Syllabus

Applied Mathematics & Statistics 553.391
Dynamical Systems
Fall, 2021
(4 credits, EQ)

Description
Mathematical concepts and methods for describing and analyzing linear and nonlinear systems that evolve over time. Topics include boundedness, stability of fixed points and attractors, feedback, optimality, Lyapunov functions, bifurcation, chaos, fractals and catastrophes. Examples drawn from population growth, economic behavior, physical and engineering systems. The main mathematical tools are linear algebra and basic differential equations.

Prerequisites
Linear Algebra (EN.553.291, AS.110.201, AS.110.212, or equivalent)
Calculus 3 (AS.110.202, AS.110.211, or equivalent)

Instructor
Professor Gregory Eyink, eyink@jhu.edu, http://www.ams.jhu.edu/~eyink
Office: Wyman Park N449, 410-516-7201
Office hours: Thu 4-6pm and by appointment, at https://wse.zoom.us/j/7633492271

Teaching Assistant
Lowen Peng, lpeng22@jhu.edu
Office: Wyman Park N430
Office hours: Thur 2:30-4:30pm, in office or https://jhubluejays.zoom.us/j/91517753787

Meetings
Section: Thu, 12:00-12:50 pm, Krieger 302, https://jhubluejays.zoom.us/j/99946370931

Textbook
Required: Stephen H. Strogatz Nonlinear Dynamics and Chaos, 2nd Ed., CRC Press (2018). See Strogatz’ website [here]. We will cover the following chapters in more or less detail, and supplemented with some additional material:

- Chapter 1: Overview
- Chapter 3: Bifurcations
- Chapter 5: Linear Systems
- Chapter 7: Limit Cycles
- Chapter 9: Lorenz Equations
- Chapter 12: Strange Attractors
- Chapter 2: Flows on the Line
- Chapter 4: Flows on the Circle
- Chapter 6: Phase Plane
- Chapter 8: Bifurcations Revisited
- Chapter 11: Fractals
- Infinite-Dimensional Dynamics
Online Resources
Please point your browser to [http://www.ams.jhu.edu/~eyink/Dynamics](http://www.ams.jhu.edu/~eyink/Dynamics) for all assignments, solutions, and lecture handouts. Occasionally, the website will also be used to provide reminders and additional information. (Typically this info will also be transmitted to the class via email.) Please check the website frequently for updates.

*Piazza*: This term we will be using Piazza for class discussion. The system is highly catered to getting you help fast and efficiently from classmates, the TA, and myself. Rather than emailing questions to the teaching staff, I encourage you to post your questions on Piazza. If you have any problems or feedback for the developers, email team@piazza.com.

Find our class signup link at: [https://piazza.com/jhu/fall2021/553391](https://piazza.com/jhu/fall2021/553391)

*Blackboard*: We shall not use Blackboard a great deal, but Panopto recordings of all lectures will be available there for asynchronous viewing. Go to [https://blackboard.jhu.edu/webapps/blackboard](https://blackboard.jhu.edu/webapps/blackboard).

Course Objectives

1. Learn the basic mathematics of the qualitative theory of ordinary differential equations
2. Learn how to analyze solutions of differential equations using geometric and numerical methods
3. Learn how to apply dynamical systems methods to problems arising in diverse areas of mathematics, science and engineering

Course Topics

- geometric view of ODE’s
- bifurcations, catastrophes
- linearization, saddles, nodes, spirals
- stability, instability, Lyapunov functions
- periodic, quasi-periodic, and ergodic motions
- numerical solution of ODE’s
- phase plane analysis, index theory
- limit cycles, Hopf bifurcation, Poincaré-Bendixson theorem
- attractors, chaos, Lyapunov exponents
- fractals, strange attractors

Course Expectations & Grading

*Grading*: S/U grading is the default, but students can opt for standard letter grading by request to the instructor. The student’s final grade will be based upon homework and exams. The breakdown will be:

<table>
<thead>
<tr>
<th>Item</th>
<th>Percent of Grade</th>
</tr>
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<tbody>
<tr>
<td>Homework</td>
<td>50%</td>
</tr>
<tr>
<td>Midterm Exam</td>
<td>25%</td>
</tr>
<tr>
<td>Term Paper</td>
<td>25%</td>
</tr>
</tbody>
</table>

Throughout the semester the following grading rule will be used:

