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**Paper Code : PH-301**

**PUID : 03003 ( To be mentioned in the main answer script )**

## 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 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) A butterfly is flying inside a hollow sphere. What is the type of constrain ?

a) Holonomic b) Non-holonomic

c) Scleronomic d) Rheonomic.

ii) A cube of side $a$ is placed in a uniform electric field $\vec{E} = \hat{i}\vec{E}_0$. the total electric flux through the cube is

a) $2a^2E_0$ b) $6a^2E_0$

c) $4a^2E_0$ d) 0.





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iii) The relation between $\vec{D}$ (Displacement vector), $\vec{E}$ (Electric field) and $\vec{P}$ (Polarization vector) is

a) $\vec{D} = \varepsilon_0 \vec{E} - \vec{P}$ b) $\vec{D} = \varepsilon_0 \vec{E} + \vec{P}$

c) $\vec{D} = \varepsilon_0 \vec{P} + \vec{E}$ d) $\vec{D} = \vec{E} + \vec{P}/\varepsilon_0$.

iv) The differential form of Ampere's circuital law is

a) $\vec{\nabla} . \vec{B} = \mu_0 \vec{J}$ b) $\vec{\nabla} \times \vec{B} = \mu_0 \vec{J}$

c) $\vec{\nabla} . \vec{B} = \vec{J}$ d) $\vec{\nabla} \times \vec{B} = \mu_0 \varepsilon_0 \vec{J}$.

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

a) along $\vec{E} . \vec{B}$ b) along $\vec{E} \times \vec{B}$

c) along $\vec{B}$ d) along $\vec{E}$.

vi) An electric dipole placed in a non-uniform electric field experiences

a) a torque but not a force

b) a force as well as a torque

c) a force but not a torque

d) neither a force nor a torque.

vii) The two parallel wires carry current along opposite directions. The resultant force experienced by the two wires is

a) repulsive b) attractive

c) torsional d) no force.

viii) For any scalar function $\phi = xyz$, Curl ( grad $\phi$ ) at ( 1, 1, 1 ) is

a) $(\hat{i} + \hat{j} + \hat{k})$ b) $2(\hat{i} + \hat{j} + \hat{k})$

c) $\frac{1}{\sqrt{3}}(\hat{i} + \hat{j} + \hat{k})$ d) 0.

ix) If a charged particle of mass $m$ is accelerated through potential difference $V$, the de-Broglie wavelength is proportional to

a) $V$ b) $V^{-\frac{1}{2}}$

c) $V^2$ d) $V^{\frac{2}{3}}$.

x) If a wave function $\psi(x)$ is normalized, then

$\iiint \overset{*}{\psi}(x)\psi(x)\,dv$ is

a) 0 b) $\infty$

c) 1 d) 1/2.

xi) A coin is tossed $n$ times. The number of microstates is

a) $2^n$ b) $2n!$

c) $n^2$ d) $2^n / n!$

xii) The Fermi energy of a free electron gas depends on the electron density $n$ as

a) $n^{\frac{1}{3}}$ b) $n^{-\frac{1}{3}}$

c) $n^{\frac{2}{3}}$ d) $n^{-\frac{2}{3}}$.













xiii) For a projectile with position co-ordinate ( $x$, $y$, $z$ ), the number of cyclic co-ordinates is

a) 1 b) 2

c) 3 d) 4.

xiv) The value of $[\hat{x}, \hat{p}^n]$ is

a) $\hat{i}\, n\hbar\, p_x^{n-1}$ b) $\hat{i}\, n\hbar\, x^{n-1}$

c) $\hat{i}\, \hbar\, p_x^{\frac{n-1}{n}}$ d) 0.

xv) The degrees of freedom of a system consisting of $N$ particles subjected to $l$ number of constraints is equal to 

a) $(3N + l)$ b) $(3Nl)$

c) $(3N)^l$ d) $(3N - l)$.

## GROUP – B

### ( Short Answer Type Questions )

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

2. a) If the function $\varphi(x, y, z) = 2xy + z^2$, is its corresponding field sonenoidal or irrotational ?

b) Derive the Coulomb law from Gauss' law. 3 + 2

3. A capacitor is made of two spherical sphere conductors of radii $a$ and $b$ ( where $a < b$ ), with vacuum in the intervening space. If the external sphere is kept at ground and the outer one has a charge density $\sigma$, then solve the Laplace's equation to find the electrostatic potential in the space between the spheres.

