

No. of Printed Pages : 10

MPH-002/MPH-003

M. SC. (PHYSICS) (MSCPH)

Term-End Examination

December, 2025

MPH-002 : CLASSICAL MECHANICS-I

AND

MPH-003 : ELECTROMAGNETIC THEORY

Time : 3 Hours

Maximum Marks : 50

Instructions :

- 1. Students registered for both MPH-002 and MPH-003 courses should answer both the question papers in two separate answer books entering their enrolment number, course code and course title clearly on both the answer books.*
- 2. Students who have registered for any of the MPH-002 or MPH-003 should answer the relevant question paper after entering their enrolment number, course code and course title on the answer book.*

Part-A**MPH-002 : CLASSICAL MECHANICS—I***Time : $1\frac{1}{2}$ Hours**Maximum Marks : 25*

Note : *All questions are compulsory. Internal choices are given. You may use a calculator.*

1. Attempt any *one* part : 1×5=5
- (a) Consider the head-on elastic collision between two particles of masses m_1 and m_2 which are both travelling in the same direction with velocities u_1 and u_2 , respectively. If the kinetic energy of the two particles are equal before the collision, calculate the values of m_1/m_2 and u_1/u_2 , for which the mass m_2 will be at rest after the collision. 5
- (b) Define constraints. Using the motion of a simple pendulum as an example, show

the effect of constraints in terms of the number of dynamical degrees of freedom of the system. Clearly mark the equations of constraints. 5

2. Attempt any *one* part : $1 \times 5 = 5$

(a) Derive the Euler-Lagrange equations of motion for the Lagrangian,

$$L = \frac{1}{2} m \dot{x}^2 - \frac{1}{2} k(x - a)^2. \quad \text{Define the}$$

energy function for a system with the Lagrangian L . Derive the energy function for the given Lagrangian. 5

(b) If l is the angular momentum for the system undergoing motion along a spiral path of the form $r = r_0 e^{a\theta}$. Find the effective potential $V(r)$, when the total energy E is zero. 5

3. Attempt any *one* part : 1×5=5

(a) The Lagrangian for a particle of mass 'm' moving freely of a sphere of radius 'A', has the following Lagrangian,

$$L = \frac{1}{2} mA^2(\dot{\theta}^2 + \sin^2 \theta \cdot \dot{\phi}^2).$$

Write down the equations of motion. Determine the generalized momenta P_θ and P_ϕ and the cyclic coordinates. 5

(b) Using conservation of angular momentum, show that the time period of revolution of a planet around the sun (T) is related to a , the semi-major axis of the elliptical orbit by the relationship $T^2 \propto a^3$. 5

4. Attempt any *one* part : 1×10=10

(a) (i) Consider two identical simple pendulums of mass m connected by a spring of spring constant k . When one pendulum is clamped, calculate the time period of the second pendulum. 5

- (ii) A particle of mass $m = 1$ is subject to a force $F(t) = Ae^{-\lambda/2t}$. If the initial position and speed are both zero, find $q(t)$. 5
- (b) (i) Consider two identical pendulums with each bob of mass 0.25 kg and length 0.5 m, connected by a spring to form a compound pendulum. If the spring constant is 4 Nm^{-1} , calculate the time periods of the two normal modes of the system. 5
- (ii) Derive the expression for the Laplace-Runge-Lenz vector for an inverse square force. 5

(b) A spherical capacitor is made up of two hollow concentric metal spheres of inner radius R_1 and outer radius R_2 . A charge $+Q$ is placed on the inner sphere and an equal and opposite amount of charge appears on the inner side of outer sphere. Solve Laplace's equations for the system and obtain the expression for its electric potential given that the inner metallic sphere is maintained at a constant potential V_0 . 5

(c) Two parallel plates, which have cross-sectional area of 200 cm^2 , carry equal and opposite charge $2 \times 10^{-7} \text{ C}$. The

space between the plates is filled with a dielectric material and electric field within the dielectric is $3.3 \times 10^5 \text{ Vm}^{-1}$.

What is the dielectric constant of the dielectric if the electric field across the plates without the dielectric is given by $E_0 = \sigma/\epsilon_0$, where σ is the surface charge density of the plates ? 5

- (d) In the Bohr hydrogen atom, the orbital angular momentum of the electron is quantized in units of ' h ' ($= 6.6 \times 10^{34} \text{ Js}$), where ' h ' is Planck's constant. Calculate the smallest allowed magnitude of the atomic dipole moment in JT^{-1} . Take $m_e = 9.1 \times 10^{-31} \text{ kg}$. 5

- (e) A 1.0 m long toroid is closely wound by 200 turns of wire carrying a steady current of 1.0 A. The magnetic field \vec{B} in the toroid is found to be $1.2567 \times 10^{-4} \text{ Wb m}^{-2}$.

Calculate : 5

- (i) \vec{H}
- (ii) χ_m and K_m
- (iii) M in the toroid.

2. Answer any *one* part : 1×10=10

- (a) Using the method of images, find an expression for the electric potential V due to charge near an earthed infinite conducting plane. Write the boundary conditions for the problem and verify that the electric potential satisfies them. 10

- (b) Write down the Maxwell's equations for the electromagnetic waves propagating in vacuum. Hence deduce an expression for the wave equation for \vec{E} field. What is the expression for the speed of propagation of electromagnetic wave in vacuum ? 4+5+1

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