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**FIRST SEMESTER 2021-2022**

# Course Handout Part II

Date: 20-08-2021

In addition to part-I (General Handout for all courses appended to the time table) this portion gives further specific details regarding the course.

*Course No.* : BITS F316

## Course Title : Nonlinear dynamics and Chaos

## Instructor-in-Charge : ARAVINDA RAGHAVAN

**Scope and Objective of the Course:**

This course introduces the basic concepts of nonlinear dynamics and chaos. Through graphical and analytical techniques ordinary differential equations, especially those which are not exactly solvable, are qualitatively analyzed to understand the stability of systems. These ordinary differential equations represent dynamics in a wide range of systems that include buckling beams, turbulent flow of fluids, growth of insect population, progress of chemical reactions, war between nations, propagation of nerve impulses, and oscillation of electronic circuits.

**Textbooks:**

1. Steven H. Strogatz, “Nonlinear dynamics and Chaos” West view Press

**Reference books**

1. Robert C. Hilborn, “ Chaos and Nonlinear dynamics – An introduction for scientists and engineers” Oxford University Press
2. M Lakshmanan and S. Rajasekar “Non Linear Dynamics” Springer
3. Edward Ott, “Chaos in dynamical systems” Cambridge university press
4. James Gleick, “Chaos: Making of a new Science” Penguin

**Course Plan:**

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| **Lecture No.** | **Learning objectives** | **Topics to be covered** | **Chapter in the Text Book** |
| 1-2 | To trace the history and significance of non-linear dynamical systems | History and importance of non-linear dynamics, fractals and chaos, autonomous and non-autonomous systems, map of degrees of freedom and non-linearity | Chap. 1 |
| 3 | To illustrate non-linearity and chaos through logistic maps | Introduction to logistic maps | 10.0-10.2 |
| 4-8 | To introduce the phase space and graphically analyze the stability of one-dimenional systems | Phase space flows on the line, Linear stability analysis, Fixed points, phase space trajectory | Chap 2 |
| 9-14 | To apply bifurcation analysis to study practical 1D systems. | Bifucrcations – Saddle-node, transcriticial, and pitchfork bifurcations | Chap.3 |
| 15-19 | To transpose the problem of non-uniform oscillation to phase space dynamics on a circle. | Phase space flows on the circle | Chap.4 |
| 20-23 | To break down higher order differential equations into first order differential equations to analyze the stability of 2Dsystems | Phase space flows in two dimensions | Chap.5 |
| 24-29 | To investigate and classify fixed points in 2D | Phase portraits, Existence and Uniqueness, fixed points, conservative systems | Sec. 6.0-6.7 |
| 30-32 | To study the unique fixed point in 2D – Limit cycles | Limit cycles, Poincare-Bendixson theorem | Sec. 7.0, 7.1,7.3-7.5 |
| 33-35 | To apply bifurcation analysis to study practical 2D systems. | Bifurcations in two dimensional phase space | Sec. 8.0-8.3, 8.6 |
| 35-36 | To apply concepts of non-linear dynamics to chaotic systems and identify the characteristics of chaotic dynamics | Lorenz equations | Sec. 9.0-9.2 |
| 37-38 | To analyze logistical maps | Fixed points, period doubling, Liapunov exponent | 10.3-10.6 |
| 39-40 | To introduce fractals and its application to understand phase space dynamics | Cantor Set, Dimensions, Self-similar fractals, Strange attractors, Application to Henon map | Chap. 11, Chap. 12.1-12.2 |
| 40-42 | To analysis student projects | Conclusion and outlook |  |

**Evaluation Scheme:**

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| **Component** | **Duration** | **Weightage (%)** | **Date & Time** | **Nature of Component** |
| Mid-semester exam | 1.5 hours | 35 % | 22/10/2021 9.00 - 10.30AM | Closed book |
| Quiz/Project work |  | 25 % |  | Open Book |
| Comprehensive exam | 2 hours | 40 % | 22/12 FN | Closed Book |

**Chamber Consultation Hour:** To be announced in the class

**Notices:** Notices will be displayed either on the Physics department notice board and the course management system.

**Make-up Policy:** It is applicable to the following two cases and it is permissible on production of evidential documents.

**(i)** Debilitating illness.

**(ii)** Out of station with prior permission from the Institute.

**Academic Honesty and Integrity Policy**: Academic honesty and integrity are to be maintained by all the students throughout the semester and no type of academic dishonesty is acceptable.

**INSTRUCTOR-IN-CHARGE**