7. (a) A ring of radius R and uniform linear charge density λ is placed on XY plane with the centre coinciding with the origin. Calculate the electrostatic field at $(0,0,z_0)$. Comment on the situation when $z_0 >> R$.

(b) The potential due to a spherically symmetric charge distribution is given by $\Phi(r) = \frac{ke^{-r}}{r}$, k being a constant. Find out the charge density for this distribution.

(c) Two infinite parallel plates are kept at $z = \pm a$ at potentials V_1 and V_2 respectively. Solve the Laplace equation in the region $-a < z < a$ and find the potential and electric field at $z = 0$.

(4 + 2) + 3 + 3 = 12

Group – E

8. (a) Write Biot-Savart law for the magnetic effect of current. Obtain the magneto static field produced inside an infinite solenoid carrying a current *I*.

(b) Obtain the differential form of Faraday's law using Stoke's theorem.

(c) Draw the B-H curve for soft iron and steel and compare the two loops.

(d) What do you mean by magnetic susceptibility? Plot the relation between magnetic susceptibility and absolute temperature.

(1 + 3) + 2 + 3 + (1 + 2) = 12

9. (a) The vector potential corresponding to a magnetic field is given by $\vec{A}(\vec{r}) = C\left(\sin \pi y\, \hat{i} - \sin \pi x\, \hat{j}\right)$, C is a constant scalar. Show that the magnetic field is zero at $(\frac{1}{2}, \frac{1}{2})$.

(b) (i) Write three major differences between paramagnetic, diamagnetic and ferromagnetic material.

(ii) A time varying magnetic field $\vec{B} = B_0 \cos \omega t \left(\hat{i} + \hat{k}\right)$ is allowed to pass through a circular loop of area $\pi R^2 \left(\hat{j} + \hat{k}\right)$, R being the radius of the loop. Find the maximum value of induced e. m. f. in the loop.

(c) A sample of gold having magnetic susceptibility -3.6×10^{-5} is placed in a magnetising field of strength 60×10^3 A.turn / m. Find the magnetic induction within the sample.

3 + (3 + 3) + 3 = 12

PHYSICS - I
(PHYS 1001)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) For three different non-coplanar vectors $\vec{A}, \vec{B}, \vec{C}$; $\vec{A}.\vec{B} \times \vec{C}$ is equal to
(a) $\vec{B}.\vec{C} \times \vec{A}$ (b) 0 (c) $\vec{A} \times \vec{B} \times \vec{C}$ (d) $\vec{A}.\vec{C} \times \vec{B}$

(ii) If $\vec{\nabla}.\vec{A} = \rho$(const), for a closed surface S enclosing a volume V,
(a) $\oint \vec{A}\, dv = \vec{A}S$ (b) $\oint \vec{A}.d\vec{s} = AV$ (c) 0 (d) $\oint \vec{A}.d\vec{s} = \rho V$

(iii) Which of the following force law represents a central force?
(a) $\vec{F} = \frac{k\cos\theta}{r^2}\hat{r}$ (b) $\vec{F} = \frac{k\cos\theta}{r^3}\hat{\theta}$
(c) $\vec{F} = kr^2\hat{r}$ (d) $\vec{F} = \frac{k}{r^2}\hat{\theta}$

(iv) Motion of a system in a critically damped oscillation is
(a) oscillatory (b) harmonic
(c) linear (d) non-oscillatory.

(v) The potential energy of a particle executing SHM having amplitude 'a' is equal to its kinetic energy when displacement of the particle is
(a) $\pm$a (b) $\pm\frac{a}{\sqrt{2}}$ (c) $\pm\frac{a}{2}$ (d) $\pm\frac{a}{4}$

(vi) The ratio of He and Ne in a helium-neon laser is of the order of
(a) 1:15 (b) 1:10 (c) 1:1 (d) 10:1.

(vii) A moving charge produces
(a) $\vec{E}$ field only (b) $\vec{B}$ field only
(c) both $\vec{E}$ and $\vec{B}$ field (d) none of (a), (b) & (c).
Where $\vec{E}$ and $\vec{B}$ have their usual meaning.

