Course: M.Sc (Physics)

Semester	1
Paper Number	2 (MPHC4112)
Paper Title	Classical Mechanics I and Non-Linear Dynamics
No. of Credits	6
Course description/objective	**Group A:** This course is set to develop understanding on Classical Mechanics at an advance level with a brief revision of the undergraduate level course in the same subject. The student will be able to apply the Lagrangian as well as Hamiltonian techniques for a variety of problems. Further the course helps the students to understand the link between Classical Mechanics and advanced areas like Quantum / Statistical Physics. **Group B:** This course aims to provide an understanding about chaotic and non-linear systems. It aims to make a comprehensive study of the tools to analyse, quantify and understand chaos in, both discrete maps as well as continuous systems. It also incorporates a part where students will be able to learn and use these tools hands on through a computational lab and understand these systems even better.
Course Outcome	**Group A** CO1: Thorough Revision on Lagrangian and Hamiltonian approaches helps the students to build confidence in solving problems. CO2: Mathematical analysis with the Principles of Variational Calculus is an important tool in understanding classical mechanical system and it enables the students to derive other equation of motion. CO3: Canonical transformations and Poisson Bracket formalism help the students in further learning in advanced areas like Quantum Mechanics. CO4: Rigid body dynamics is understood in terms of the Eulerian angles to explain rotation, precession and nutation. **Group B** CO1: Gain knowledge about classical non-linear systems, both discrete and continuous. CO2: Learn techniques to analyze non-linear 1 dimensional iterative maps and understand their connection to continuous systems CO3: Understand chaos mathematically CO4: Learn phase space analysis of 1 dimensional and higher dimensional linear and non-linear systems CO5: Learn different tools for analyzing chaos and chaotic systems
Syllabus	**Group A: Classical Mechanics–I** Revision of Canonical formalism: Lagrangian and Hamiltonians, P.B formalism. Rotations, Rigid bodies and Classical Scattering Theory; An overview of the Lagrangian formalism; Some specific applications of Lagarange's equation; small oscillations, normal modes and frequencies. [6 lectures] Hamilton's principle; Calculus of variations; Hamilton's principle; Lagrange's equation from Hamilton's principle; Legendre transformation and Hamilton's canonical equations; Canonical equations from a variational principle; Principle of least action. [6 lectures] Canonical transformations; Generating functions; examples of canonical transformations; group property; Integral variants of Poincare; Lagrange and Poisson

brackets; Infinitesimal canonical transformations;

Conservation theorem in Poisson bracket formalism; Jacobi's identity; Angular momentum and Poisson bracket relations.

[8 lectures]

Action angle variables, Hamilton-Jacobi theory, The Hamilton Jacobi equation for Hamilton's principle function; The harmonic oscillator problem; Hamilton's characteristic function;

[6 lectures]

Rigid bodies; Independent coordinates; orthogonal transformations and rotations (finite and infinitesimal);

Euler's theorem, Euler angles; Inertia tensor and principal axis system; Euler's equations; Heavy symmetrical top with precession and nutation.

[10 lectures]

<u>Group B: Non-Linear Dynamics</u>

Theory:

Physics of nonlinear systems, dynamical equations and constants of motion, phase space, fixed points, stability analysis, bifurcations and their classifications, Poincarè section and iterative maps.

[8 lectures]

One dimensional non-invertible maps, period doubling and universality, intermittency, invariant measure, Lyapunov exponents. Two dimensional systems, Henon map, idea of attractors, Lorenz equations.

[8 lectures]

Fractal geometry and concept of dimensions.

[4 lectures]

Introduction to Hamiltonian systems and integrability.

[4 lectures]

<u>Computation Lab:</u>

Discrete time problems: Time-series analysis, Iterative maps and Cobweb diagrams, The logistic map, Bifurcation, State space methods: orbits, Chaos and sensitivity to initial conditions.

Continuous systems: The damped driven pendulum: Expected features, approach to chaos through the period doubling route, other non-linear oscillators.

[12 lectures]

<u>Group A:</u>

1. Classical Mechanics : Goldstein, Poole & Safko, Pearson, 3 rd ed 2011

	2. Classical Mechanics : John R. Taylor, University Science Books, 2005 3. Classical Mechanics : Walter Greiner, Springer, 2009 4. Theoretical Mechanics: M. R. Spiegel, Schaum Series, McGraw Hill, 2017 **Group B**: 1. Chaos and Fractals - An Elementary Introduction, D.P. Feldman, OUP 2. Nonlinear Dynamicsand Chaos, S. H. Strogatz, Perseus Books 3.Chaotic Dynamics - an introduction, G. L. Baker and J. P. Gollub, CUP 4. The NonlinearWorkbook, Willi - Hans Steeb, World Scientific (3rd edition) 5. Nonlinear Physics with Mathematica for Scientists and Engineers, R. H. Enns and G. C. McGuire, Berkhauser publications.
Evaluation	Total: 100 Group A: CIA (10) + 40 (End Semester Examination) Group B: Theory (30) + Computation Lab (20) Theory: 5 (CIA) + 25 (End Semester Examination) Computation Lab: 5 (LNB) + 15 (End Semester Examination)