MAULANA ABUL KALAM AZAD UNIVERSITY OF TECHNOLOGY, WEST BENGAL

Paper Code : PH-401

PHYSICS-II

Time Allotted : 3 Hours *Full Marks* : 70

The figures in the margin indicate full marks.

*Candidates are required to give their answers in their own words*Type equation here. *as far as practicable.*

GROUP – A

(Multiple Choice Type Questions)

1. Choose the correct alternatives for any *ten* of the following : $10 \times 1 = 10$

i) Total electric flux (ϕ) of electric field ($\vec{E}$) over a surface S is

a) $\vec{E}.d\vec{S}$

b) $\oint_S \vec{E}.d\vec{S}$

c) $\vec{E} \times d\vec{S}$

d) $\oint_S \vec{E} \times d\vec{S}$.

ii) The Poisson's equation in a region of space with volume charge density ρ is

a) $\nabla^2 V = \frac{\rho}{\varepsilon_0}$ b) $\nabla^2 V = -\frac{\rho}{\varepsilon_0}$

c) $\nabla^2 V = 0$ d) $\nabla V = \frac{\rho^2}{\varepsilon_0}$.

iii) Electrical susceptibility χ_e is

a) $\chi_e = \frac{P}{\varepsilon_0 E}$ b) $\chi_e = \frac{P}{3\varepsilon_0 E}$

c) $\chi_e = \varepsilon_0 EP$ d) $\chi_e = \frac{3\varepsilon_0 E}{P}$.

iv) A wire of length L carrying a current I is bent into a circle. The magnitude of the magnetic field at the centre of the circle is

a) $\frac{\pi\mu_0 I}{L}$ b) $\frac{\mu_0 I}{2\pi L}$

c) $\frac{\mu_0 I}{2L}$ d) $\frac{2\pi\mu_0 I}{L}$.

v) The work done by the Lorentz force $\vec{F}$ on a charged particle is

a) $\vec{F}.d\vec{r}$ b) zero

c) $\frac{q}{\varepsilon_0}$ d) $q F$.

vi) The magnetic flux linked with a coil at any instant ' t ' is given by $\varphi_t = 5t^3 - 100t + 200$. The *emf* induced in the coil at $t = 2$ seconds is

a) 200 V b) 40 V

c) 20 V d) − 20 V.

vii) The direction of propagation of electromagnetic wave is given by

a) Along the direction of $\vec{E}$

b) Along with direction of $\vec{B}$

c) Along the direction of $\vec{E} \times \vec{B}$.

d) None of these.

viii) The relation between scalar potential ϕ and vector potential $\vec{A}$ is

a) $\vec{\nabla} \times \vec{A} = \mu_0 \varepsilon_0 \frac{\partial \phi}{\partial t}$ b) $\vec{\nabla} \times \vec{A} = -\mu_0 \varepsilon_0 \frac{\partial \phi}{\partial t}$

c) $\vec{\nabla} \cdot \vec{A} = \mu_0 \varepsilon_0 \frac{\partial \phi}{\partial t}$ d) $\vec{\nabla} \cdot \vec{A} = -\mu_0 \varepsilon_0 \frac{\partial \phi}{\partial t}$.

ix) The normalized wave function for a particle moving in a one-dimensional potential box of length L is

a) $\psi = \sqrt{\frac{2}{L}} \sin \frac{n\pi}{xL}$ b) $\psi = \sqrt{\frac{2}{L}} \sin \frac{n\pi x}{L}$

c) $\psi = \sqrt{\frac{L}{2}} \sin \frac{n\pi x}{L}$ d) $\psi = \sqrt{\frac{2}{L}} \sin \frac{\pi x}{nL}$.

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x) The constraint involving rolling of a particle without sliding is

a) Conservative b) Holonomic

c) Rheonomic d) Non-holonomic.

xi) If total charge in a system is conserved, then

a) $\vec{\nabla} \cdot \vec{J} = 0$ b) $\vec{\nabla} \cdot \vec{J} = \frac{\partial \rho}{\partial t}$

c) $\vec{\nabla} \cdot \vec{J} = -\frac{\partial^2 \rho}{\partial t^2}$ d) $\vec{\nabla} \cdot \vec{J} = -\frac{\partial \rho}{\partial t}$.

xii) The ground state energy of a particle moving in a one-dimensional potential box is given in terms of the length of the box as

a) $\frac{2h^2}{8ml^2}$ b) $\frac{h^2}{8ml^2}$

c) $\frac{h}{8ml^2}$ d) 0.

xiii) Which of the following is a fermion ?

a) Photon b) Electron

c) Phonon d) Alpha particle.

xiv) Lagrange Equation of motion is

a) $\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_j}\right) - \frac{\partial L}{\partial \dot{p}_j} = 0$ b) $\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_j}\right) - \frac{\partial L}{\partial q_j} = 0$

c) $\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_j}\right) + \frac{\partial L}{\partial \dot{p}_j} = 0$ d) $\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_j}\right) + \frac{\partial L}{\partial q_j} = 0$.

xv) The relation between thermodynamic probability Ω and entropy S of a thermodynamic system is given by

a) $S = ln\,\Omega^k$ b) $S = \Omega^k$

c) $S = ln\,\Omega$ d) $S = k\,ln\,S$.

