AE6270: Nonlinear Dynamics

Instructor: Keegan J. Moore, Ph.D.
Fall 2026

What This Class is About

Welcome to AE6270: Nonlinear Dynamics. This course investigates nonlinear dynamical systems undergoing mechanical vibrations and develops tools to analyze their behavior both theoretically and using data. The first half provides the necessary theoretical foundation in nonlinear dynamics and vibrations, while the second half focuses on the analysis of these systems using computational and experimental data. Concepts from the theoretical portion guide the application and interpretation of data-driven techniques.

Course Topics:

1. Phase Space Analysis of Nonlinear Systems
2. Asymptotic and Perturbation Methods
3. Poincaré Maps and Chaos
4. Nonlinear Normal Modes and Energy Transfers
5. Time-Frequency Representation & Analysis
6. Signal Decomposition and Empirical Slow-Flow Analysis
7. Data-Driven Nonlinear System Identification

Catalog Description: Nonlinear vibration methods through averaging and multiple scales, bifurcation, periodic and quasi-periodic systems, transition to chaos, characterization of chaotic vibrations, thermodynamics of chaos, chaos.
Credits Hours: 3

Key Information

Lectures will be recorded and posted on Canvas.

Course Communication

Microsoft Teams: We will Microsoft Teams for course communication between groups and for answering questions.

Canvas: We will use Canvas for all course assignments, announcements, and website functions. All homework, solutions, and handouts will be posted to Canvas, and you will need to download them from there.

Contacting the Instructor

MS Teams:	Preferred method. Direct message me on Teams or @me in your group's channel.
Email:	kmoore@gatech.edu (Likely slow to respond)

Be sure to read my availability/response policy.

Course Objectives

Course Learning Objectives:
By the end of this course, students will be able to:

1. Identify sources of nonlinearity and analyze their effects on system response based on orbits in the phase plane.
2. Quantitatively probe and analyze the behavior of nonlinear vibrating systems using perturbation methods.
3. Compute and analyze backbone curves for conservative systems; primary, subharmonic, and superharmonic resonances for forced systems; and internal resonances for unforced MDOF systems.
4. Compute Poincaré maps and interpret the underlying dynamics including periodic, quasi-perioidic, and chaotic

responses.

5. Understand nonlinear normal mode theory including internal resonances and frequency-energy plots and compute them for low-dimensional systems.
6. Analyze and interpret the evolution of nonlinear vibrating systems using time-frequency analysis.
7. Extract harmonic components from vibration time series and interpret their connection to the underlying nonlinear normal modes governing the response.
8. Identify and characterize strongly nonlinear resonances that arise in vibration responses using empirical slow-flow dynamics.
9. Identify and parameterize mathematical models for strongly nonlinear vibrating systems based on simulated or measured response data.
10. **Grow and succeed as a learner by embracing feedback loops, deliberate practice, and productive failure.**

Assessments

- **Class Notes** (daily in class): We will complete guided notes together in class in lieu of traditional lectures. This approach is designed to minimize the time needed to write down the details and to maximize the time spent understanding the underlying ideas.
- **Team Worksheets** (roughly once a week): You will work in your assigned teams to derive lecture topics or solve example problems using a guided worksheet. You will need to coordinate a ~50-minute window as a team to work on the worksheet together. You may not finish the worksheet in that amount of time and that is okay. The goal is to work together to and learn from each other.
- **Homework** (deadline as assigned): You will produce solutions to assigned problems based on the course topics.
- **Check-ins** (twice, around weeks 6 and 13): Twice in the semester, I will ask you to reflect on your progress and compare it to the criteria for grades in our course. To do this, you will write a reflection about your work in the class, your understanding, and your goals for the rest of class. The goal is to ensure that we both agree on where you are, and what you need to do to succeed in class. Details will be given in class and posted on Teams or Canvas.
- **Portfolio** (**submit on Canvas at the end of your section's final exam period**): The final exam is to submit your portfolio: A collection of your work that showcases your development as a dynamicist and learner in this class.

All assignments will be submitted on Canvas. I will give you feedback via Canvas. If you have questions about an assignment, you can message me directly or through your group's channel on Teams or talk to me during office hours.

