Syllabus template

Semester: VII	
Programme : PHYSICS	
Course : Advanced Classical Mechanics & Classical Electrodynamics	
Paper code: M2C4PH260121T	**Credits: 2+2**
Hours/week : 4	
Category: Core/MDC/SEC/VAC : CORE(Major)	
Theory / Practical / Composite : THEORY	
No of Modules : 2	

Course Overview: Advanced Classical Mechanics

This course develops advanced concepts in classical mechanics with emphasis on rotational motion, oscillatory systems and canonical formulations. It begins with rigid body dynamics, covering rotations, Euler angles, inertia tensor, Euler's equations and the motion of a heavy symmetric top. The course then introduces the theory of small oscillations, focusing on eigenvalue method, normal modes and normal coordinates. Canonical transformations and their properties are studied through generating functions, Poisson brackets and integral invariants, leading to the formulation of equations of motion.

Course Overview: Classical Electrodynamics

This course is an advanced study of electromagnetic radiation and wave phenomena arising from time-varying charge and current distributions. Beginning with scalar and vector potentials and gauge transformations, the course develops the mathematical foundations necessary to solve Maxwell's equations using Green's function techniques. It then examines radiation from localized sources, including dipole radiation and antenna systems. The latter part of the course focuses on radiation from moving charges, covering both non-relativistic and relativistic regimes. Important physical processes such as bremsstrahlung, synchrotron radiation, and Cherenkov radiation are discussed, along with the total power radiated by accelerated charges. The course integrates mathematical rigor with physical interpretation of radiation systems.

Course Outcome: Advanced Classical Mechanics

1. The students gain an understanding of the motion of rigid bodies.
2. From this course, the students gain an understanding of small oscillations and normal modes.
3. The students learn about canonical transformations and Poisson brackets.

Course Outcome: Classical Electrodynamics

1. The students represent the fields in terms of the scalar and vector potentials and learn how to apply the gauge transformations
2. The solution of the inhomogeneous wave equation using Green's function methods for time-dependent electromagnetic sources.
3. The students can analyse the concept of electromagnetic radiation from localized oscillating sources, including electric dipole radiation, angular distribution of radiated power, and radiation from a center-fed linear antenna.

4. The students can derive and interpret Liénard–Wiechert potentials and fields for moving point charges under uniform and accelerated motion.
5. The students would be able to distinguish between radiation from nonrelativistic and relativistic accelerated charges and explain some important physical mechanisms.
6. The students can analyse angular radiation distributions, and evaluate the total power radiated by an accelerated charge.

Prerequisites: A basic course on electromagnetic theory

SYLLABUS

UNIT/Module	CONTENT	HOURS or NUMBER OF CLASSES	CO Mapping	COGNITIVE LEVEL
I.	**Advanced Classical Mechanics** **A) Rigid Body Dynamics:** Generalized 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.	**9L**	CO1	K2, K3, K4, K5, K6
	B) Small oscillations: the eigenvalue problem and the principal axis transformation, frequencies of free vibration and normal coordinates, normal modes.	**5L**	CO2	K2, K3, K4, K5, K6
	C **Canonical transformations:** Generating functions; examples of canonical transformations; group property; Integral invariants of Poincare; Lagrange and Poisson brackets; Infinitesimal canonical transformations; Conservation theorem in Poisson bracket formalism; Jacobi's identity; Angular momentum and Poisson bracket relations; equations of motion.	**10L**	CO3	K2, K4, K5
II.	**CLASSICAL ELECTRODYNAMICS** **A)** Vector and scalar potentials, Gauge transformations: Lorentz and Coulomb gauge,	**5L**	CO1, CO2	K1, K2, K3, K4

	Helmholtz theorem (with proof); Inhomogeneous wave equation; Green function for the inhomogeneous wave equation.			
	B) Simple radiating systems: Fields and radiation of a localized oscillating source, electric dipole fields and radiation, angular distribution of radiation due to an oscillating dipole. Center-fed linear antenna.	**5L**	CO3	K2, K3, K4
	C) Radiation by moving charges: Lienard-Wiechert potentials and fields for a point charge, charges moving with uniform velocity, accelerated charges, radiation from accelerated charges moving (i) with low velocities and (ii) with relativistic velocities, bremsstrahlung, synchrotron radiation; Cherenkov radiation.	**11L**	CO4, CO5	K2, K3, K4, K5
	D) Total power radiated by an accelerated charge – Larmor's formula, angular distribution of radiation.	**3L**	CO6	K3, K4, K5, K6