<table>
<thead>
<tr>
<th>Letter Grade</th>
<th>Percent of Total</th>
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</thead>
<tbody>
<tr>
<td>A-/A/A+</td>
<td>90-100%</td>
</tr>
<tr>
<td>B-/B/B+</td>
<td>80-89%</td>
</tr>
<tr>
<td>C-/C/C+</td>
<td>70-79%</td>
</tr>
<tr>
<td>D-/D/D+</td>
<td>60-69%</td>
</tr>
<tr>
<td>F</td>
<td>0-59%</td>
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</tbody>
</table>
**Homework:** Homework will consist of problems covering material up to 2 days before the due date. Please review the Homework Submission Guidelines below. Homework cannot be accepted for credit after solutions have been posted on-line. If a homework is missed and there is a valid excuse, then it will be removed from the student’s total grade for the course, and the remainder of the homework assignments re-weighted. **Exams:** There is no senior option for this course. Make-ups for the Midterm may be available if exams are missed due to illness or family emergency. Make-up exams are only available if discussed with the instructor at least 1 day before the date of the exam. If an emergency arises after that time and there is a valid excuse, then the exam will be removed from the student’s total grade for the course, and the remainder re-weighted accordingly. Proper documentation of the emergency must be presented before either of these options can be offered. **Attendance:** Students are not formally penalized for missing lectures/sections. However, it is the student’s responsibility to arrange to obtain notes for any missed classes and to turn in any homework due on the date of the missed class. Although participation in online discussion at Piazza will not be graded, statistics of participation by each student will be monitored and may play a role deciding grades in borderline cases. **Homework Submission Guidelines** Please make sure your name is on your homework submission. Please write neatly if you submitted scanned work. The unreadable is ungradeable. Please submit your problems in the order they appear on the assignment sheet. Please make sure to show all work and document any assumptions you are making. If you use special computer software (e.g., Matlab, Python, Excel, etc.) to complete your homework/project, please read, and adhere to, the Software Usage Guidelines (see below). Homework is due by 5pm Eastern US time on the posted date unless otherwise instructed. **Software Usage Guidelines** You may use any applicable software to do homework assignments, e.g. Matlab, Python, Excel, etc. Please include not only printouts of results but also all relevant codes. The codes should be sent by e-mail to the TA or instructor (e.g. in a zipped directory). The answers from the computer must include the requisite amount of explanation. Unless specifically instructed otherwise, you may use symbolic computation software for theoretical problems, but again you must include printouts of relevant code. **Term Paper** 1. The term paper must report on a published research paper in any area of science or engineering, which employs dynamical-systems concepts and methods from the course. This is a report only: no original work is expected or required. 2. The scientific background of the dynamical models developed in the paper should be clearly described, intelligible to a general science reader (namely, the instructor!) 3. All mathematical analysis in the paper using concepts and methods taught in the course (fixed points, linearization, nullclines, bifurcation classification, Poincare-Bendixson theorem, Lyapunov exponents, etc.) should be explained and elaborated. 4. All numerical results of the paper must be reproduced which can be done so using the Matlab codes provided in the course. 5. The paper should have a length consistent with the above requirements, but at least 20 pages. As the paper is worth a substantial fraction of the course grade, high quality and signs of significant effort are expected. 6. Term papers are due on the final day of class. PDF copies of the research article that is reported on must also be included, as well as any codes used for numerical work. 7. Candidate research papers must be pre-approved for reports by the course instructor (Gregory Eyink). Electronic copies should be e-mailed to him for review. It is a good idea to begin to look for possible research papers after the midterm. The bibliography of the course textbook by Strogatz is an excellent source of possible papers. You may also find helpful on-line search engines such as Google Scholar

[http://scholar.google.com](http://scholar.google.com)
to locate papers by searching on key words that reflect your own interests (e.g. “dynamical systems” + “oncology”). You may also search on papers by author, title, etc. and find papers which cite a given paper, related articles, etc. Ask the course instructor for help if you are experiencing any difficulty.

Key Dates
Key dates (exams, etc.) are at [http://www.ams.jhu.edu/~eyink/Dynamics/schedule.html](http://www.ams.jhu.edu/~eyink/Dynamics/schedule.html)

Assignments & Readings
Reading assignments also at [http://www.ams.jhu.edu/~eyink/Dynamics/schedule.html](http://www.ams.jhu.edu/~eyink/Dynamics/schedule.html)
Dates given there are only approximate, and will vary somewhat from year to year.

Ethics
The strength of the university depends on academic and personal integrity. In this course, you must be honest and truthful. Ethical violations include cheating on exams, plagiarism, reuse of assignments, improper use of the Internet and electronic devices, unauthorized collaboration, alteration of graded assignments, forgery and falsification, lying, facilitating academic dishonesty, and unfair competition.

In addition, the specific ethics guidelines for this course are:

1. If you work in a group you must write up your solutions separately. Anything that looks too much like someone else’s work is likely to be considered cheating. Such assignments will receive a grade of zero and you may be subject to other disciplinary action.
2. If you work in a group on coding for homework, the group cannot create a joint computer printout and copy it for all group members. Even if you work in a group, you must still do the software work yourself and turn in your own output.
3. You are free to use any online material (books, articles, Wikipedia pages, etc.) to assist you in the solutions of homework, but any such material must be cited in your submission with an appropriate reference (e.g. url). If material is taken without credit from an online (or any other) source, it will be considered plagiarism.
4. If the midterm or final exam are given as take-homes (which will be decided by class vote), then you must attest in writing that you have not been assisted by any classmate, friend or family member.

