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) The cylindrical coordinates of a point are given by $(2, \frac{\pi}{3}, 0)$. The point lies on the
- (a) YZ plane
- (b) XZ plane
- (c) XY plane
- (d) Intersection of XY and XZ planes

(ii) Suppose $\vec{A}$ has a constant magnitude. Then
- (a) $\vec{A}.\frac{d\vec{A}}{dt} = 0$
- (b) $\vec{A} \times \frac{d\vec{A}}{dt} = 0$
- (c) $\vec{A}$ and $\frac{d\vec{A}}{dt}$ are perpendicular
- (d) Both (a) and (c)

(iii) The position vector $\vec{r}$ is
- (a) Irrotational
- (b) Solenoidal
- (c) A source field
- (d) Both (a) and (c)

(iv) Which of the following force law does not imply conservation of angular momentum?
- (a) $\vec{F} = Kr^2\hat{r}$
- (b) $\vec{F} = K\sin\theta\hat{r}$
- (c) $\vec{F} = Kr\cos\theta\hat{r}$
- (d) $\vec{F} = Kr^2\hat{\theta}$

where $\hat{r}, \hat{\theta}$ are the unit vectors and k is a constant.

(v) For a linear damped system which otherwise shows an SHM in absence of damping, the oscillatory solution is possible only for
- (a) Large damping
- (b) Weak damping
- (c) Critical damping
- (d) Maximum damping

(vi) The curve representing the damping factor vs relaxation time is a
- (a) Parabola
- (b) Hyperbola
- (c) Straight Line
- (d) Circle

(vii) At velocity resonance the phase difference between the displacement and the driving force is
- (a) $\frac{\pi}{2}$
- (b) $\frac{\pi}{4}$
- (c) π
- (d) 0

(viii) An electrostatic field is
(a) conservative (b) time dependent
(c) both (a) and (b) (d) None of (a), (b) & (c).

(ix) The light vector $\vec{E} = \cos(kz - \omega t)\hat{\imath} + \sin(kz - \omega t + \frac{\pi}{3})$ is
(a) plane polarized (b) left circularly polarized
(c) elliptically polarized (d) right circularly polarized

(x) If $\vec{B}$ is a magnetic field then $\vec{\nabla}.\vec{B} = 0$ for
(a) both magnetostatic and time-dependent fields
(b) only magnetostatic fields
(c) only time-dependent fields
(d) none of the above.

Group - B

2. (a) Find the directional derivative of $\Phi = 4xz^3 - 3x^2y^2z$ at $(2,-1,2)$ in the direction $2\hat{\imath} - 3\hat{\jmath} + 6\hat{k}$. *[(CO1)(Remember/LOCQ)]*

(b) Suppose $\vec{\nabla} \times \vec{A} = 0$. Evaluate $\vec{\nabla}.\left(\vec{A} \times \vec{r}\right)$ where $\vec{r}$ is the position vector. *[(CO1)(Evaluate/HOCQ)]*

(c) Find the constants a, b, and c such that the vector field $\vec{A} = (-4x - 3y + az)\hat{\imath} + (bx + 3y + 5z)\hat{\jmath} + (4x + cy + 3z)\hat{k}$ is irrotational. *[(CO1)(Remember/LOCQ)]*

(d) Determine the plane polar coordinate unit vectors in terms of $\hat{\imath}$ and $\hat{\jmath}$ and vice versa. *[(CO1)(Evaluate/HOCQ)]*

3 + 3 + 3 + (1.5 + 1.5) = 12

3. (a) The radius vector of a particle moving under the influence of a central force is given by $\vec{r}(t) = \alpha t\hat{\imath} + \beta t^2\hat{\jmath}, t$ represents time. Evaluate its areal velocity at $t = 2$. *[(CO2)(Evaluate/HOCQ)]*

(b) The polar equation of the orbit of a planet around the sun is given by $r(\theta) = \frac{5}{5+\cos\theta}$. Demonstrate that the force acting between the sun and the planet varies inversely with the square of the distance between them. *[(CO2)(Understand/LOCQ)]*

(c) The angular velocity of the earth with respect to its own axis is $\vec{\omega} = \omega\hat{k}$. If a particle of mass m starts moving with a velocity $\vec{v} = 5\hat{\imath}^{/} + 3\hat{k}^{/}$ along the latitude 60N, where, $\hat{k}$ is the unit vector along the direction of the earth axis and $\hat{\imath}^{/}$, $\hat{\jmath}^{/}$ and $\hat{k}^{/}$ are unit vectors along the downward direction following the longitude, along the eastward direction following the latitude and along the outward drawn normal respectively for the coordinate system associated with the particle, respectively.

(i) Construct the expression of $\vec{\omega}$ in terms of the unit vectors of the relevant rotating frame. *[(CO2)(Construct/IOCQ)]*

(ii) Evaluate the magnitude and direction of the Coriolis force acting on the particle. *[(CO2)(Evaluate/HOCQ)]*

4 + 4 + (2 + 2) = 12

Group - C

4. (a) A particle is performing damped oscillation following the equation $25\ddot{x} + 2\alpha\dot{x} + x = 0$. (i) Find the condition of critical and weak damping. (ii) Find logarithmic decrement in terms of α in case of weak damping. *[(CO3)(Remember/LOCQ)]*

(b) The differential equation of a series LCR circuit driven by AC voltage is given by $L\ddot{q} + R\dot{q} + \frac{q}{C} = V_0 \cos\omega t$. Where the symbols have their usual meaning.

(i) Determine the expression of average power dissipated due to Damping.

(ii) Determine the condition for which the power would be maximum.