Due dates: We adopt a **real-world policy** on due dates in AE6270. Due dates exist but they are rarely ironclad. Most of the time, they are only there to motivate you to complete the task; if you need more time to get the job done well, you email whoever set the deadline and ask if you can have some more time. Studies have shown that deadline extensions, *when requested in moderation and when truly needed*, can significantly improve performance.

If you need an extension on a due date, message me and explain what you need. Please propose a concrete new deadline (e.g. "I can get this to you by tomorrow at 11:59pm"). If you ask for many extensions, we'll work together to find ways to help you keep up. Note that you may not get timely feedback if you need an extension on something.

If you have significant extenuating circumstances that cause you to miss multiple assignments, please come to drop-in hours to discuss broader accommodations. I'll be flexible, but it helps to know what you need so that I can find the best way to help.

Revisions

You may revise and resubmit work on **one** homework set each week. A "week" for this purpose is defined to start at 12:01am Monday and end 11:59pm Sunday.

Each revision must include a short reflection that summarizes the important items that caused issues on the previous submission, along with a ***specific*** explanation of what you did to improve your understanding and how you have demonstrated that improvement in this revision.

The reflection is essential in each revision. Without the reflection, the revision is incomplete and will not be reviewed. If your progress didn't meet the objectives, there was a major reason: What was it? In dynamics, even "small" things can make a major difference in logic and correctness.
You may revise the same homework more than once in a week with my permission.

Most students will need to do revisions on multiple homework sets; waiting until late in the semester will cause you to run out of time. I highly recommend planning to revise one set per week, and consulting with me to make sure you understand my feedback before you submit a revision

How do I earn a grade?

I want you to focus exclusively on learning and growth in this course, and not on your grade. Thinking too much about grades is unhealthy and distracts you from what's important: *learning and growth*, which takes place as the result of engagement with feedback loops: Try something, figure out what went well and what didn't, get feedback, then use the feedback to try again. Your grade in the course should reflect how well you *eventually understand* the concepts.

Your job in the course is to create a body of work that gives concrete evidence of two things: *How well you understand the analysis of nonlinear vibrations*, and *how well you engage with class*. The table below lists some criteria, some of which (the **boldface** ones) are essential, of things you can do toward this goal. Throughout the semester I will give you detailed feedback on assignments (particularly homework) that will get you engaged in a virtuous cycle of improvement. You can suggest additions to these lists.

Ways to show understanding of the analysis of nonlinear vibrations using data:

- **Produce complete solutions to problems using the techniques developed in class (after revision).**
- **Demonstrate deep understanding of these topics: phase portraits, weak vs strong nonlinearity, backbone branches, nonlinear resonances, bifurcations and chaos, nonlinear normal mode theory, time-frequency analysis, signal decomposition, empirical slow-flow dynamics, and nonlinear system identification.**
- **Demonstrate that you have met each of the learning objectives.**
- Find and use connections between ideas (in worksheets, homework, or other places).
- Share your ideas through discussions with the class or by asking insightful questions.
- Relate the course content to your own research or work, or by finding real world examples of the phenomena.

Ways to show engagement with class:

- **Participate in solving the worksheets with your team members. Don't just do your own thing during the worksheets.**
- Actively participate in discussions (there are different ways to "participate").
- Complete all work, in and out of class. Actively seek out resources to catch up if you miss class.
- Be a leader in your groups (there are different ways to demonstrate leadership).
- Be an active and engaged member of your groups and contribute meaningfully to all group work.
- Support classmates and help them succeed.

wTo earn an A	To earn a B	To earn a C
Consistently meet almost all the criteria above, missing **at most 1 or 2** items, and including all the boldface ones.	Frequently meet many of the criteria above, missing **at most 3 or 4 items**, and including all but one the boldface ones. Show meaningful progress on many of the criteria you don't meet.	Either meet a few of the criteria consistently (**4-5 total, including at least 2 bold items**) *or* meet many (**8-10**) criteria but less often. Show meaningful progress on a few more.

