Course Type	Course Code	Name of Course	L	T	P	Credit
DE	NMED522	Nonlinear Oscillations	3	0	0	3

Course Objective

- This course emphasizes how the presence of nonlinearities in a system may introduce totally novel phenomena. By their nature, exact solutions of nonlinear ordinary differential equations are rarely obtainable and, in most cases, numerical techniques for solving equations are adopted.
- This course would help students to develop analytical minds to analyze nonlinear systems which exist in real-life applications.

Learning Outcomes

Upon successful completion of this course, students will be able to:

- Apply the concepts of nonlinear oscillation to solve practical problems in this field.
- Estimate quantitatively the solutions by using energy, harmonic balance and averaging methods.
- Get exposure to bifurcation and chaos.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Introduction: Phase diagram, damped linear oscillator, nonlinear damping, limit cycles, parameter-dependent conservative systems.	04	Students will learn how to deduce important characteristics of the solutions of differential equations without actually solving them.
2	Plane autonomous systems and linearization: The general phase plane, linear approximation at equilibrium points, general solution of linear autonomous plane systems, phase paths, stable and unstable nodes, saddle point, stable and unstable spirals, homoclinic and heteroclinic paths.	05	The main features of the phase plane of autonomous systems will be introduced.
3	Periodic solutions: Averaging methods, energy-balance method for limit cycles, amplitude and frequency estimates in polar coordinates, equivalent linear equation by harmonic balance.	04	The students will be able to assess the complexity in strongly nonlinear cases.
4	Perturbation methods: Forced oscillations of nonautonomous systems, Duffing's equation, forced oscillations far from resonance and near resonance with weak excitation, soft and hard springs, forced oscillation of a self-excited equation, homoclinic bifurcation.	06	The students will learn various perturbation techniques for solving system equations which contain a small nonlinear parameter.
5	Singular perturbation methods: non-uniform approximations to functions on an interval, coordinate perturbation, time-scaling for series solutions of autonomous equations, multiple-scale technique applied to saddle points and nodes.	05	The students will understand singular perturbations for non-uniform expansions.
6	Forced oscillations: Harmonic and subharmonic response, the jump phenomenon, van der Pol oscillator, subharmonics of Duffing's equation by	06	The students will learn to investigate forced stability of harmonic and subharmonic

	perturbation.		responses and entrainment using the van der Pol plane method.
7	Stability: Poincare stability, stability of time solutions, Liapunov stability, structure of n-dimensional inhomogeneous linear systems, stability and boundedness for linear systems, linear approximation at equilibrium points for first-order systems in n variables, Mathieu's equation arising from a Duffing equation.	06	The students will be able to do stability analysis.
	Bifurcations and manifolds: Simple bifurcations, the fold and the cusp, structural stability, Hopfbifurcations, higher order systems manifolds, some characteristic features of chaotic oscillations.	06	The students will be familiarize with different nonlinear phenomena such as homoclinic bifurcation, strange attractors and chaos.
Total		42	

Text Book:

1. Nonlinear Ordinary Differential Equations: An Introduction to Dynamical Systems, 3rd edition (1999) by D.W.Jordan and P.Smith, Oxford University press.

Reference Books:

1. Nonlinear Oscillations by Ali HasanNayfeh and Dean T. Mook, Wiley Classics Library Edition (1995).
2. Introduction to Nonlinear Oscillations by Vladimir I. Nekorkin, Higher Education Press, Wiley-VCH (2015).