# 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) A vector field $\vec{v}(x, y, z) = f(y)\hat{i} + g(x)\hat{j}$ is necessarily
(a) irrotational (b) sink
(c) source (d) solenoidal.

(ii) Div curl $\vec{A}$ is equal to
(a) $\vec{\nabla} \times (\vec{\nabla} \times \vec{A})$ (b) $\vec{\nabla}.\vec{A} + \vec{\nabla} \times \vec{A}$
(c) $\vec{\nabla}.\vec{A}$ (d) zero.

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

(iv) Mathematically, Coriolis acceleration is given by
(a) $\ddot{\vec{r}}$ (b) $2\vec{\omega} \times \dot{\vec{r}}$ (c) $2\dot{\vec{r}} \times \vec{\omega}$ (d) $\vec{\omega} \times (\vec{\omega} \times \vec{r})$,
where the terms have their usual meaning and overhead dot gives time derivative.

(v) In a free-damped motion the relaxation time increases with the
(a) increase in frequency (b) increase in damping factor
(c) decrease in frequency (d) decrease in damping factor.

(vi) In case of forced oscillation, the amplitude resonance frequency
(a) increases with damping factor
(b) decreases with damping factor
(c) increases with time
(d) decreases with time.





(vii) Number of optic axis in a uniaxial crystal is
(a) one (b) two (c) five (d) three.

(viii) A polarized wave given by light vector $\vec{E}(z, t) = E_0\cos(\omega t - kz)\hat{i} + E_0\sin(\omega t - kz)\hat{j}$ is
(a) linearly polarized wave (b) elliptically polarized wave
(c) circularly polarized wave (d) plane polarized wave.

(ix) The dimension of polarizability in SI unit is
(a) $Fm^2$ (b) Fm (c) $Fm^{-1}$ (d) $Fm^{-2}$.

(x) At a very large distance the electric field on the axis of a uniformly charged circular ring behaves like that of a
(a) dipole (b) quadrupole
(c) neutral object (d) point charge.

## Group – B

2. (a) A surface is given by the equation $z^2 = x^2 + y^2$. Find a unit normal at the point (1, 0, -1).

(b) If $\vec{r}$ is the vector from some fixed point $(x_0, y_0, z_0)$ to the point $(x, y, z)$ and r is its length, show that $\vec{\nabla}(r^2) = 2\vec{r}$.

(c) (i) Show that a vector field given by an equation $\vec{E}(x, y, z) = (2xy + z^3)\hat{i} + x^2\hat{j} + 3xz^2\hat{k}$ is irrotational.
(ii) Calculate the divergence of the same vector field at a point (1,0,1).
(iii) Show that for a scalar field $\Psi$, $\vec{\nabla} \times \vec{\nabla}\Psi = \vec{0}$.

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

3. (a) Show that for a particle undertaking motion in a central force field, angular momentum remains conserved.

(b) The orbit of a particle under the influence of a central force is given by $r = e^{-\theta}$. Find out the corresponding force law.

(c) Write Kepler's laws of planetary motion.

(d) What is Coriolis force? Under what conditions do we get non-zero Coriolis acceleration?

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

## Group – C

4. (a) A damped harmonic oscillation performed by a particle is given by the following equation:
$\frac{d^2x}{dt^2} + 2\pi\frac{dx}{dt} + \omega_0^2 x = 0.$
(i) Write down the condition for which the motion will represent a weakly damped oscillation.
(ii) Find out the value of its logarithmic decrement.

(b) Write down the differential equation of forced vibration mentioning each and every term.

(c) Obtain mathematically the expression for the amplitude resonance frequency. Show graphically how amplitude resonant frequency shifts on the frequency axis with the decrease of damping.

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

5. (a) Find the state of polarization when the $x$ and $y$ components of the electric field are given by $E_x = E_0 \sin(\omega t + kz)$ and $E_y = E_0 \cos(\omega t + kz)$.

(b) Does $y = A\sin^2(kx - wt)$ represent a progressive harmonic wave? Justify your answer.

(c) Explain briefly the phenomenon of population inversion.

(d) State the physical significance of Einsein's A and B coefficient in LASER and find relation between them.

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

## Group – D

6. (a) Two point charges q and 2q are located at (1, 1) and (1, -1). Find the field and potential at the origin (0, 0).

(b) Calculate electric potential due to a uniformly charged ring of diameter 2cm and total charge 1C at a point on the axis of the ring at a distance of 1m if the ring is placed in xy-plane at z = 0.

(c) Obtain Poisson equation starting from differential form of Gauss's law of electrostatics.

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

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





7. (a) (i) State the Laplace's equation in electrostatics.
(ii) Under what condition does Poisson's equation reduce to Laplace's equation?

(b) Following Laplace's equation obtain the expression for electrostatic field within the region of two conducting spheres of radii a and b where the outer one is earthed. Also, assume that potential of the inner sphere is $V_1$ volt.

(c) Derive the expression of atomic polarizibility for a neutral atom.

(d) The dielectric constant of Helium at $0^0$C is 1.0000684. If the gas contains $2.7 \times 10^{24}$ atoms/$m^3$, find the radius of the electron cloud.

**(1 + 2) + 4 + 3 + 2 = 12**

## Group – E

8. (a) Write down Biot-Savart law of magnetostatics. Using the law obtain the expression for magnetic field produced due to an infinitely long conductor carrying current along $\hat{k}$.

(b) In case of a linear medium show that $\mu = \mu_0(1 + \chi_m)$, where the symbols have their usual meaning.

(c) A magnetic field $4\times10^{-3}\hat{k}$ tesla exerts a force of $(4\hat{i} + 3\hat{j})\times10^{-10}N$ on a particle having charge of $1\times10^{-9}C$ and moving in x-y plane. Calculate the velocity of the particle.

(d) Obtain differential form of Faraday's law from its integral form.

**(1 + 3) + 4 + 2 + 2 = 12**

9. (a) (i) The vector potential corresponding to a magnetic field is given by $\vec{A}(\vec{r}) = C(y\hat{i} - x\hat{j})$, C is a constant scalar. Show that the said magnetic field is constant.
(ii) Plot susceptibility vs temperature for a paramagnetic material and paramagnetic phase of a ferromagnetic material.

(b) A square loop of side 'a' is placed parallel to xy-plane in presence of a vertical magnetic field along z-axis. The loop is carrying a current 'i'. Calculate the force acting on each side of the loop, magnetic moment of the loop and torque acting on the loop.

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