MAE 541 / APC 571: Applied Dynamical Systems

Course information, Spring 2026

Instructors

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Schedule

Time: TTh, 9:00–10:20am
Location: Friend Center 008

Course summary

Many mathematical models of (physical) phenomena are nonlinear, and even the simplest of them can exhibit surprising complexity and chaos. This course will introduce and develop the modern theory of dynamical systems with a view to analyzing some such models in engineering and the sciences.

Topics to be covered include the following: stability of equilibria and periodic orbits; Poincaré maps; invariant manifolds; structural stability and bifurcation; center manifolds and normal forms; averaging and perturbation methods; homoclinic orbits and chaos; Smale horseshoes, symbolic dynamics, and strange attractors; and an introduction to ergodic theory.

Prerequisites

Some familiarity with ODEs and linear systems (e.g., MAE 305, MAT 322, or MAE 434). Please contact the instructor if you are in doubt about your background knowledge.

Grading

Homework: 70%
Final project: 30%

Final projects will be done in pairs (or perhaps groups of three), and the topic will be chosen by the students and approved by the instructor. Oral presentations will be given for both the proposed topic, and for the final project itself.

AI policy

Use of generative Artificial Intelligence (AI) is permitted, under certain circumstances, but must be disclosed. In addition, if you use generative AI in your homework assignments or for the final project, you must save all prompts (e.g., chat history) and be willing to provide these to the instructors on request.

It is not permitted to "ask AI" for solutions to homework problems. Use of AI is permitted to help with programming, or for clarifying concepts, providing examples, etc, but not for doing the work assigned to the student.

Collaboration

Collaboration with other students is *highly encouraged*.

However, all work you turn in must be your own. Copying work from others (or from other sources, such as the internet) is not collaboration: it is plagiarism, and it is a serious violation of University policy.

Course text and references

Main text:

Guckenheimer, J. and Holmes, P. *Nonlinear Oscillations, Dynamical Systems and Bifurcations of Vector Fields*, Springer 1983. (Get corrected seventh printing, 2002.)

Optional supplement:

Hirsch, M.W., Smale, S., and Devaney, R.L. *Differential Equations, Dynamical Systems and an Introduction to Chaos*, Academic Press/Elsevier, 2004. (A very nice introduction, more elementary than G&H. Significantly revised edition of the classic Hirsch and Smale 1974, with material on iterated mappings, the Lorenz attractor, etc.)

Other texts, on library reserve:

Andronov, A.A., Vitt, A.A., and Khaikin, S.E. *Theory of Oscillators*, Dover (paperback), 1987 (Pergamon, 1966). (The classical background.)

Arnold, V.I., *Ordinary Differential Equations*, MIT Press, 1973. (A basic introduction in the modern geometrical style; similar level to Hirsch-Smale-Devaney.)

Arrowsmith, D. and Place, C.M. *An Introduction to Dynamical Systems*, Cambridge University Press, 1990. (Covers similar ground to G&H)

Cornfeld, I.P., Fomin, S.V., Sinai, Ya.G., and Sossinskii, A.B., *Ergodic Theory*, Springer 1982. (Rigorous overview of ergodic theory.)

Glendinning, P. *Stability, Instability, and Chaos*, Cambridge 1994. (Between Strogatz and G&H in level.)

Kuznetsov, Y.A. *Elements of Applied Bifurcation Theory*, Springer, 1995. (Focuses on local and global bifurcations, center manifolds, normal forms.)

Lasota, A. and Mackey, M.C. *Chaos, Fractals, and Noise: Stochastic Aspects of Dynamics*, Springer, 1994. (Emphasizes the evolution of densities, rather than individual trajectories.)

Moon, F.C. *Chaotic and Fractal Dynamics*, Wiley 1992. (An introduction aimed at engineers. Many nice examples, informal style.)

Perko, L. *Differential Equations and Dynamical Systems*, Third edition, Springer, 2000. (An introductory text a little gentler than G&H, covering much of the same material.)

Strogatz, S.H. *Nonlinear Dynamics and Chaos*, Addison-Wesley, 1994. (A gentle and informal introduction.)

Wiggins, S. *Introduction to Applied Nonlinear Dynamical Systems and Chaos*, Springer 1990. (Covers similar ground to G&H, with some more detail. A new and expanded edition appeared in 2003.)

Schedule (tentative)

Dates refer to the first lecture of that week, and section numbers refer to Guckenheimer and Holmes.

Week	Date	Topic	Section
1	1/30	Intro, stability, Liapunov functions, linear systems	1.0–1
2	2/6	Hartman-Grobman thm, stable & unstable mfds; maps	1.2-4
3	2/13	Poincare maps, structural stability, planar systems	1.5,1.7–8
4	2/20	Local bifurcations, center manifolds	3.1–2
5	2/27	Normal forms, codimension-1 bifurcations of flows	3.3-4
6	3/5	Codimen-1 bifurcations of maps	3.5
7	3/19	Averaging, Melnikov's method	4.1–5
8	3/26	Chaotic maps, symbolic dynamics, Smale's horseshoe	5.0–1
9	4/2	Invariant sets and hyperbolicity, Smale-Birkhoff thm	5.2–3
10	4/9	Strange attractors, geometric Lorenz	5.4–7, 6.4
11	4/16	Ergodicity, ergodic theorems, mixing	Cornfeld Ch 1
12	4/23	Global bifurcations, Shil'nikov's theorem	6.1, 6.5