Text Books

MODULE – A

1. Introduction to Classical Mechanics: R.G. Takwale & P.S. Puranik (Tata McGraw-Hill).
2. Classical Mechanics: John R. Taylor (University Science Books)
3. Introduction to Classical Mechanics: With Problems and Solutions: David J. Morin (Cambridge University Press)
4. Classical Mechanics: K.C. Gupta (S. Chand Publishing)
5. Classical Mechanics: A course of Lectures: A.K. Raychaudhuri (Oxford University Press).

MODULE – B

1. Classical Electrodynamics (3rd edition, Wiley) – J.D. Jackson
2. Introduction to Electrodynamics (4th edition, Pearson)– D. J. Griffiths
3. Foundations of Electromagnetic Theory (4th edition, Pearson) – Reitz, Milford and Christy
4. Principles of Electromagnetics – Sadiku and Kulkarni (6th edition, OUP)

Suggested readings

1. Classical Mechanics: H. Goldstein, C. Poole & J. Safko (Pearson).
2. Classical Mechanics: N.C. Rana & P.S. Joag (Tata McGraw-Hill).
3. Classical Dynamics of Particles and Systems, Thornton and Marion (Cengage India Private Limited)
4. Classical Electricity and Magnetism (2nd edition, Dover Publications) – Panofsky and Phillips
5. Interpretation of Classical Electromagnetism, W.G.V. Rosser (Springer Dordrecht)

Web Resources (OER)
1. **Classical Mechanics by Richard Fitzpatrick (https://farside.ph.utexas.edu/teaching/301/301.pdf)**
2. **MIT OCW - CLassical MEchanics III (https://ocw.mit.edu/courses/8-09-classical-mechanics-iii-fall-2014/)**
3. **Classical Electromagnetism by Richard Fitzpatrick (https://farside.ph.utexas.edu/teaching/jk1/Electromagnetism.pdf)**
4. **Classical Electrodynamics - Uppsala University (https://www.uu.se/en/study/course?query=1FA257)**
Evaluation: Theory CIA: 30 (2x10 + 5/assgn.+ 5/attn.). Semester Exam: 35
Paper Structure for Theory Semester Exam Module : For each 35 mark module, 15 Marks from 3 marks questions (5 out of 7) 20 Marks from 10 marks questions (2 out of 3)

Course outcomes (COs) for Advanced Classical Mechanics and Cognitive Level Mapping

Cos	CO Description	Cognitive levels
CO1	The students gain an understanding of the motion of rigid bodies.	K2, K3, K4, K5, K6
CO2	From this course, the students gain an understanding of small oscillations and normal modes.	K2, K3, K4, K5, K6
CO3	The students learn about canonical transformations and Poisson brackets.	K2, K4, K5

Course outcomes (COs) for Classical Electrodynamics and Cognitive Level Mapping

COs	CO Description	Cognitive levels
CO1	The students represent the fields in terms of the scalar and vector potentials and learn how to apply the gauge transformations	K1, K2, K3
CO2	The solution of the inhomogeneous wave equation using Green's function methods for time-dependent electromagnetic sources.	K2, K3, K4
CO3	The students can analyse the concept of electromagnetic radiation from localized oscillating sources, including electric dipole radiation, angular distribution of radiated power, and radiation from a center-fed linear antenna.	K2, K3, K4
CO4	The students can derive and interpret Liénard–Wiechert potentials and fields for moving point charges under uniform and accelerated motion.	K2, K3, K4
CO5	The students would be able to distinguish between radiation from nonrelativistic and relativistic accelerated	K2, K4, K5

	charges and explain some important physical mechanisms.	
CO6	The students can analyse angular radiation distributions, and evaluate the total power radiated by an accelerated charge.	K3, K4, K5, K6