and answer relevant mathematical questions. Students are encouraged to discuss the problems with classmates; however, the final write-up should be individual. Both mathematical accuracy and clarity of argument will be assessed and count towards the final grade (see grading above). The problem sheet grades are cumulative, but the two lowest scores will be dropped. Solutions to the problem sheets should be neatly written-up, or typed-up in *e.g.* LaTeX, and submitted on Canvas as a pdf before the posted deadline. *Tentatively, the problem sheets shall be due Friday by 11:59pm*. *A grace period of 6 hours shall be given for submission, however any submissions during this period (without prior permission) will be docked 10%.* Submissions after the grace period will not be accepted. The instructor should be informed of any problems with completing the assessed homework.

Non-Assessed Homework: Further Work and Practice Exam Questions

On top of the assessed homework, further work may be posted on Canvas and handed out in class but will not be collected or graded; this will include practice exam questions. This work is intended to help consolidate your knowledge and prepare for the exams. Feel free to post any questions about the non-assessed portion of the course on Piazza or bring them to the office hours.

Generic Course Learning Outcomes

By the end of the course, students should be able to:

- Understand how to use one-dimensional maps and difference equations and apply them to linear and nonlinear problems.
- Make graphical solutions, study bifurcations, and predict the onset of chaos.
- Study the dynamics of first-order differential equations (one-dimensional flows), including linear and nonlinear equations, their graphical solutions, and the presence of bifurcations.
- Study the dynamics of two-dimensional flows: draw a phase plane portrait, determine stability of fixed points, show the existence of periodic solutions and limit cycles.
- Use tools for studying global behavior of flows including Lyapunov functions, Poincare–Bendixson Theorem, and gradient flows.
- Examine the behavior of three-dimensional flows, including their Lyapunov exponents, make a Poincare section, and understand the behavior of strange attractors and chaos.

Course Outline

Tentative Semester Schedule: The course will follow *Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering* by Steven Strogatz. The material will not be understood upon a first read but should be studied in multiple iterations. The course will follow the tentative schedule:

Part 1: One-Dimensional Flows	
Week 1	Course Introduction; Chapter 1: Overview
Week 2	Chapter 2: Flows on the line
Week 3	Chapter 3: Bifurcations
Week 4	Chapter 3: Bifurcations
Part 2: Two-Dimensional Flows	
Week 5	Midterm (10/04); Chapter 5: Linear systems
Week 6	Chapter 5: Linear systems
Week 7	Chapter 6: Phase Plane
Week 8	Chapter 6: Phase Plane
Week 9	Chapter 7: Limit Cycles
Week 10	Chapter 7: Limit Cycles; Midterm (11/01);
Part 3: Chaos	
Week 11	Chapter 9: Lorenz Equations
Week 12	Chapter 9: Lorenz Equations
Thanksgiving Recess	
Week 13	Chapter 10: One-Dimensional Maps
Week 14	Chapter 10: One-Dimensional Maps
Week 15	Chapter 11: Fractals; Review Class
Finals Week	
Final	21 December 2:45 PM – 4:45 PM, location to be announced.

Typical Week Schedule: A typical week will follow the following timetable:

Monday	Tuesday	Wednesday	Thursday	Friday
Class	Office Hours (V)	Class		Class; Homework; Office Hours

How to Succeed in this Course

Students should attend all classes. Contribution to the office hours and discussion boards are also highly recommended. The classes are informal instructional lectures ran by the instructor, any interruption for questions or observations are welcomed and highly recommended — there are no 'silly' questions in this course! The class will often have informal discussions. During these discussions, we shall work together through group activities to help develop the students understanding of the course content, as well as to

hone our modeling skills; participation in discussions is expected. The office hours are for any questions (either about the course or the bigger picture) but are also a chance to just say 'hi' and chat with fellow mathematicians. You do not have to have a specific question to come to the office hours but can instead just come to listen. Finally, any course related questions should be sent to the instructor via email at tgchandler@wisc.edu.