[(CO3)(Evaluate/HOCQ)]

(c) What is population inversion in laser? *[(CO3)(Remember/LOCQ)]*

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

5. (a) The light vector of a linearly polarized light is given by $\vec{E} = (2\hat{\imath} + 3\hat{\jmath})\cos(kz - \omega t)$.

(i) Determine the equation of its plane of vibration.

(ii) If it is allowed to pass through a half wave plate made of negative crystal with optic axis parallel to Y-axis determine the state of polarization of the transmitted light. *[(CO3)(Evaluate/HOCQ)]*

(b) (i) What is metastable state for a lasing system? *[(CO6)(Remember/LOCQ)]*

(ii) Develop the expression of Einstein A and B coefficients for lasing system in equilibrium. *[(CO6)(Apply/IOCQ)]*

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

Group – D

6. (a) Find the force on a point charge $Q_1 = 20\,\mu C$ due to a charge $Q_2 = -300\,\mu C$ where Q_1 is located at $(0,1,2)\,cm$ and Q_2 is located at $(2,0,0)\,cm$. Given: $\varepsilon_0 = 8.85 \times 10^{-12}\,C^2/Nm^2$. *[(CO4)(Remember/LOCQ)]*

(b) Consider a line charge distribution of length L having uniform linear density of charge λ_0. Evaluate the electric field at any point on the perpendicular bisector of the line charge. Show that if the field point is at a distance much greater than L, the line charge behaves effectively like a point charge.

[(CO4)(Evaluate/HOCQ)]

(c) Consider a cube (each side of length 2 $meters$) centered at the origin and with sides parallel to the coordinate axes. The cube has a volume charge distribution with charge density $\rho = 50x^2 cos(\pi y/2)\,Coulombs/m^3$. Determine the net charge enclosed in the cube. *[(CO4)(Evaluate/HOCQ)]*

3 + (4 + 2) + 3 = 12

7. (a) The potential due to a spherically symmetric charge distribution is given by $\varphi(r) = \frac{ke^{-r/a}}{r}$; k, a being constants. Determine the charge density for the distribution. *[(CO4)(Evaluate/HOCQ)]*

(b) Two infinite planes parallel to XY-plane are located at $z = 2a$ and $z = 4a$. They are kept at potentials $2V$ and $4V$ respectively. Evaluate the potential at $z = 3a$. Also develop the magnitude and direction of electric field at $z = 3a$.

[(CO4)(Apply/IOCQ)]

(c) The displacement vector and the electric field at any point inside a polarized object are given by $\vec{D} = 2x\hat{\imath} + 2\sqrt{3}y\hat{\jmath} + \sqrt{5}z\hat{k}$ and $\vec{E} = x\hat{\imath} + 2\sqrt{3}y\hat{\jmath} + \sqrt{5}z\hat{k}$ respectively. Assuming the permittivity of the vacuum to be unity, find the polarization vector, angle between the electric field and the polarization at a point $(1, 1, 1)$. *[(CO4) (Remember/LOCQ)]*

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

Group - E

8. (a) State Ampere's law in differential form and convert it into its integral form. Show that the current density vector appearing in Ampere's law corresponds to steady current. *[(CO4)(Remember/LOCQ)]*

(b) Show that two vector potentials $\overrightarrow{A_1} = (3y^2\hat{\imath} + z^3\hat{\jmath})$ and $\overrightarrow{A_2} = (6x + 3y^2)\hat{\imath} + (y + z^3)\hat{\jmath} + z^2\hat{k}]$ represent the same magnetic field. Explain the reason. *[(CO4)(Remember/LOCQ)]*

(c) Develop the general relation between the magnetic induction vector $\vec{B}$ and the magnetic intensity vector $\vec{H}$ in a magnetic material. Identify a class of magnetic materials for which the relation $\vec{B} = \mu\vec{H}$ does not work. *[(CO5)(Apply/IOCQ)]*

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

9. (a) A rectangular loop of length l and width b is carrying a steady current I in an anticlockwise direction. Make use of the formula $\vec{m} = \frac{I}{2}\oint \overrightarrow{r'} \times \overrightarrow{dr'}$ where the symbols have their usual meanings to evaluate the magnetic moment of this loop. *[(CO5)(Apply/IOCQ)]*

(b) The magnetic intensity in a certain material having permeability $\mu = 5\mu_0$ is given by $\vec{H} = 2\hat{\imath} + 5\hat{\jmath} - 8\hat{k}$. What are the susceptibility of the material, the magnetization $\vec{M}$ and the magnetic induction $\vec{B}$? *[(CO5)(Remember/LOCQ)]*

(c) Write down Faraday's law in integral form and reduce it to its differential form. *[(CO4)(Understand/LOCQ)]*

(d) A circular coil having 25 turns and a radius of 5 m is held in a uniform magnetic field of 8×10^{-3} $Tesla$ with the field being perpendicular to the plane of the coil. Determine the induced emf in the coil, if the magnetic field is removed in 0.4 s. *[(CO4)(Evaluate/HOCQ)]*

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

Cognition Level	*LOCQ*	*IOCQ*	*HOCQ*
Percentage distribution	*40.6*	*18.8*	*40.6*

Course Outcome (CO):

After the completion of the course students will be able to

1. Understand and apply Vector Calculus as tool for solving different physical problems.
2. Analyse the nature of central forces and rotating frame phenomenon to understand basic space science and real world applications.
3. Interpret different types of oscillatory motion and resonance.
4. Apply fundamental theories and technical aspects in field of electricity and magnetism in solving real world problems in that domain.
5. Understand the electrical and magnetic properties of different types of materials for scientific and technological uses.
6. Develop analytical and logical skill in handling problems in technology related domain.

**LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.*