To earn a D or F: A grade of "D" is the result of a good-faith, but unsuccessful, effort to earn a "C". An "F" is given where there is no evidence of meaningful progress and usually results from a near-complete disengagement from the course.

Grades on individual assignments: None of the individual items in the course are graded. Instead, you will get feedback on your work, whether it's a homework assignment, worksheet, etc. on a regular basis. Most of the work you submit can be revised, and you will get extensive feedback when this is the case. Otherwise, there are no points to keep track of. Simply focus on mastery and improvement and gradually build your body of work that provides concrete evidence that you've met the criteria in the lists above.

Check-in meetings: Twice during the semester, I'll ask you to compare your work to the criteria above and write a brief description of your current progress. We will discuss and agree on where your current grade is, then plan for how to achieve your goals. The check-in meetings will be scheduled for each student in weeks 6 and 13. You can always request additional check-in meetings.

Portfolio: At the end of the semester, you will make the case that you've earned one of these grades. The portfolio is the main way that you will do this. In the portfolio, you will describe what grade you believe you have earned and then back this up with the evidence (worksheets, homework problems, etc.) that support your description.

Does this mean that you'll get whatever course grade you ask for? No. If you state that you deserve an "A" in the course but don't have sufficient evidence to support it, you probably won't be assigned an A. Instead, we'll talk about the criteria list and what you *have* done, then come to agreement on a grade that your portfolio evidence supports.

Earning an "A" in AE6270 is not easy. You might find it's harder to earn an A here than in a course with a traditional exams/points approach, because you're being asked to show evidence of growth and mastery *across all concepts*. You can't have a poor understanding of one area and mask it over with a strong understanding in another area and averaging the two. An A requires consistent growth and eventual excellence in all areas of the course, no exceptions!

However, I am on your side—your personal consultant and coach whose main priority is your success. We will discuss these grade descriptions as a class and may make modifications to them if needed. Please know that I have your interests at heart and will act with professional judgment. In turn, I ask you to trust me: I have zero interest in tricking you, playing "gotcha" with technicalities, or assigning grades in an arbitrary way. **You are in control of your grade.**

Portfolio

Your **portfolio** in AE6270 is a collection of your best work that shows how you have grown as a dynamicist and learner and attained mastery of the content from day 1 to the end of the semester. You will use your portfolio to make a convincing case that you have met the criteria for a course grade.

Due date: Your portfolio is due at the end of the final exam period for your section, uploaded to Canvas. (There's no final exam in the course and no activities currently planned for the final exam period.)

What should be in the portfolio? Roughly, the portfolio will include (more guidelines will be posted later):

- **Table of Contents**
- **Reflection Essays:** Short responses to prompts that give you a chance to showcase your growth throughout the course. These prompts will be posted later in the semester.
- **Team Assessment:** A reflection on how well you and your team worked together throughout the course. This is your opportunity to **assess your teammates** on their performance in the team.
- **Your Grade**: A guided reflection that describes which grade you are aiming to earn, and how your portfolio shows that you've met the criteria for that grade. You'll need to argue to support the grade you feel you deserve. You should reference content from the appendices in this statement to provide ample evidence for your claim.

Appendices:

- **Guided Notes:** A collection of your completed guided notes that illustrate your engagement in class.

- **Course Worksheets:** A collection of your final completed worksheets.
- **Homework Problems and Reflections:** A collection of your final completed homework problems.

Revisions: You can revise any of the assignments another time before including them in the portfolio. Your goal is to show how you've met the criteria for each grade by the end of the semester. If something confused you early on, but you've figured it out now, make the revision and include it. If you revise something, **make sure to indicate that in the narrative for your grade.**

How your portfolio is used to determine your grade: When you submit your portfolio, I will read the entire main body (Reflection Essays, Team Assessment, and Your Grade) in entirety as well as anything that you specifically cite from the appendices. For the content in the appendices that you do not cite, I will skim through it to look for completeness and evidence of engagement. If you make a convincing case that you've earned a particular grade, then you'll earn that grade. That's it. You're in charge.

