

NONLINEAR DYNAMICS

PHYS 471 & PHYS 571

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Office hours: 14:00 \rightarrow “ ∞ ”

Quarter: Winter, 2014-2015

Course Schedule: Tuesday, Thursday, 11:00 - 12:20

Room: 12-919

Objective: To provide an introduction to the basic concepts of Nonlinear Dynamics which are useful in the physical sciences.

Requirements: Final grades will be based on homework assignments. Problems assigned to graduate students will be more difficult and more numerous than those assigned to undergraduate students.

The following text will be used: None.

All texts that cover the material to the extent and depth that it should be covered are either out of print or too expensive. Supporting materials will be written by myself and be placed on the my web site for this course: <http://www.physics.drexel.edu/~bob/Courses.html> .

In lieu of a required text, two excellent books are available on the web. The first discusses entirely conservative systems:

W. S. Koon, M. W. Lo, J. E. Marsden, and S. D. Ross, *Dynamical Systems, the Three-Body Problem and Space Mission Design*

<http://www2.esm.vt.edu/sdross/books/>

An alternate way to find this is: type Shane D. Ross into your browser. He will be your first "hit". Go to his web page and toggle on 'books'.

The second deals mostly with dissipative systems: P. Cvitanovic and all the usual characters, *Chaos: Classical and Quantum*,

<http://chaosbook.org/chapters/ChaosBook.pdf>

An alternate way to find this is: type chaosbook into your browser and click on “Chaos: Classical and Quantum”.

Course Topics:

- Overview
- Challenge: Three Body Problem
- Predictable and Random: Deterministic and Stochastic
- Linear Dynamics: Flows and Maps
- Potentials, equilibria, stability, bifurcation diagrams
- Catastrophe Theory
- Logistic Map, Henon map, Other one dimensional maps
- Linearization around fixed points
- Numbers of Fixed Points: Euler Characteristic
- Bifurcation diagrams of one dimensional maps
- Periodic orbits
- Chaos in one dimensional maps
- Stretching and Lyapunov exponents
- Fractals
- Invariant Measure
- Ergodic hypothesis
- Topological Entropy
- Flows and the Uniqueness Theorem
- Some standard three dimensional flows: Duffing, van der Pol, Lorenz, Rössler

- Stretching and Folding, Tearing and Squeezing
- Horseshoes
- Symmetry
- Analysis tools: Geometric, Dynamical, Topological
- Measures: Fractals, Lyapunov Exponents, Knots
- A Program for Nonlinear Dynamics

The following texts and collections will be used to provide appropriate detail:

R. Gilmore and M. Lefranc
The Topology of Chaos
John Wiley and Sons, Inc., NY, 2002, 495 pp.
ISBN 0-471-40816-6

R. Gilmore and C. Letellier
The Symmetry of Chaos
Oxford University Press, NY, 2007

H. G. Solari, M. A. Natiello, and G. B. Mindlin
Nonlinear Dynamics, A Two Way Trip from Physics to Math
Institute of Physics: Briston and Philadelphia, 1996, 347 pp.
ISBN 0-7503-0380-8

E. A. Jackson
Perspectives of Nonlinear Dynamics, Vol. 1, 496 pp.
Perspectives of Nonlinear Dynamics, Vol. 2, 633 pp.
Cambridge University Press: Cambridge, 1991
ISBN 0-521-42632-4 + ISBN 0-521-42633-2

D. K. Arrowsmith and C. M. Place
An Introduction to Dynamical Systems
Cambridge University Press: Cambridge, 1990, ??? pp.
ISBN 0-521-31650-2

C. Letellier,
Chaos in Nature,
Singapore: World scientific, 2013

P. Cvitanovic
Universality in Chaos
Adam Hilger, Ltd.: Bristol, 19??, 513 pp.
ISBN 0-85274-765-9

R. H. Abraham and C. D. Shaw
Dynamics - The Geometry of Behavior
Aerial Press, Inc.: P.O.Box 1360, Santa Cruz, CA 95061, 19??, ??? pp.
ISBN 0-942344-00-6

R. H. Abraham and C. D. Shaw
Dynamics - The Geometry of Behavior
Part 0: *Manifolds and Mappings*
Part 1: *Periodic Behavior*
Part 2: *Chaotic Behavior*
Part 3: *Global Behavior* 122 pp., 136 Illus, ISBN 0-942344-03-4
Part 4: *Bifurcation Behavior*
Aerial Press, Inc.: P.O.Box 1360, Santa Cruz, CA 95061, 19??, ???pp.

D. Ruelle
Chaotic Evolution and Strange Attractors
Cambridge University Press: Cambridge, 1989, 96 pp.
ISBN 0-521-36830-8

A. J. Lichtenberg and M. A. Lieberman
Regular and Stochastic Motion
Springer-Verlag: New York, 1983, 499 pp.
ISBN 0-387-90707-6

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E. Ott
Chaos in Dynamical Systems
Cambridge University Press: Cambridge, 1993, 385 pp.
ISBN 0-521-43799-7

K. T. Alligood, T. D. Sauer, and J. A. Yorke
Chaos - An Introduction to Dynamical Systems
Springer-Verlag: New York, 19'96, 603 pp.
ISBN 0-387-94677-2

P. Collet and J.-P. Eckmann
Iterated Maps on the Interval as Dynamical Systems
Birkhäuser: Basel + Boston, 1980, 248 pp.
ISBN 3-7643-3026-0

B.-L. Hao
Chaos
World Scientific: Singapore, 1986, 576 pp.
ISBN 9971-966-51-4

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J. M. T. Thompson and H. B. Stewart
Nonlinear Dynamics and Chaos
John Wiley and Sons: Chichester, 1986, 376 pp.
ISBN 0-471-90960-2

P. Bergé, Y. Pomeau, and C. Vidal
Order Within Chaos
John Wiley and Sons: New York, 1984, 329 pp.
ISBN 0-471-84967-7

G. L. Baker and J. P. Gollub
Chaotic Dynamics, An Introduction
Cambridge University Press: Cambridge, 1990, 182 pp.
ISBN 0-521-38897-X

H. G. Schuster
Deterministic Chaos, An Introduction
VCH: Weinheim, 1995, 291 pp.
ISBN 3-527-29088-5

N. B. Tufillaro, T. Abbott, and J. Reilly
An Experimental Approach to Nonlinear Dynamics and Chaos
Addison-Wesley: Reading, MA, 199?, 420 pp.
ISBN 0-201-55441-0

D. Kaplan and L. Glass
Understanding Nonlinear Dynamics
Springer-Verlag: New York, 1995, 420 pp.
ISBN 0-387-94423-0

S. H. Strogatz
*Nonlinear Dynamics and Chaos, With Applications to Physics,
Biology, Chemistry, and Engineering*
Addison-Wesley: Reading, MA, 1994, 498 pp.
ISBN 0-201-54344-3