Syllabus template

Semester: 7	
Programme: Mathematics	
Course: Mechanics-2	
Paper code: C4MT230711T	**Credits:4**
Hours/week: 4	
Category: Core/MDC/SEC/VAC: Major	
Theory / Practical / Composite: Theory	
No of Modules: Nil	

Course Overview: Mechanics-2

This course develops the mechanics of particles and rigid bodies from basic conservation laws to advanced analytical mechanics. It begins with Newtonian concepts such as momentum, energy, centre of mass, and constraints, then moves to rigid body kinematics and dynamics, virtual work, calculus of variations, Lagrangian mechanics, and symmetry principles including Noether's theorem**.**

Course Outcome: On successful completion of the course a student will be able to do the following:

1. **Recall and explain** the fundamental concepts of a system of particles, including centre of mass, linear momentum, angular momentum, and energy conservation.
2. **Classify and interpret** different types of constraints, generalized coordinates, and degrees of freedom in mechanical systems.
3. **Apply** the principles of rigid body kinematics to determine translational and rotational motion, inertia tensor, principal axes, and principal moments of inertia.
4. **Analyze** the motion of rigid bodies and systems of particles using parallel axis theorem, perpendicular axis theorem, and angular momentum decomposition.
5. **Demonstrate** the principle of virtual work and D'Alembert's principle for free and constrained mechanical systems.
6. **Solve** standard problems in calculus of variations, including shortest path, brachistochrone, minimal surface, and geodesic problems.
7. **Derive and use** Euler–Lagrange equations and Lagrange's equations for unconstrained and holonomically constrained systems.
8. **Evaluate** the role of cyclic coordinates, generalized momentum, and conservation laws in Lagrangian mechanics.
9. **Relate and interpret** symmetry properties of physical systems to conservation laws using Noether's theorem.
10. **Construct** mathematical models of mechanical systems such as a particle on a cylinder and a block on an inclined plane using Lagrangian formulation.

Prerequisites:				
SYLLABUS				
UNIT/Module	**CONTENT**	**NUMBER OF CLASSES**	**CO Mapping**	**COGNITIVE LEVEL**
I.	Mechanics of a system of particles: Conservation theorems for Linear and Angular momentum, Centre of mass, Kinetic and potential energy for such a system.**[3]** Constraints and their classification with examples: Holonomic constraints and concept of generalized co-ordinates-degrees of freedom of simple system like a free rigid body and a rigid body rotating about an axis fixed in space. Rigidity constraint as an example of scleronomic type constraint. Bead sliding on a uniformly rotating wire as an example of rheonomic constraint. Unilateral & bilateral constraints **[4]**	**7 classes**	**CO1, CO2**	**K2, K3, K4**
II.	Brief account of rigid body motion: Why a rigid body can have only translational and rotational motion-a consequence of invariance of rigidity constraint w.r.to time. Expression of velocity at any arbitrary point of a rigid body having translational velocity $\vec{u}$ and angular velocity $\vec{\omega}$ (no derivation). Rotation of a rigid body about an axis fixed in space: Inertia tensor at any point of a rigid body, its symmetry and orthogonal diagonalizability, existence of principal axes and principal	**25 classes**	**CO3, CO4**	**K3, K4**

	moments of inertia-simple illustrations. Parallel and Perpendicular Axis theorems and their uses in some simple cases. Centre of mass of a rigid body and its properties: Total angular momentum of the rigid body being the resultant of two angular momenta, viz, angular momentum due to the motion of the centre of mass and the angular momentum relative to the centre of mass. Simple problems on moment of inertia and on rotational motion of a rigid body about an axis fixed in space**. [15**] Principle of Virtual work & its converse: Ideas of impossible displacement, Virtual displacement, Virtual work. Principle of virtual work for a free rigid body as well as for a rigid body moving subject tone or more constraints .D'Alembert's Principle and the Lagrangian formulation [as an illustration , motion of a single particle moving in a plane using plane polar co-ordinates], simple problems on virtual work **[10]**			
III.	Calculus of Variations : Shortest path b/w two points in a plane; Brachistochrone problem; Minimal surface of revolution ;Shortest path b/w two points on a sphere(geodesic). Derivation of Euler Lagrange's equations from Hamilton's Principle for two or more dependent variables so as to be applicable to Lagrangian formulation**.[6]**	**6 classes**	**CO5**	**K3, K4**

IV.	Lagrangian Mechanics: Ideas of configuration space, generalized co-ordinates, generalized velocities, Action integral, Conservation theorems and symmetry properties of Lagrangian, generalized momentum and concepts of cyclic or ignorable co-ordinates, Lagrange's equations for unconstrained systems, Lagrange's equations for systems subject to holonomic constraints: stationary nature of Action integral. Illustrative examples: particle confined to move on a cylinder and block sliding on an inclined plane. **[10]** Noether's theorem on symmetry of space-time: connection b/w conservation laws and symmetry, interpretation of Noether's theorem through the example of conservation law(s)in an inverse square type central force field [**4**]	**14 classes**	**CO6, CO7**	**K2, K3, K4, K5**
Text Books				
1. Classical Mechanics: Herbert Goldstein				
2. Classical Mechanics: Rana, Joag				
Suggested readings				
Web Resources				
Evaluation: Theory CIA: **20+5+5=30** Semester Exam: **70**				
Paper Structure for Theory Semester Exam Module: 7 questions each of **10** marks out of a set of **13** questions.				

Course outcomes (COs) and Cognitive Level Mapping

COs	CO Description	Cognitive levels
CO1	Explain and apply conservation laws of linear momentum, angular momentum, and energy to analyze the dynamics of systems of particles, including centre of mass motion.	**K2, K3**
CO2	Classify different types of constraints (holonomic, non-holonomic, scleronomic, rheonomic, unilateral, bilateral) and determine degrees of freedom using generalized coordinates in simple mechanical systems.	**K2, K4**
CO3	Analyze rigid body motion using concepts of translational and rotational motion, inertia tensor, principal axes, and apply parallel and perpendicular axis theorems to solve problems.	**K3, K4**
CO4	Apply the principles of virtual work and D'Alembert's principle to formulate equations of motion for constrained mechanical systems and solve related problems.	**K3, K4**
CO5	Formulate and solve variational problems using Euler–Lagrange equations derived from Hamilton's principle for physical systems.	**K3, K4**
CO6	Develop Lagrangian formulations for unconstrained and holonomically constrained systems, and analyze motion using generalized coordinates and conservation laws.	**K3, K4, K5**
CO7	Interpret Noether's theorem and establish the relationship between symmetries and conservation laws in classical mechanical systems.	**K2, K4**