The following campus services might also be useful:

- University Health Services
- Undergraduate Academic Advising and Career Services
- Office of the Registrar
- Office of Student Financial Aid
- Dean of Students Office
- Enrollment, Scheduling, & Placement Help

Course Evaluation

Students will be provided with an opportunity to evaluate this course and your learning experience. Student participation is an integral component of this course, and your confidential feedback is important. I strongly encourage you to participate in the course evaluation.

Privacy of Student Records & the Use of Audio Recorded Lectures Statement

Lecture materials and recordings for this course are protected intellectual property at UW-Madison. Students in this course may use the materials and recordings for their personal use related to participation in this class. Students may also take notes solely for their personal use. If a lecture is not already recorded, you are not authorized to record my lectures without my permission unless you are considered by the university to be a qualified student with a disability requiring accommodation. [Regent Policy Document 4-1] Students may not copy or have lecture materials and recordings outside of class, including posting on internet sites or selling to commercial entities. Students are also prohibited from providing or selling their personal notes to anyone else or being paid for taking notes by any person or commercial firm without the instructor's express written permission. Unauthorized use of these copyrighted lecture materials and recordings constitutes copyright infringement and may be addressed under the university's policies, UWS Chapters 14 and 17, governing student academic and non-academic misconduct.

Students' Rules, Rights & Responsibilities

To see the Undergraduate Guide's Rules, Rights, and Responsibilities information, please refer to https://guide.wisc.edu/undergraduate/#rulesrightsandresponsibilitiestext

Diversity & Inclusion Statement

Diversity is a source of strength, creativity, and innovation for UW-Madison. We value the contributions of each person and respect the profound ways their identity, culture, background, experience, status, abilities, and opinion enrich the university community. We commit ourselves to the pursuit of excellence in teaching, research, outreach, and diversity as inextricably linked goals. The University of Wisconsin-Madison fulfills its public mission by creating a welcoming and inclusive community for people from every background – people who as students, faculty, and staff serve Wisconsin and the world.

Academic Integrity Statement

By virtue of enrollment, each student agrees to uphold the high academic standards of the University of Wisconsin-Madison; academic misconduct is behavior that negatively impacts the integrity of the institution. Cheating, fabrication, plagiarism, unauthorized collaboration, and helping others commit these previously listed acts are examples of misconduct which may result in disciplinary action. Examples of disciplinary action include, but is not limited to, failure on the assignment/course, written reprimand, disciplinary probation, suspension, or expulsion.

Accommodations for Students with Disabilities Statement

The University of Wisconsin-Madison supports the right of all enrolled students to a full and equal educational opportunity. The Americans with Disabilities Act (ADA), Wisconsin State Statute (36.12), and UW-Madison policy (UW-855) require the university to provide reasonable accommodations to students with disabilities to access and participate in its academic programs and educational services. Faculty and students share responsibility in the accommodation process. Students are expected to inform faculty [me] of their need for instructional accommodations during the beginning of the semester, or as soon as possible after being approved for accommodations. Faculty [I], will work either directly with the student [you] or in coordination with the McBurney Center to provide reasonable instructional and course-related accommodations. Disability information, including instructional accommodations as part of a student's educational record, is confidential and protected under FERPA. (See: McBurney Disability Resource Center.)

Academic Calendar & Religious Observances

The 2023–2024 academic calendar and religious observances can be found at https://secfac.wisc.edu/academic-calendar/ Pursuant to university policy UW-880 (https://policy.wisc.edu/library/UW-880), students are required to inform their instructors during the first two weeks of class about any religious conflicts with quizzes and exams taking place during the semester. Students who will miss quizzes and/or exams during the semester because of religious holidays/observances must email the instructor, Dr Thomas G J Chandler, at tgchandler@wisc.edu to inform of possible conflicts. He will work with the individual student to find suitable alternatives that adhere to university and departmental guidelines. Note that if a conflict is not raised during the initial two-week period, then we cannot guarantee that suitable accommodations will be provided. Because of this, it is vital that students with religious conflicts contact their instructors in a timely manner during the first two weeks of class.