Report any violations you witness to the instructor.
You can find more information about university misconduct policies on the web at these sites:

- Graduate students: [http://e-catalog.jhu.edu/grad-students/graduate-specific-policies/](http://e-catalog.jhu.edu/grad-students/graduate-specific-policies/)

Personal Wellbeing

- If you are sick please notify me by email so that we can make appropriate accommodations should this affect your ability to attend class, complete assignments, or participate in assessments. The Student Health and Wellness Center is open and operational for primary care needs. If you would like to speak with a medical provider, please call 410-516-8270, and staff will determine an appropriate course of action based on your geographic location, presenting symptoms, and insurance needs. Telemedicine visits are available only to people currently in Maryland. See also this [link](https://covidinfo.jhu.edu/health-safety).
- Johns Hopkins COVID-19 Call Center (JHCCC), which can be reached at 443-287-8500 seven days a week from 7 a.m. to 7 p.m., supports all JHU students, faculty, and staff experiencing COVID-19 symptoms. Primarily intended for those currently within driving distance of Baltimore, the JHCCC will evaluate your symptoms, order testing if needed, and conduct contact investigation for those affiliates who test positive. More information on the JHCCC and testing is on the coronavirus information website at [https://covidinfo.jhu.edu/health-safety](https://covidinfo.jhu.edu/health-safety).
- All students with disabilities who require accommodations for this course should contact me at their earliest convenience to discuss their specific needs. If you have a documented disability, you
must be registered with the JHU Office for Student Disability Services (385 Garland Hall; 410-516-4720; studentdisabilityservices@jhu.edu) to receive accommodations. See the OSDS website [http://web.jhu.edu/disabilities].

• Students who are struggling with anxiety, stress, depression or other mental health related concerns, please consider connecting with resources through the JHU Counseling Center. The Counseling Center will be providing services remotely to protect the health of students, staff, and communities. Please reach out to get connected and learn about service options based on where you are living this fall at 410-516-8278, online at [http://studentaffairs.jhu.edu/counselingcenter].

• Student Outreach & Support is fully available to help support students. Students can self-refer or refer a friend who may need extra support or help getting connected to resources. To connect with SOS, please email deanofstudents@jhu.edu call 410-516-7857, or students can schedule to meet with a Case Manager by visiting the Student Outreach & Support website and follow Schedule an Appointment.

Classroom Climate
As your instructor, I am committed to creating a classroom environment that values the diversity of experiences and perspectives that all students bring. Everyone here has the right to be treated with dignity and respect. I believe fostering an inclusive climate is important because research and my experience show that students who interact with peers who are different from themselves learn new things and experience tangible educational outcomes. Please join me in creating a welcoming and vibrant classroom climate. Note that you should expect to be challenged intellectually by me, the TAs, and your peers, and at times this may feel uncomfortable. Indeed, it can be helpful to be pushed sometimes in order to learn and grow. But at no time in this learning process should someone be singled out or treated unequally on the basis of any seen or unseen part of their identity.

If you ever have concerns in this course about harassment, discrimination, or any unequal treatment, or if you seek accommodations or resources, I invite you to share directly with me or the TAs. I promise that we will take your communication seriously and to seek mutually acceptable resolutions and accommodations. Reporting will never impact your course grade. You may also share concerns with the department chair (Fadil Santosa, fsantos9@jhu.edu), Director of Undergraduate Studies (Donniell Fishkind, dfishkil@jhu.edu), the Assistant Dean (Darlene Saporu, dsaporu@jhu.edu) for Diversity and Inclusion, or the Office of Institutional Equity (oie@jhu.edu). In handling reports, people will protect your privacy as much as possible, but faculty and staff are required to officially report information for some cases (e.g. sexual harassment).

University Policy on Incompletes
The university recognizes that the Fall 2021 semester is surrounded with uncertainty and many students may find themselves in unexpected situations where study is difficult if not impossible. Students who are confronted with extraordinary circumstances that interfere with their ability to perform their academic work may request an incomplete grade from the instructor. While approval of such a request is not automatic, it is expected that faculty will make every effort to accommodate students dealing with illness in the family and other pandemic-related hardships. The instructor and student must establish a timetable for submitting the unfinished work with a final deadlinenow later than the end of the third week of the Spring 2022 semester. Exceptions to this deadline require a petition from the instructor to the student’s academic advising office before this date. When entering an Incomplete grade in SIS, faculty must include a reversion grade which represents the grade the student will receive if s/he does not complete the missing work by the agreed-upon deadline.

Deadlines for Adding, Dropping and Withdrawing from Courses
Students may add a course up to September 10, 2021. They may drop courses up to October 11, 2021 provided they remain registered for a minimum of 12 credits. Between October 11 and November 12,
In 2021, a student may withdraw from a course with a W on their academic record. A record of the course will remain on the academic record with a W appearing in the grade column to indicate that the student registered and then withdrew from the course.

For more information on these and other academic policies, see this link.

**ABET Outcomes**

- Ability to apply mathematics, science and engineering principles (a).
- Ability to design a system, component, or process to meet desired needs (c).
- Ability to identify, formulate and solve engineering problems (e).
- Ability to use the techniques, skills and modern engineering tools necessary for engineering practice (k).