

Math 721: Nonlinear Dynamics and Chaos I

Fall 2019

Lecture Times: Mon/Wed 1:00pm-2:15pm, AB 634

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Office Hours: Tues 11am-noon, Thur 3-4pm, or by appointment.

Course website: WebCampus is at wcl.unr.edu or webcampus.unr.edu or canvas.unr.edu

Required Textbook: Nonlinear Dynamics and Chaos, 2nd by Strogatz.

Course Description: This is the first part of a two-semester sequence of courses (MATH 721 & 722). This course starts with an introduction to stability analysis and bifurcation phenomena in 1-, 2-, and n -dimensional systems of Ordinary Differential Equations. Students will get hands-on experience using analytical and computational methods to analyze such models. See the SLOs below for additional topics to be covered in this course.

Prerequisite: Math 330 (Linear Algebra) or equivalent.

Objective: Students will obtain familiarity with concepts and methods in the field of dynamical systems, apply those concepts and methods to analyze dynamic models analytically and computationally, and will learn how to interpret and critically evaluate such results.

Student Learning Outcomes: Upon completion of this course, students will be able to demonstrate an advanced level of competency in:

1. geometric approach to 1 and 2- dimensional flows, stability analysis, Lyapunov stability and Lyapunov function method, classification and analysis of bifurcation of equilibria in 1 and 2-dimensional flows, conservative, reversible and dissipative systems, index theory.
2. application of Poincare-Bendixon theorem, Lienard system, Hopf bifurcations, global bifurcation of cycles, hyperbolic systems.
3. asymptotic methods, weakly coupled nonlinear oscillators, synchronization phenomena in nonlinear systems and real world models.

Homework: There will be assigned reading, and homework due approximately every other week that may be graded on completion. Please write or type solutions legibly – I may give zero credit for problems that are too difficult to read. Your solutions should show all relevant work, and be a clear explanation of your reasoning. Supplementary electronic files (e.g. coding scripts) are to be emailed to the instructor (as no more than 3 attachments, or if needed as a single zip file) using the naming convention: **SURNAME-HWX.ext**.

Exams: There will be two mid-terms and no final exam.

Project: Each student will complete a project and submit a term paper at the end of the course. The instructor will help students identify a good topic, and will consult closely with them during the semester.

Computing Resources: This course requires the use of mathematical software, all of which is either free or available to use through UNR. Students are assumed to have access to a computer with, e.g., Matlab, the free software R (www.r-project.org) or similar software (e.g., Python). Students using R are strongly encouraged to use the front-end RStudio (www.rstudio.com). Additional software (e.g., XPP/Auto) may be used as well.

Course Topics: Below is a tentative list topics for the course. See the course website for a more detailed list of topics, and updated schedule.

1. Dynamics of linear systems
2. Equilibrium stability analysis
3. Bifurcations in 1- and 2-dimensions
4. Bifurcations in higher dimensions
5. Averaging method
6. Normal forms
7. Center manifolds
8. Poincaré maps
9. Numerical tools for bifurcation analysis

Grading and Required Work: Your course grade will be determined by your homework (50%), exams (30%), and final project (15%), and the highest of those three scores (5%).

The grading scale will be as follows (this may get curved at the instructor's discretion):

A if 93.0 – 100%	C+ if 77.0 – 79.9%	F if 0 – 54.9%
A- if 90.0 – 92.9%	C if 70.0 – 76.9%	
B+ if 87.0 – 89.9%	D+ if 68.0 – 69.9%	
B if 83.0 – 86.9%	D if 62.0 – 67.9%	
B- if 80.0 – 82.9%	D- if 55.0 – 61.9%	

Make-up Work: There will be no make-ups for exams, except for University-approved reasons. You must let the instructor know about medical issue on the day of the exam, or if you are unable to do so, as soon as possible. Any student participating in official University-approved activities that will interfere with an exam must make arrangements with the instructor at least two weeks prior to the exam that will be missed. UNR policies are provided in [UAM 3.020](#) and at <https://med.unr.edu/shc/insurance/clinic-policies>. Any student requiring accommodations through the DRC must schedule their exams on the same day as the in class exam.

Etiquette: Please be considerate of your fellow students, TA, and instructor. Please turn off all your electronics (phone, laptop, etc.) before class. Behavior that may disrupt the learning environment will not be tolerated. To clarify what counts as disruptive, please ask the instructor.

Academic Success Services: Your student fees cover usage of the Math Center (PSAC 300, www.unr.edu/mathcenter), Tutoring Center (PSAC 320, www.unr.edu/tutoring), and University Writing Center (PSAC 350, www.unr.edu/writing_center). These centers support your classroom learning; it is your responsibility to take advantage of their services. **Keep in mind that seeking help outside of class is the sign of a responsible and successful student.**

Disability Services: Any student with a disability needing academic adjustments or accommodations is requested to speak with the Disability Resource Center (PSAC 230, www.unr.edu/drc) as soon as possible to arrange for appropriate accommodations. This course may leverage 3rd party web/multimedia content, if you experience any issues accessing this content, please notify your instructor.

