AME 522
Nonlinear Dynamical Systems, Vibrations, and Chaos

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The purpose of this course is to introduce the methods of analysis and simulation used in the description of nonlinear mechanical, chemical, and biological, systems, and in general nonlinear dynamical systems. The wish-list of topics covered in this course includes:

1. Basic over-view of Nonlinear Dynamical Systems and Oscillations in Engineering and Nature

    Computational Approaches

2. Flows on a Line, Stability, Bifurcations; Flows on the Circle and Nonlinear Mechanical Systems, Phase locking

3. Nonlinear systems Analysis and Multi-dimensional Flows, Phase Portraits, Nullclines: dynamics and various notions of stability; Lyapunov Stability

4. Lyapunov Stability and Instability Theorems

5. Local Analysis: Hyperbolic Fixed Points, Stable Manifold and Grobman-Hartman's Theorem; Nonhyperbolic Fixed Points, Use of Lyapunov Theorems, Invariance Principle

6. Global analysis: Limit Cycles, Dissipative Systems, Gradient Systems, Reversible Systems, Bendixon's Result, Index Theory

7. Fast and Slow Dynamics, Center Manifolds, Periodic "bursts" in nonlinear systems; Weakly Nonlinear Oscillations, Two-timing and Averaging Methods, Van der Pol's Equation

8. Limit Cycles, Subcritical and Supercritical Hopf Bifurcations, Hysteresis in Driven Pendulum, Global Bifurcations of Cycles

9. MIDTERM EXAM (approximate week)

10. Infinite Period Bifurcations, Homoclinic Bifurcations, Poincare Maps, Linear stability of Periodic Orbits, Floquet Multipliers

11. Coupled Oscillators and Pseudo-periodic Orbits; Lorenz system, Chaos, Lyapunov Exponents, Computational Aspects, Transient Chaos

12. One-dimensional maps, Period doubling, Two-dimensional Maps, Fractals, Baker's and Horse-shoe transformation

Course Text: <u>Nonlinear Dynamics and Chaos</u> by Steven Strogatz, 2nd Edition

Some Reference Texts: <u>Dynamical Systems,</u> by D. Arrowsmith and C. Place
                      <u>Nonlinear Systems</u>, by P. Drazin
                      <u>Differential Equations and Dynamical Systems</u>, by L. Perko
                      <u>A Treatise on Analytical Dynamics,</u> by L.A. Pars
                      <u>Nonlinear Oscillations, Dynamical Systems and Bifurcation of Vector Fields</u>, by
                       J. Guckenheimer and P. Holmes
                      <u>Nonlinear Systems,</u> by H. Khalil

Grading: 60% Homework   Homework Assignments will be given out every lecture.
                40% Midterm Exam
                There will be one Midterm Exam.
                The midterm exam will be around the 8thweek-9th week of class.

Homework Policy: 1. All students are encouraged to confer with <u>anyone</u> on how to solve the homework
                    problems. The aim for each student is to learn the material from <u>multiple perspectives</u>.
                2. Each student will write-up his/her homework that is submitted <u>I</u>NDEPENDENTLY, i.e.,
                   without anybody else's help.
                3. Homework is required to be turned in <u>on or before</u> the specified day that it is due. Late
                   homework will <u>not</u> be graded.
                4. All students MUST turn in their homework *before* <u>class starts on the day that it is due</u>.
                Every attempt will be made to return graded homework back to the students within a week
                   following its submission.

Office Hours: Thursday 1:00-2:00 PM

Class Policy: 1. If a student is found cheating on the homework, the student will be given a warning. If found
                   to be cheating again, the student will get a zero on the grade set aside for the homework grade
                   for the entire course.
                2. A student found cheating on <u>any</u> exam will get an 'F' grade on the course.