IIT Mandi
Proposal for a New Course

Course number : **Nonlinear Dynamics and Chaos**
Course Name : MA 560
Credit Distribution : 3-0-0-3
Intended for : Elective for M.Sc./ MTech/PhD/BTech (All Branches)
Prerequisite : IC 110, IC 111 for BTech, Ordinary Differential Equations for M.Sc/MTech/PhD
Mutual Exclusion : None

1. Preamble:

It is an applied mathematics course designed to provide an introduction to the theory and basic concepts of Nonlinear Dynamics and Chaos. This course will concentrate on simple models of dynamical systems, their relevance to natural phenomena. The main goal of this course is to introduce and describe nonlinear phenomena in physical systems by only using a minimum background in physics and mathematics. The emphasis will be on nonlinear phenomena that may be described by few variables that evolve with time. There will be problem sets that will require use of computer. The computer exercises will be mainly based on the use of MATLAB, but students will be free to use different software tools as desired.

2. Course Modules with quantitative lecture hours:

Module 1: Introduction to Nonlinear Dynamics and Chaos, Recent applications of Chaos, Computer and Chaos, Dynamical view of the world (3hours)

Module 2: Basics of nonlinear science: Dynamics, Representations of Dynamical Systems, Types of Dynamical Systems, Nonlinearity, Vector Fields of Nonlinear Systems, Nonlinear systems and their classification, Dissipative Systems, Deterministic vs. Stochastic Systems, Degree of Freedom, State Space, Phase Space, Attractor (5 hours)

Module 3: Existence and uniqueness of solutions, Fixed points and Linearization, Flows on line, Fixed Points and its Stability, Analytical Approach, Graphical approach, Simulation of Equations (5 hours)

Module 4: Elementary Bifurcation Theory: Saddle Node, Transcritical, Pitchfork, Imperfect, Hopf bifurcation (4 hours)

Module 5: Two dimensional Flows, Simple Harmonic Mass-Spring Oscillator (4 hours)

Module 6: Limit Cycle, Ruling out closed orbits, Poincare Benedixson theorem (4 hours)

Module 7: Chaos and tools for its Detection: Chaos and Butterfly effect (SDIC), Center manifold theory and Poincare maps, Lyapunov Exponents, Power spectrum, phase, Stable and Unstable Manifolds, Frequency Spectra of Orbits, Dynamics on a Torus, analysis of Chaotic Time Series. Examples of chaotic systems: Lorenz Equations, Application of Chaos in sending secret messages, Rossler Equations, Chua's Circuit, Introduction to Fractals, Dimensions of fractals, Cantor Set and Koch curve (6 hours)

Module 8: One dimensional map, Logistic Map, Henon map, Period doubling Route to chaos, Feigenbaum constants (5 hours)

Module 9: Statistical description of Chaotic Systems: The concepts of invariant measure, Sinai-Ruelle-Bowen measures, ergodicity and mixing, Lyapunov exponents, and the dynamical (Kolmogorov-Sinai) entropy, and connecting them to the fractal dimension of invariant sets, and to the escape rate from a chaotic repeller. (6 hours)

Laboratory/practical/tutorial Modules: NA

3. **Text books :**

1. Nonlinear Dynamics: a two-way trip from Physics to Maths, H.G. Solari, M.A. Natiello and G.B. Mindlin, Overseas publication, 2019.
2. Jordan, D. W., and P. Smith. Nonlinear Ordinary Differential Equations. New York,Oxford University Press 2007

4. **References:**

3. Chaos: An Introduction to Dynamical systems, K. Allgood, T.Sauer, J.A.Yorke, Springer Verlag 1998.
4. Does God Play a Dice? The Mathematics of Chaos, Ian Stewart, Blackwell, NewYork.
5. Nonlinear Dynamics Integrability Chaos and Pattern, Laksmanan M

Rajsekhar, Springer.
6. Chaotic and Fractal Dynamics, F.C. Moon, Wiley
7. M W Hirsch, S Smale, R L Devaney, Differential Equations, Dynamical Systems, and an Introduction to Chaos
8. Anatole Katok et Boris Hasselblatt, Introduction to the modern theory of dynamical systems, Cambridge University Press, 1995
9. Peter Walters, An introduction to ergodic theory, Springer, 1982

5. Similarity with the existing courses:
(Similarity content is declared as per the number of lecture hours on similar topics)

S. No.		Course Code	Similarity Content	Approx. % of Content
1.		Nil	Nil	Nil

6. Justification of new course proposal if cumulative similarity content is >30%: Not Applicable