B.Sc. Physical Sciences with Physics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 7-2 : CLASSICAL DYNAMICS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Classical Dynamics DSE 7-2	4	3	1	0	

COURSE OBJECTIVES

- To introduce variational principles and their application to derive equations of motion for complex systems with constraints.
- To deepen the understanding of foundational principles of Classical Mechanics including Lagrangian and Hamiltonian formalisms
- To Develop an understanding of symmetries and conservation laws through Noether's Theorem
- To Analyze the motion of particles in central force fields, including planetary motion and scattering.
- To Explore the behavior of systems undergoing small oscillations, with emphasis on coupled systems and normal modes
- To describe motion in non-inertial frames and the dynamics of rigid bodies.

LEARNING OUTCOMES

By the end of this course, students will be able to:

- Apply the calculus of variations to derive the Euler-Lagrange equations and use them to analyze constrained mechanical systems.
- Use generalized coordinates and cyclic variables to simplify and solve problems in classical dynamics.
- Formulate and analyze mechanical systems using Lagrangian and Hamiltonian formalisms.
- Construct and analyze Hamiltonian systems, including canonical equations, and Poisson brackets.
- Analyze the motion of particles under central forces and solve scattering problems.
- Understand and compute normal modes and normal frequencies in small oscillation problems, including coupled oscillators.

- Describe motion in rotating frames and identify fictitious forces like centrifugal and Coriolis forces.
- Understand the dynamics of rigid bodies.
- Develop critical thinking and problem-solving skills

SYLLABUS OF DSE 7-2
THEORY COMPONENT
(Hours: 45)

Unit I **(16 Hours)**

Lagrangian and Hamiltonian Formulation
Calculus of Variation with examples, Generalized coordinates, Hamilton's Principle and Euler-Lagrange equations of motion. Constrained systems (holonomic). Applications of Euler-Lagrange Equation. Generalised Momenta and forces, Cyclic coordinates. Noether's Theorem and Conservation Principles.
Legendre transformation, Hamilton's equations and applications. Phase space and phase trajectories. Poisson brackets and its properties.

Unit II **(12 Hours)**

Central Force and Orbital Mechanics
Feature of Motion under Central Forces. Reduction of two body problem to equivalent one body problem. Effective potential, Energy diagrams. Equation of motion under central force and its formal solution. Classification and Stability of orbits**,** Conditions for Closed Orbits (Bertrand's Theorem). Kepler's laws for planetary motion, Scattering in central force field with example of Rutherford scattering, Transformation of scattering problem to laboratory coordinates.

Unit III **(9 Hours)**

Theory of small oscillations
Stable equilibrium and small amplitude oscillations. Solution of Eigenvalue equation. Normal modes and normal frequencies of oscillations. Damped and Forced Oscillations, Coupled oscillators.
Non-Inertial Frames
Non-inertial frames and fictitious forces. Uniformly rotating frames. Centrifugal and Coriolis forces.

Unit IV **(8 Hours)**

Rigid Body Dynamics
Rotation matrices, Euler angles. Angular momentum and rotational kinetic energy of rigid bodies, Moment of Inertia Tensor. Euler's equations of motion for rigid body. Torque-free motion.

REFERENCES

Essential Readings

1. The Feynman Lectures on Physics, Volume I and II, R. P. Feynman, R. B. Leighton and M. Sands, California Institute of Technology (2010).
2. Classical Mechanics, H. Goldstein, C. P. Poole, J. L. Safko, 3/e, Pearson Education (2014).
3. Classical Mechanics, John R. Taylor, University Science Books (2005).
4. Classical Mechanics, R. Douglas Gregory, Cambridge University Press (2015).
5. Mechanics, L. D. Landau and E. M. Lifshitz, Pergamon (2010).
6. Classical Mechanics, P. S. Joag, N. C. Rana, McGraw Hall Education (2017).
7. Classical Mechanics, Tai L. Chow, CRC Press (2013).

Additional Readings

1. Analytical Mechanics: Solutions to Problems in Classical Physics, I. Merches, D. Radu, CRC Press (2015).
2. Solved Problems in Classical Mechanics, O. L. Delange and J. Pierrus, Oxford University Press (2010).
3. Classical Dynamics of particles and system, S. T. Thornton, J. B. Marion, 2012, Cengage Learning.
4. Theory and Problems of Theoretical Mechanics, Murray R. Spiegel, McGraw Hill Education (1977).