GROUP – B
(Short Answer Type Questions)

Answer any *three* of the following $3 \times 5 = 15$

2. What is Stokes' theorem ? Verify the theorem for the function $\vec{F} = x^2\,\hat{i} + xy\,\hat{j}$ integrated round the square in the place $z = 0$ whose sides are along the lines $x = 0$, $y = 0$, $x = a$ and $y = a$. 1 + 4

3. State the Ampere's law of magnetostatics. Obtain its differential form from the integral one. Apply this law to deduce an expression of magnetic field due to a straight conductor of infinite length carrying current. 1 + 2 + 2

4. Derive the Lagrangian and Hamilton's equation of motion for simple pendulum and hence find the time period of oscillation. 1 + 3 + 1

5. If two distinguishable particles are distributed over three non-degenerate energy levels of energies E, 2E and 3E then (a) calculate the total number of microstates of the system and (b) find the total energy of the distribution for which the thermodynamic probability is maximum. 3 + 2

6. a) What are the basic postulates of quantum mechanics ?

b) Find the energy difference between the ground state and first excited state of an electron moving in a one-dimensional potential box of length 1Å. 2 + 3

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GROUP – C
(Long Answer Type Questions)

Answer any *three* of the following. $3 \times 15 = 45$

7. a) Define displacement vector $\vec{D}$ and show that for an isotropic dielectric $\vec{D} = \varepsilon_0 \vec{E} + P$, where $\vec{P}$ is the polarization vector.

b) Show that the electronic polarizability is proportional to the atomic volume.

c) Using Gausse's law find the electric field for a long cylindrical object which carries charge distribution proportional to the distance from the axis r for inside and outside of the cylinder.

d) Prove that $\vec{E}$, $\vec{B}$ and $\vec{k}$ are mutually perpendicular to each other. 3 + 4 + 4 + 4

8. a) Define energy levels and energy states and distinguish between them.

b) Show that the average energy of an electron in a metal at $T = 0$ is $\frac{3}{5}\varepsilon_F$ where ε_F is the Fermi energy.

c) Three particles each of which can be in one of the ε, 2ε, 3ε, 4ε energy states have total energy 7ε. Find the macrostates and the microstates and list them according to MB, BE and FD statistics.

d) Draw the Fermi distribution function at (i) $T = 0$ and (ii) $T_1 > T_2 > 0$ K. 2 + 4 + (2 + 2 + 2) + 3

9. a) What do you mean by degenerate state ? Explain.

b) If a system has two eigenstates ψ_1 and ψ_2 with eigenvalues E_1 and E_2, under which condition the linear combination of $(\psi = a\psi_1 + b\psi_2)$ will be an eigenstate ?

c) If the wave function ψ (x) of a quantum mechanical particle is given by

$$\psi(x) = a \sin \frac{\pi}{L} x, \quad \text{for} \quad -\frac{L}{2} \le x \le \frac{L}{2}$$

$$= 0 \quad \text{for otherwise}$$

Determine the value of a. Also determine the value of x where the probability of finding the particle is maximum. Putting the value of a, calculate $< p_x^2 >$ for the given function.

d) Plot ψ and $|\psi|^2$ as a function of position for ID box problem. (1 + 2) + 2 + (2 + 2 + 2) + 4

10. a) State Poynting theorem.

b) Starting from Maxwell's equation show that the electric field can be written as $\vec{E} = -\nabla\phi - \frac{\partial \vec{A}}{\partial t}$.

c) Find the magnetic field at the centre of a semicircular conducting loop of radius 3·14 cm carrying current $\frac{1}{\pi}$ amp.

d) If ϕ is a scalar potential associated with the electric field $\vec{E}$ and $\vec{A}$ is the vector potential associated with the magnetic induction $\vec{B}$, show that they must satisfy the equation $\nabla^2\phi + \frac{\partial}{\partial t}\left(\vec{\nabla} \cdot \vec{A}\right) = -\frac{\rho}{\varepsilon_0}$.

e) Check whether the electrostatic field given by $\vec{E} = axy^2(y\hat{i} + x\hat{j})$ is conservative or not.

2 + 3 + 3 + 5 + 2

11. a) What do you mean by wave function ?

b) Find the magnetic field at a point P (z) on the axis of a circular current carrying conductor. Hence find the magnetic field at the centre of circular ring.

c) Construct Hamiltonian and find Hamilton's equation of motion for simple pendulum of which point of suspension is moving horizontally with acceleration f.

d) Show that the energy difference between two consecutive energy levels of a one-dimensional potential box with rigid walls is given by $\Delta E = \frac{\hbar^2 \pi^2}{2ml^2}(2n+1)$ 2 + (4 + 1) + (2 + 4) + 2