- If you *underestimate* your grade in the portfolio (i.e., you judge yourself too harshly) then I may assign a higher grade, based on your evidence and what I have seen from your work.
- If you *overestimate* your grade (i.e., you suggest a higher grade than the evidence supports) then we will discuss it in our check-in meetings, and I will probably ask for an additional check-in meeting to discuss the grade criteria and arrive at a grade we can both agree on.
- **Under no circumstances will I assign a grade lower than what you suggest for yourself, without discussing it with you first!** Through our check-in meetings and any discussion in between those, there should be no surprises.

Policies

Availability and response policy: *You can ask a question about anything at any time*. MS Teams is the preferred medium, but I also welcome visits during drop-in hours; appointments are also available. **If you email me, there may be a significant delay in my response.** If you message me between 8:00am and 4:00pm on a weekday, I will do my best to respond on the same day. If you message me after 4:00pm on a weekday, I'll respond the following day or as early as I can. If you message me late Friday or on a weekend, I'll respond by Monday morning unless I am traveling. Sometimes it's easier to talk in person or over a Teams call than messaging, so I may ask you to meet with me during drop-in hours rather than answering directly in a message.

Teams and Cooperative Learning: This course will emphasize ***cooperative learning.*** Teamwork will be required throughout the semester and will be used to develop communication skills. A team will consist of **three** or **four** people (adjusted based on class size). The general rules regarding the "team" are

1. The instructor will form teams (but students are asked to submit names they may wish to work with for their team) during the first week of the semester. Once formed, teams will be expected to submit a name for their team. Changes will only be made due to schedule conflicts, etc. and can only be made upon petition of the instructor.
2. If an individual is dissatisfied with the team and wants to quit, he/she must petition the instructor for permission; if you do quit, you will have to link up with another group or work on your own.
3. If the group decides that one of the members is not pulling his/her weight in the process, that group may petition the instructor to "fire" that member; if that person is fired, they must join another team, or they will have to work alone.

AI & Generative Tools Policy: This course emphasizes understanding, modeling, and interpreting nonlinear dynamical systems and nonlinear vibrations using analytical methods and data-driven tools (MATLAB and Python). Students may use AI-based tools as assistive aids and all use must be cited (see Disclosure Requirement). The following guidelines apply:

Permitted Uses:

- Help interpret error messages or debug code
- Suggest syntax, plotting routines, or numerical workflows
- Assist with documentation, commenting, or code organization
- Provide high-level explanations of mathematical or computational concepts for learning support

Prohibited Uses:

- Generate complete homework or worksheet solutions
- Perform derivations, proofs, or analyses that the student cannot independently explain
- Replace required theoretical reasoning, interpretation, or critical analysis
- Bypass the learning objectives of an assignment or the course

Disclosure Requirement: If AI tools are used for an assignment, students must briefly disclose how they were used and which tool was used (e.g. "AI assistance through ChatGPT 5.2 was used to debug Python code for numerical integration"). Failure to disclose constitutes an academic integrity violation.

Students are fully responsible for:

- The correctness of their submitted work
- Understanding and being able to explain any results, code, or analysis
- Ensuring compliance with Georgia Tech's academic integrity policies

Conduct & Expectations: All students are expected to behave in a respectful and appropriate manner in all interactions with others in this course. Students acting in a manner that is disruptive or impedes learning will be asked to leave and disengage. Students that are asked to leave will be required to meet with the instructor and may be subject to disciplinary action as described by the Institute Policies.

Accommodations for Students with Disabilities: Students who require accommodations should contact the **Office of Disability Services (ODS)** at www.disabilityservices.gatech.edu as early as possible to obtain an accommodation letter. Students are responsible for sharing approved accommodation documentation with the instructor in a timely manner.

Academic Integrity and Collaboration

Students are expected to comply with the **Georgia Tech Academic Honor Code**. All work submitted in this course must represent the student's own effort. Any instance of academic dishonesty, including plagiarism or misrepresentation of individual contributions, will be handled in accordance with Georgia Tech policies and may result in disciplinary action.

CREDITS: A large portion of this teaching approach and syllabus was adapted from Prof. Robert Talbert's course on Modern Algebra at Grand Valley State University.