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 : 1×5=5

(a) Derive the Euler-Lagrange equations of motion for the Lagrangian, $L = \frac{1}{2}m\dot{x}^2 - \frac{1}{2}k(x-a)^2$. 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, $L = \frac{1}{2} mA^2(\dot{\theta}^2 + \sin^2\theta.\dot{\phi}^2)$. Write down the equations of motion. Determine the generalized momenta $P_\theta$ and $P_\phi$ 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 $F(t) = A e^{-\lambda/2 t}$. 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

## 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 may use a calculator.*

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1. Answer any *three* parts : 3×5=15

   (a) What is the electric potential due to a positive point charge Q at a distance '*r*' from it ? Determine the electrical potential due to an electric dipole at an arbitrary point P, far away from it, at a distance *r* from its mid-point. The line joining point P with mid-point of dipole makes an angle θ with its axis. 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 $2 \times 10^{-7}$ C. The

space between the plates is filled with a dielectric material and electric field within the dielectric is $3.3 \times 10^5\ \mathrm{Vm}^{-1}$. What is the dielectric constant of the dielectric if the electric field across the plates without the dielectric is given by $E_0 = \sigma/\varepsilon_0$, where $\sigma$ 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*' (= $6.6 \times 10^{34}$ Js), where '*h*' is Planck's constant. Calculate the smallest allowed magnitude of the atomic dipole moment in $JT^{-1}$. Take $m_e = 9.1 \times 10^{-31}$ 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 $1.2567 \times 10^{-4}\,\text{Wb}\,\text{m}^{-2}$.

Calculate : 5

(i) $\overline{H}$

(ii) $\chi_m$ 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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