No. of Printed Pages : 11

MPH–002/MPH–003

M. SC. (PHYSICS) (MSCPH)
Term-End Examination
June, 2025

MPH-002 : CLASSICAL MECHANICS–I

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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. 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 moving with velocity $\vec{v}$, undergoes an elastic collision with a particle of mass 3 m which is initially at rest. The kinetic energy of the particle (m) after collision is one-fourth of its kinetic energy before the collision. Calculate the angles of the direction of motion of the two particles after the collision using conservation of linear momentum.

(b) Write down the equation of constraint for two particles connected by a massless rod of length L. The system is moving in X-Y-plane such that the velocity of the centre of the rod is along its length.

2. Attempt any *one* part : 5×1=5

(a) A cylinder of radius R and mass *m* rolls without slipping down an inclined plane of length, *s* making an angle θ with the horizontal. Obtain the Lagrangian and determine the equation of motion if the moment of inertia of the cylinder is $\frac{mR^2}{2}$.

(b) A spherical pendulum of mass m and length A, has the Lagrangian :

$$L = \frac{1}{2} m A^2 (\dot{\theta}^2 + \dot{\phi}^2 \sin^2 \theta) + mg A \cos\theta$$

Determine the generalized momenta and energy function.

3. Attempt any *one* part : 5×1=5

(a) Derive the Euler-Lagrange equation of motion for a simple pendulum with a bob of mass $2m$ which is tied to a string of length L_0, where L_0 is a constant.

(b) Obtain the effective potential for a particle of mass m with angular momentum l, undergoing motion along a spiral path of the form $r = \mathrm{A}e^{b\theta}$ when the total energy is zero. A and b are positive constants.

4. Attempt any *one* part : 10×1=10

(a) Consider two coupled pendulums each of mass m and length l. Write down the V and T matrices for the system. It is given that k is the spring constant of the spring connecting the bobs. 10

(b) A particle of mass m moves in a central force field described by the potential

$V(r) = \frac{-k}{r}\exp\left(\frac{-r}{a}\right)$, where k and a are positive constants.

(i) Determine the force. 2

(ii) If the motion of the particle is restricted to a plane $(r, \dot{\theta})$, write the Lagrangian and obtain the equation of motion for r. 7

(iii) Obtain the effective potential. 1

Part—B

MPH–003 : ELECTROMAGNETIC THEORY

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

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

1. Answer any *three* parts : 3×5=15

   (a) A coaxial cable consists of a thin inner solid copper wire and an outer sheath of braided copper wire. The linear charge density of the inner wire is $-\lambda$ and that of the outer wire is λ. Using Gauss' law, determine the electric fields at a point : 3+2

(i) in the region inside the inner wire, and

(ii) in the region between the wires.

(b) Write Poisson's equation for the charge density of a wire given by $\rho(z) = \frac{2\rho_0 x}{L}$, where L is the length of the wire. Determine the electric potential and electric field due to the wire for the following boundary conditions : 5

$$V(x) = 0 \text{ at } x = 0$$

and $$\frac{\partial V(x)}{\partial x} = 0 \text{ at } x = L.$$

(c) Assuming that the electrons in the atoms of dielectric materials are bound to their respective nuclei by harmonic forces, show that the polarisation is given by :

$$\vec{P} = \frac{Nq^2}{m\omega_0^2}\vec{E}$$

where ω_0 is the natural frequency of oscillations of electron about the nucleus. 5

(d) Calculate the magnetic field $\vec{B}$ and the magnetising field $\vec{H}$ at (i) a point 90 mm from a long straight wire carrying a current of 10 A and (ii) the centre of a 1500 turn solenoid which is

0.20 m long and carries a current 1.5 A flowing in it. (3+2)

[Take $\mu_0 = 4\pi \times 10^{-7}$ Hm^{-1}]

(e) Derive the wave equation for magnetic field $\vec{B}$ from Maxwell's equations for vacuum. 5

2. Answer any *one* part : 1×10=10

(a) (i) Show that for a linear and isotropic dielectric kept in an electric field, the surface bound charge density is given by : 5

$$\sigma_b = \vec{P} . \hat{n}$$

(ii) Show that for non-uniform polarisation of a dielectric placed in an electric field, the bound charge density is given by : 5

$$\rho_b = -\nabla . \vec{P}$$

(b) Explain the concept of magnetic vector potential. Show that the magnetic vector potential due to an infinite straight wire carrying current I, at a distance r from the wire is given by :

$$\vec{A}(\vec{r}) = -\frac{\mu_0 I}{2\pi} \ln(r)\hat{z}$$

where $\hat{z}$ denotes the direction of current. 2+8

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