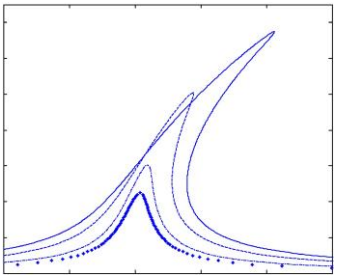
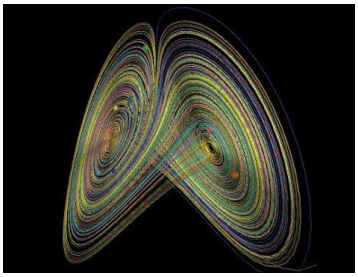
University of Colorado Boulder

ASEN 5519 Nonlinear Mechanical Vibrations

Spring 2022





Course Description:

This course introduces at the graduate level the principles and techniques of nonlinear mechanical vibrations, covering the basic theory of large-amplitude mechanical oscillations; phase-plane analysis and stability; asymptotic and perturbation methods of Lindstedt-Poincare, multiple scales, harmonic balance; external excitation, primary resonances and subharmonic and superharmonic resonances; and nonlinear wave propagation. The course is suitable for students planning to pursue this advanced subject further in either an academic or industrial setting. It is also useful for students interested in integrating linear and nonlinear vibration analysis into their system engineering activities for both aerospace and mechanical engineering applications. Both analytical and numerical treatments will be utilized.

The course aims to develop a working knowledge as well as a deep sense of intrigue in fundamental phenomena pertaining to nonlinear mechanical oscillators and nonlinear elastic wave motion with a view that such phenomena manifests in numerous other physical (and potentially nonphysical, such as social) systems. The emphasis is less in modeling, but rather on core dynamical behavior involving complex nonlinear interactions between notions like resonance, dissipation, dispersion, etc.

Instructor: Prof. Mahmoud I. Hussein, AERO 354, UCB 429, Smead Department of Aerospace Engineering Sciences, University of Colorado Boulder, CO 80309; Tel: (303) 492-3177; Email: mih@colorado.edu

Office Hours: By email appointment

Textbook: Nayfeh, Ali H. and Mook, Dean T., *Nonlinear Oscillations*, John Wiley & Sons, 1995
https://onlinelibrary.wiley.com/doi/book/10.1002/9783527617586

Reference: *Linear Vibrations:*
Rao, Singiresu S., *Mechanical Vibrations*, 6th Edition, Addison-Wesley, 2016
Nonlinear Vibrations:
Strogatz, S. H., *Nonlinear Dynamics & Chaos*, Addison-Wesley, 1994

Lectures: Tuesdays and Thursdays 4:00-5:15 pm; Room AERO N250

Homework: There will be roughly 4-5 homework sets in the semester.

Project: Term project will be a central activity in the course. It will involve analytical and numerical analysis of a carefully selected nonlinear vibration system. Each project team will consist of two students (with some exceptions possible). Final results and conclusions will be reported in the form of a conference-style paper and presentation.

Examinations: Two in-class examinations will be given, one around the middle of the semester and one at the end of the semester.

Grading:
Homework ……. 20%
Project …… 40%
First Exam ……. 20%
Second Exam ……. 20%

Prerequisite: ASEN 4123 Mechanical Vibrations or equivalent are recommended but not required

Preliminary Course Outline

- Overview of Linear Vibrations
  - Single Degree-of-freedom Systems – Free Vibrations
  - Single Degree-of-freedom Systems – Forced Vibrations
  - Introduction to Multiple Degree-of-freedom Systems – Free/Forced Vibrations

  [Class notes]
- Modeling of Dynamical Systems by Lagrange's Equations

  [Class notes]
- Introduction to Nonlinear Vibrations

  [Class notes; Chapter 1]
- Free Nonlinear Vibrations of Single Degree-of-freedom Systems – Undamped

  [Class notes; Chapter 2]
- Free Nonlinear Vibrations of Single Degree-of-freedom Systems – Damped

  [Class notes; Chapter 3]
- Forced Nonlinear Vibrations of Single Degree-of-freedom Systems – Undamped/Damped

  [Class notes; Chapter 4]
- Nonlinear Wave Propagation

  [Class notes; Section 8.1]