(viii) Susceptibility χ of a paramagnetic gas varies with temperature T as
(a) $\chi \propto T$ (b) $\chi \propto T^{-1}$ (c) $\chi \propto T^{-2}$ (d) $\chi \propto T^{2}$

(ix) Which of the following vector field does not represent a magnetic field?
(a) $\vec{B} = B_0 (x\hat{\imath} + y\hat{\jmath})$ (b) $\vec{B} = B_0 (x\hat{\imath} - y\hat{\jmath})$
(c) $\vec{B} = B_0 (x\hat{\imath} + x\hat{\jmath})$ (d) $\vec{B} = B_0 (y\hat{\imath} + y\hat{\jmath})$

(x) The relation between a magnetic field $\vec{B}$ and corresponding vector potential $\vec{A}$ can be given by
(a) $\int \vec{A}.d\vec{l} = \int \vec{B}.d\vec{S}$ (b) $\int \vec{A}.d\vec{S} = \int \vec{B}.d\vec{l}$
(c) $\int \vec{A} \times d\vec{l} = \int \vec{B} \times d\vec{S}$ (d) $\int \vec{A} \times d\vec{S} = \int \vec{B} \times d\vec{l}$

Group – B

2. (a) (i) If $d\vec{l}$ is an infinitesimal length element of a closed loop on XY plane show that $\oint d\vec{l}$=0.
(ii) Show that vector field $\vec{F}(x, y, z) = 2xy\hat{\imath} + x^2\hat{\jmath} + \hat{k}$ is conservative. Find the corresponding scalar potential.

(b) Show that $\vec{\nabla} \times (\vec{\nabla} \psi) = 0$ always, where ψ is a scalar field.

(c) Write down the relations between the set of unit vectors in cylindrical co-ordinates and that of Cartesian coordinates.

[2 + (2 + 3)] + 2 + 3 = 12

3. (a) Show that for a particle undertaking motion in a central force field , the central force itself is a conservative in nature. What are the consequences of it?

(b) Given the equation of an orbit of a particle under the action of central force is $r = ae^{-\theta}$. Hence calculate the corresponding central force.

(c) (i) Write down the five term acceleration formula for a particle in rotational coordinate system.
(ii) What is the effect of Coriolis force on a particle falling freely under the action of gravity?
(iii) Comment on the equation $\vec{g}_{eff} = \vec{g} - \vec{\omega} \times (\vec{\omega} \times \vec{r})$

(2 + 2) + 3 + (2 + 2 + 1) = 12

Group – C

4. (a) The equation of motion for particle performing forced oscillation is given by $\frac{d^2x}{dt^2} + 0.07\frac{dx}{dt} + 0.16x = 3\sin(0.3)t$.
(i) Find out the amplitude of steady state oscillation.

(ii) Find out the phase difference between driving force and displacement in the steady state oscillation.
(iii) Calculate the frequency of amplitude resonance.

(b) Show that if $u(x, t)$ and $v(x, t)$ satisfies the equations $\frac{\partial u}{\partial x} = \frac{\partial v}{\partial t}$ and $\frac{\partial u}{\partial t} = \frac{\partial v}{\partial x}$ then both u and v represent classical wave with unit velocity.

(c) The light vector of a polarized light is given by $\vec{E} = 3\sin(2t - 3z)\hat{i} + 4\cos(2t - 3z)\hat{j}$
(i) Find the direction of propagation of the light.
(ii) Identify the state of polarization.

(3 + 2 + 2) + 2 + (1 + 2) = 12

5. (a) How can you differentiate between circularly polarized light and an unpolarized light.

(b) (i) What do you mean by optic axis of an uniaxial crystal?
(ii) Calculate the ratio of the stimulated emission rate to the spontaneous emission for an incandescent lamp operating at a temperature of 1000 K. Assume the average wavelength is 0.5nm.

(c) (i) Obtain the relation between acceptance angle and refractive indices of the core and cladding of an optical fibre.
(ii) What is population of inversion? Why is it necessary for operation of a laser source?

2 + (1 + 3) + (3 + 2 + 1) = 12

Group – D

6. (a) Two equal and opposite point charges are placed at (1,1) and (1,-1). Calculate the field as well as potential at the point (1, 4).

(b) For an infinitely long line charge distribution obtain the expression for electric field at a point along the perpendicular bisector of the conductor.

(c) Suppose a charge Q is distributed within a sphere of radius R in such a way that the charge density at a distance r from the centre of the sphere is given by,
$\rho(r) = \{K(R - r)\}$ for $0 < r < R$
$= 0$ for $r > R$
Determine constant K in terms of Q and R.

(d) Find the electric field $\vec{E}$ at any point (r, θ), where potential is $\varphi(r, \theta) = r^2 \cos\theta$.

(2 + 2) + 3 + 3 + 2 = 12