INSTRUCTION DIVISION
FIRST SEMESTER 2016-2017
Course Handout (Part II)

02/08/2016

Course No. : BITS F316
Course title : Nonlinear dynamics and Chaos
Instructor-in-charge : Rakesh Choubisa

1. **Scope and Objective of the course**
This is an introduction to Chaos. The student will be introduced to systems that demonstrate chaotic behavior, the vocabulary and tools to characterize chaotic systems, the route to chaos, and the fractal geometry of chaotic attractors.

2. **Textbook**

1) Robert C. Hilborn, " Chaos and Nonlinear dynamics – An introduction for scientists and engineers" Oxford University Press
2) Steven H. Strogatz, "Nonlinear dynamics and Chaos" West view Press

Reference Books
M Lakshmana and S. Rajasekar "Non Linear Dynamics" Springer
G. L. Baker and J. P. Gollub, "Chaotic dynamics – an introduction", Cambridge university press
Edward Ott, "Chaos in dynamical systems" Cambridge university press
James Gleick, "Chaos: Making of a new science" Penguin

3. **Course Plan**

Lecture Number.	**Learning objective**	**Topics to be covered**	**References**
1	Identify chaotic behavior and systems.	Introduction to chaos: linear and nonlinear systems, Bifurcations, routes to chaos, universality in chaos, Sensitivity to initial conditions, fractals, examples of chaotic systems	Hilborn: Chap 1 Ott: Chap 1
2-3	Choose the vocabulary to describe dynamical systems	Dynamical systems, Degrees of freedom, state space and trajectories of conservative and dissipative systems, fixed points, attractors, evolution of area in state space, dissipation and divergence theorem, stable and unstable fixed points, basin of attraction	Baker: Sec 2.1 Lakshmanan Chap. 3
4	Generate Poincare sections.	Poincare sections, State space diagrams and Poincare sections	Baker : Sec 2.2 and Sec 3.2
5	Identify the dynamics in 1-d state space	Fixed points in 1-D state space, Linear stability analysis, trajectories in 1-D state space, Impossibility of oscillations	Strogatz Sec 2.6 Lakshmanan 3.3-3.4 Hilborn Sec 3.6-

			3.8
6-10	Classify and identify the Bifurcations in 1-d state space	Saddle point, transcriticial, and pitchfork bifurcations; Examples of bifurcations – Lasers, Ecosystem, rotating hoop; Catastrope, Examples of Catastrophe	Strogatz Sec 3.0-3.7 Lakshmanan Chap:4
11-13	Analyse the stability of fixed points in 2-d state space	2-D state space; Linear stability analysis in 2-D state space – characteristic directions, eigenvalues, eigenvectors; classification of attractors – stable and unstable fixed points, Limit cycles; Hyperbolic fixed points, and structural stability; phase portraits; Example – Lotka Voltera model of competition	Strogatz Sec 5.1-5.2, 6.1-6.4
14-15	Classify the attractors in 2-D state space	Limit cycles, Poincare-Bendixson theorem, Example – glycolysis; No chaos in 2-D.	Strogatz Sec 7.0-7.3
16-18	Classify and identify the bifurcations in 2-D state space	Saddle node, Transcritical, and Pitchfork bifurcation; Hopf bifurcations; Oscillating chemical reactions.	Strogatz Sec 8.0-8.3
19-21	Describe period doubling route to chaos	Logistic map – a model of population variation; Period doubling behavior, chaos, periodic windows – fixed points, period doubling behavior, Chaos and Lyapunov exponent; Period doubling in dynamical systems – examples	Hilborn: Sec 5.3-5.4
22-23	Identify Quasi-periodic behavior	Introduction to Quasi-periodicity, frequency spectrum and attractor	Ott: Sec 6.1
24-25	Describe Quasi-periodic route to chaos	Quasi-periodicity and Poincare sections, Quasi-periodic route to chaos, Universality in quasi-periodic route to chaos, frequency locking, winding numbers	Hilborn: Sec6.1-6.6
26-27	Maps demonstrating quasi-periodicity	Circle Map, devil's staircase, chaos and universality	Hilborn: Sec 6.7-6.8
28-34	Three Dimensional State Space and Chaos	Duffing Oscillator, Rossler System, Lorentz equations and other electronic systems	Hilborn: Chapter:4 & Lakshmanan: Chapter:6 &7
35-36	Identify and characterize fractals	Introduction to fractals, dimension of fractals	Baker: Sec 5.1
37-38	Generate a fractal set in a dynamical system	Dynamical systems yielding a fractal set, Generalized Bakers Map	Ott: Sec 3.1-3.2
39-40	Calculate Lyapunov exponent	Lyapunov exponent and dimensions, Universal scaling and Lyapunov exponent, Determination of fractal dimensions in experiments, Reconstruction of an attractor	Baker: Sec 5.2-5.3 Ott: Sec 3.7-3.8
Remaining classes	Apply the theory to different physical phenomena.	Applications of chaos – pattern formation, chaos in lasers, DLA.	Baker: Chapter 7 Hilborn: Chapter 11

			Research papers

4. Evaluation Scheme

EC No.	Evaluation component	Duration	Weightage	Date, time and venue	Nature of component
1	Midsem test	1.5 hour	30 %	<TEST_1>	Closed book
2	Take Home+ tut. test	-	30 %	To be announced in class	-
4	Comprehensive exam	3 hours	40 %	<TEST_C>	Open & Closed Book

5. **Chamber consultation Hours** To be announced in the class

6. **Notices** To be displayed in the FD-III and Physics Department Notice Board

7. **Make-up policy** Only on a case-to-case basis on medical grounds, or pressing and urgent personal matters with prior intimation to IC.

(R Choubisa)

Instructor-in-charge