4. a) Derive the expression of momentum operator. Show that 'position' operator and 'momentum' operator are not commutative.

   b) Write down the Lagrangian for a freely falling particle under gravity. (2 + 2) + 1

5. a) State Ampere's circuital law and deduce its differential form.

   b) Prove that $\vec{E} = \sin(y - t)\hat{k}$ and $\vec{B} = \sin(y - t)\hat{i}$ constitute a possible electromagnetic field. (1 + 2) + 2

6. a) Consider a three particle system each of which can exit in a energy state $\epsilon_1$, $\epsilon_2$ and $\epsilon_3$. What are the possible states, if the particles are (i) bosons, (ii) fermions ?

   b) Draw and explain the Fermi distribution function at (i) $T = 0$ K (ii) $T > 0$ K. 3 + 2

## GROUP – C

### ( Long Answer Type Questions )

Answer any *three* of the following. 3 × 15 = 45

7. a) In a region of space, the electric field is given by $\vec{E} = 3\hat{i} + 5\hat{k}$. Calculate the electric flux through a surface area 100 square unit in $X$-$Y$ plane.

   b) Explain electronic polarization of a dielectric material and find an expression for electronic polarizability in terms of radius of the atom.





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   c) Show that the equation of continuity is given by $\vec{\nabla} \cdot \vec{j} + \frac{\partial \rho}{\partial t} = 0$, where the symbols have their usual meanings.

   d) What are the limitations of Newtonian mechanics ? 3 + ( 1 + 5 ) + 4 + 2

8. a) Establish the relation $\vec{D} = \epsilon_0 \vec{E} + \vec{P}$, where the symbols have their usual meanings.

   b) If a charged particle of charge 0·5C is moving with a velocity $3\hat{i} + 4\hat{j} + 5\hat{k}$ m/s through an electric $\vec{E} = 5\hat{i} + 5\hat{k}$ and magnetic field induction $\vec{B} = 2\hat{i} - 6\hat{j} - 6\hat{k}$, then calculate the magnitude and direction of total Lorentz force.

   c) Find out Hamilton's equation of motion for a system comprising masses $M_1$ and $M_2$ connected by a massless string of length $L$ through a frictionless pulley such that $M_1 > M_2$.

   d) What is skin depth ? 4 + 5 + 5 + 1

9. a) Write down the Maxwell's field equations. hence, derive the electromagnetic wave equation in terms of electric vector ( in vacuum ).

   b) State the basic postulates of quantum mechanics.

   c) If the atomic weight and density of silver are 108 gm/mole and 10·5 gm/cm$^3$ respectively, find the Fermi energy of silver at $T$ = 0K (considering one free electron per atom). (2 + 3) + 5 + 5

10. a) Write down Schrödinger equation for one dimensional motion of a free particle in an infinite deep potential well. Find its eigenfunction and eigenenergy.

b) What is phase space ? Derive the expression of density of state in energy range $E$ to $E + dE$ in phase space.

c) The maximum electric field in an EM wave 800 V/m. Find the maximum value of magnetic intensity and the average value of Poynting vector.

5 + (1 + 4) + 5

11. a) Find the magnetic field of a circular loop carrying current $I$ on a point on the axis of the loop.

b) A short conductor of length 5 cm is placed parallel to a conductor of length 1·5 m. Both conductors carry a current of $3A$ and $2A$ respectively in the same direction. Find the nature and magnitude of the force experienced by the long conductor for their separation 3 cm.

c) What are the advantages of generalized coordinate ?

d) Obtain the equation of motion of a simple pendulum using Lagrange equation. 5 + 3 + 2 + 5









12. a) Derive Planck's law of black body radiation from Bose-Einstein statistics.

b) A system has three energy states $\epsilon$, $2\epsilon$ and $3\epsilon$. $\psi_1$, $\psi_2$ and $\psi_3$ are the corresponding normalized wave functions. At an instant the system is in a superpose state $\psi + c_1\psi_1 + c_2\psi_2 + c_3\psi_3$ and $c_1 = \sqrt{(1/3)}$ and $c_2 = \sqrt{(1/3)}$ .

i) Find $c_3$ if $\psi$ is normalized.

ii) Find out the expectation value of energy.

c) Derive the Maxwell's wave equation for a charge free non-conducting medium. Hence prove that speed of light in a non-conducting medium is less than the speed of light in vacuum. 5 + (2 + 3) + 5