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Paper Code : PH-301

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) The volume element in spherical polar coordinate is

a) $r \sin\theta dr d\theta d\phi$ b) $r^2 \sin\theta dr d\theta d\phi$

c) $\sin\theta dr d\theta d\phi$ d) $r^2 \sin^2\theta dr d\theta d\phi$.

ii) Laplace's equation for an electrostatic field is

a) $\nabla^2 V = 0$ b) $\nabla^2 V = \rho/\varepsilon_0$

c) $\nabla^2 V = -\rho/\varepsilon_0$ d) $\nabla^2 V = \infty$

iii) The electrical conductivity of an ideal dielectric is

a) infinity b) zero

c) very large d) moderate.

iv) The value of $\vec{\nabla} . (\vec{\nabla} \times \vec{A})$ is (where, $\vec{A}$ is any vector)

a) $2A$ b) $A/2$

c) A^2 d) 0.

v) The magnetic flux linked with a coil at any instant t is given by $\phi_1 = 5t^3 - 100t + 200$. the *emf* induced in the coil at $t = 2$ seconds is

a) 200 b) 40

c) 20 d) – 20.

vi) Displacement current arises due to

a) Positive charge only

b) Negative charge only

c) Time-varying electric field

d) Any of these.

vii) The differential form of Faraday's law of electromagnetic induction is

a) $\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$ b) $\vec{\nabla} \times \vec{E} = \frac{\partial \vec{B}}{\partial t}$

c) $\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$ d) $\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$.

viii) Deduction of Planck's law is possible on the basis of

a) Fermi-Dirac (F-D) statistics

b) Maxwell-Boltzmann (M-B) statistics

c) Bose-Einstein (B-E) statistics

d) Any of these.

ix) Skin depth in a poor conductor is

a) increased with frequency

b) decreased with frequency

c) first increase then decreases with frequency

d) independent of frequency.

x) If a system has f no. of generalized coordinate, then the number of Lagrange's equations for the system is

a) f b) $2f$

c) $f/2$ d) $f + 1$.

xi) Which one of the following is a fermion ?

a) Photon b) Electron

c) Phonon d) α particle.

xii) If $f(x)$ denotes the wave function of a particle in one-dimensional box then the dimension of $f(x)$ is

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

c) L^{-1} d) dimensionless.

xiii) When a dielectric material is inserted between two plates of a capacitor, the capacitance will be

a) increased b) decreased

c) same d) zero.

xiv) The divergence of magnetic flux density $(\vec{B})$ is

a) 0 b) 1

c) -1 d) infinity.

xv) Hamiltonian is a function of

a) (q_j, p_j, t) b) $(q_j, \dot{q}_j, t)$

c) $(p_j, \dot{p}_j, t)$ d) $(p_j, \dot{q}_j, t)$.

GROUP – B

(Short Answer Type Questions)

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

2. a) State Stokes' theorem.

b) Prove that

$$\nabla^2 f(r) = \frac{d^2 f(r)}{dr^2} + \frac{2}{r}\frac{df(r)}{dr}.$$ 2 + 3

3. a) Write down Faraday law of electromagnetic induction. Express it in differential form.

b) Give an example of an electrical circuit carrying non-steady current where Ampere's circuital law is not possible. (1 + 3) + 1

4. A particle is executing one-dimensional Simple Harmonic Motion under the action of potential $V = \frac{1}{2}Kx^2$. Write down the Lagrangian. Derive the Hamiltonian and Hamilton's equations. 1 + 2 + 2

5. If the value function $\Psi(x) = a \sin\frac{n\pi x}{L}$, for $0 \le x \le L$

$= 0$, for $0 \ge x \ge L$.

then determine the value of a.

6. a) What do you mean by generalised coordinate ?

b) Prove that at 0 K the average energy of Fermion is $\frac{3}{5}\epsilon_F$. 2 + 3

GROUP - C

(Long Answer Type Questions)

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

7. a) If in a region of space electric field is always in the x-direction then prove that

   (i) the potential is independent of y and z coordinates and

   (ii) if the field is constant, there is no free change in that region.

   b) Write down the differential form of Gauss' Law. Suppose that electric field in some region is found to be $\vec{E} = ar\hat{r}$ in spherical coordinates (a is a constant). Find the electric charge density.

   c) A very long cylindrical object carries charge distribution proportional to the distance from the axis (r). If the cylinder is of radius a, then find the electric field both at $r > a$ and $r < a$, by the application of Gauss' law in electrostatics.

   d) What is Electric displacement vector ? Establish the relation $\vec{D} = \varepsilon_0 \vec{E} + \vec{P}$ where symbols have their usual meanings. $(2 + 1) + (1 + 3) + 4 + (1 + 3)$

8. a) Prove that the first excited state of free particle in a cubical box has three-fold degeneracy.

   b) Find the magnetic field at a point (1, 1, 1) if vector potential at that position is

   $\vec{A} = (10x^2 + y^2 - z^2)\hat{j}$

   c) Obtain the magnetic field induction $\vec{B}$ at a point on the axis of a current carrying circular conductor (loop) with n turns.

   d) Write down the basic postulates of quantum mechanics. $5 + 3 + 4 + 3$

9. a) Deduce D' Alembert's principle from the principle of virtual work.

   b) A conducting wire in the shape of an equilateral triangle of each side a carries a current I. Calculate the magnetic field at its centroid.

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

   d) A long solenoid of 40 cm length has 300 turns . If the solenoid carries a current of 305 A, find the magnetic field at one end of solenoid.

$3 + 4 + 5 + 3$

10. a) State the basic postulate of F-D statistic and derive an expression for the probability distribution of particles obeying F-D statistics.

b) Apply B-E statistics to a photon and deduce Planck's law of spectral energy density of black body radiation.

c) Define Microstates and Macrostates with suitable examples.

d) A box contains 5 red balls and 3 white balls. The balls except their colours, are identical. What is the probability that no two are identical ? What is the probability that on two independent draws, 1 ball is red and 1 ball is white ?

e) What do you mean by Macro-canonical and Micro-canonical ensemble ? 4 + 3 + 3 + 3 + 2

11. a) State Ampere's Circuital law. Differentiate between electric field and magnetic field.

b) Express Ampere's Circuital law in terms of magnetic vector potential.

c) State Poynting theorem. Prove that $\vec{\nabla} \times \vec{E} = -\frac{\partial B}{\partial t}$ from Maxwell's equation.

d) What is the physical significance of skin depth ?

(1 + 2) + 4 + (2 + 4) + 2

12. a) What do you mean by cyclic co-ordinate ? Explain.

b) Write down the Schrödinger equation for one-dimensional motion of a free particle in one-dimensional potential box. Find its eigenfunction and eigenenergy.

c) Calculate the magnetic field at the centre of a circular lamp carrying current I.

d) If the Fermi energy level of a metal is 12eV at absolute zero temperature, find out the average energy of free electrons. (1 + 2) + (3 + 2) + 5 + 2