# M. SC. (PHYSICS) (MSCPH)

## Term-End Examination

## December, 2024

### Part–A : MPH–002 : CLASSICAL MECHANICS—I

### AND

### Part–B : MPH–003 : ELECTROMAGNETIC THEORY

*Time : 3 Hours* *Maximum Marks : 50*

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***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. However, internal choices are given. Marks for each question are indicated against it. You may use a calculator. Symbols have their usual meanings.*

1. Attempt any *one* part : 5×1=5

(a) A particle of mass $m$ travelling with speed $u$ undergoes an elastic collision with a particle of mass $9m$ which is initially at rest. After the collision, the particle ($m$) is deflected by $60^{\circ}$ with respect to its initial direction of motion. Calculate the speed of the particle ($m$) after the collision in terms of $u$. 5

(b) State D' Alembert's principle. Using it, determine the equation of motion for an Atwood's machine with masses M and 2M. 5

2. Attempt any *one* part : 5×1=5

(a) Consider a particle of mass $m$ falling freely under gravity near the surface of the earth. Obtain Lagrange's equations of motion. 5

(b) Starting from $m\ddot{r} - \frac{l^2}{mr^3} = f(r)$, show that the differential equation of an orbit for a particle of mass *m* in a central force is

$$\left[\frac{d^2u}{d\theta^2} + u\right] = -\frac{m}{l^2}\frac{d}{du}V\left(\frac{1}{u}\right), \text{ where } u = \frac{1}{r},$$

where $f(r)$ is the force as a function of $r$, $l$ is the angular momentum. 5

3. Attempt any *one* part : 5×1=5

(a) Obtain the Lagrangian and Lagrange's equation of motion for a bead of mass *m* which slides without friction along a wire in the shape of a parabola $y = Ax^2$. 5

(b) Determine the differential scattering cross-section and the total scattering cross-section of a particle of mass $m$, if it is scattered by a rigid sphere of radius A. 5

4. Attempt any *one* part : 10×1=10

(a) (i) For a particle of mass $m$ moving in a spiral orbit $r(\theta) = ke^{-2\theta}$, obtain the force law. 5

(ii) Obtain the Lagrangian for small oscillations around a point of stable equilibrium ($q_0 = 0$). 5

(b) Obtain the energy of a very weakly damped oscillator whose displacement at time $t$ is

$$q(t) = a \cos (\omega_a t + \alpha)\ e^{-\frac{\lambda}{2}t},$$

where $\omega_a = \sqrt{\omega^2 - \frac{\lambda^2}{4}}$, $\omega$ is the natural frequency, $\lambda = \frac{b}{m}$ ($b$ is the damping coefficient), $a$ and $\alpha$ are some constants and $m$ is the mass of the oscillator. 10

## Part–B

## MPH–003 : ELECTROMAGNETIC THEORY

*Time : $1\frac{1}{2}$ Hours* *Maximum Marks : 25*

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***Note :*** *All questions are compulsory. Marks for each question are indicated against it. Symbols have their usual meanings. You can use calculator.*

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1. Answer any *three* parts : 3×5=15

   (a) An infinitely long uniformly charged cylinder of radius R has positive volume charge density ρ. Determine the electric field at a point inside the cylinder. 5

   (b) Define electric polarization and explain the mechanism of polarization in polar and non-polar dielectrics. 2+3

(c) Consider a spherical cavity of radius $r$ inside a uniformly polarized dielectric of polarization $\vec{P}$. Show that the electric field at the centre of the cavity due to the bound charges on the surface of the cavity is given as : 5

$$\vec{E}_S = \frac{\vec{P}}{3\varepsilon_0}$$

(d) Calculate the magnetic vector potential inside a long solenoid with $n$ turns per unit length of radius R and carrying a steady current I. 5

(e) Derive the wave equation for electric field from Maxwell's equations in vacuum. 5

2. Answer any *one* part : 1×10=10

(a) State the conditions under which we can apply the method of images to determine electric potential. Two charges $+q$ and $+2q$ are placed at $(0, 0, d)$ and $(0, 0, 2d)$, respectively, near an earthed infinite conducting plate kept in the $x - y$ plane. Using the method of images, determine the electric potential of the system. Give appropriate diagram. Also, verify that the expression for electric potential satisfies the boundary condition : 2+4+2+2

$$V = 0 \text{ at } z = 0.$$

(b) Distinguish between diamagnetism and paramagnetism. Show that the effective induced magnetic moment produced in a diamagnetic material placed in a magnetic field is given by : 2+8

$$\left\langle \Delta \vec{m} \right\rangle = -\left( \frac{Ze^2}{6me} \right) \left\langle r^2 \right\rangle \vec{B}$$

Assume that the atomic orbit is circular.

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