Academic Misconduct: Cheating, plagiarism or otherwise obtaining grades under false pretenses constitute academic dishonesty according to the code of this university. Academic dishonesty will not be tolerated and penalties can include canceling a student's enrollment without a grade, giving an F for the course or for the assignment. The University Academic Standards Policy defines academic dishonesty, and mandates specific sanctions for violations. See the University Academic Standards policy: [UAM 6.502](#), particularly Subsection C, *Levels of Academic Dishonesty*, so that you are familiar with examples of such violations, and the mandated consequences associated with the levels of academic misconduct.

Audio and Video Recording: Surreptitious or covert video-taping of class or unauthorized audio recording of class is prohibited by law and by Board of Regents policy. This class may be videotaped or audio recorded only with the written permission of the instructor. In order to accommodate students with disabilities, some students may be given permission to record class lectures and discussions. Therefore, students should understand that their comments during class may be recorded.

The University of Nevada, Reno is committed to providing a safe learning and work environment for all. If you believe you have experienced discrimination, sexual harassment, sexual assault, domestic/dating violence, or stalking, whether on or off campus, or need information related to immigration concerns, please contact the University's Equal Opportunity & Title IX office at 775-784-1547. Resources and interim measures are available to assist you. For more information, please visit: <https://www.unr.edu/equal-opportunity-title-ix>.

Pack Provisions: ASUN Pack Provisions strives to support all members of the University with daily resources they need to ensure success. This mission is carried out by providing access to basic necessities to students in need such as food, school supplies, hygiene items and more. To utilize this service, visit ASUN Center for Student Engagement on the Third Floor of the Joe Crowley Student Union or email packprovisions@asun.unr.edu.

Tentative Class Schedule

Week	Day of Week	Date	Topic
1	Monday	August 26	Syllabus & Class Introduction
	Wednesday	August 28	Ch. 1 & 1D Dynamics (Ch. 2)
2	Monday	September 2	Labor Day -- No Class
	Wednesday	September 4	1D Dynamics (Ch. 2-3)
3	Monday	September 9	Flows on the circle (Ch. 4)
	Wednesday	September 11	Flows on the circle (Ch. 4)
4	Monday	September 16	2D Dynamics (Ch. 5)
	Wednesday	September 18	2D Dynamics (Ch. 5 & 6)
5	Monday	September 23	2D Dynamics: Phase-plane Analysis (Ch. 6,7)
	Wednesday	September 25	Discrete Maps: Fixed Points and Stability
6	Monday	September 30	Review for Exam 1
	Wednesday	October 2	Exam 1
7	Monday	October 7	2D Dynamics: Index Theory (Ch. 6)
	Wednesday	October 9	2D Dynamics: Limit Cycles & Bifurcations (Ch. 7 & 8)
8	Monday	October 14	2D Dynamics: Limit Cycles & Bifurcations (Ch. 7 & 8)
	Wednesday	October 16	Equilibrium Stability Analysis: n -dimensions
9	Monday	October 21	Bifurcations Revisited (Ch. 8 + notes)
	Wednesday	October 23	Bifurcations Revisited (Ch. 8 + notes)
10	Monday	October 28	Center Manifolds & Normal Forms
	Wednesday	October 30	Computational Bifurcation Analysis (MatCont)
11	Monday	November 4	Computational Bifurcation Analysis (MatCont)
	Wednesday	November 6	Review for Exam 2
12	Monday	November 11	Veteran's Day--No Class
	Wednesday	November 13	Exam 2
13	Monday	November 18	Chaos & Discrete Maps (Ch. 9, 10)
	Wednesday	November 20	Chaos & Discrete Maps (Ch. 9, 10)
14	Monday	November 25	Averaging Method [Thanksgiving Week]
	Wednesday	November 27	Fractals (Ch. 11) [Thanksgiving Week]
15	Monday	December 2	Advanced Topics: TBD
	Wednesday	December 4	Advanced Topics: TBD
16	Monday	December 9	Project Presentations
	Wednesday	December 11	Prep Day -- No Class
Finals Week	Monday	December 16	Final Scheduled for 9:50am-11:50am

Other Important Dates:

- Fri Aug 30: Final day to add classes **without** instructor permission
- Thu Sept 5: Final day to receive 100% refund for withdrawing from individual classes
Final day to add or swap classes **with** permission from the instructor
- Fri Oct 4: Final day to withdraw from university with 50% refund
- Mon Oct 31: Final day to drop with a 'W'

For more details and dates, see the academic calendar at
<https://www.unr.edu/academic-central/academic-resources/academic-calendar>