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) Find the value of $\vec{\nabla}.\vec{A}$, where $\vec{A} = -y\hat{\imath} + x\hat{\jmath}$ is a vector of the point on a plane.
(a) 1 (b) 0 (c) 2 (d) 3.

(ii) For a conservative vector field $\vec{V} = (2x - 4y + az)\hat{\imath} + (bx - 2y - 3z)\hat{\jmath} + (4x + cy + 2z)\hat{k}$, the value of a, b and c are
(a) 4, -4,-3 (b) 4, 4, 3 (c) -4, 4, 3 (d) -4, -4, -3.

(iii) Curl of electric field is zero when
(a) source charge is static
(b) source charge is in uniform motion
(c) does not depend on the velocity of the source charge
(d) source charge has accelerated motion.

(iv) The function $\Psi(x,t) = (Ax + Bt)^2$, where A and B are constant, represents a classical wave. The value of wave velocity
(a) $\frac{B}{A}$ (b) $\frac{A}{B}$ (c) AB (d) 1

(v) The light vector of a polarized light is given by $\vec{E}(z,t) = 3\sin(wt - kz)\,\hat{\imath} + 2\cos(wt - kz + \frac{\pi}{4})\hat{\jmath}$. The state of polarization will be
(a) left elliptical polarized (b) right elliptical polarized
(c) Linearly polarized (d) right circularly polarized

(vi) For a forced harmonic oscillator system, the velocity resonance condition can be achieved if the relation between the damping constant (b) and the natural frequency (ω_0) is:
(a) $\omega_0 = b$ (b) $\omega_0 = 2b$ (c) $\omega_0 = \frac{b}{2}$ (d) All of the above.

(vii) The induced charge density on a grounded conducting surface ($XY - plane$) due to the presence of a point charge at (0,0,2):
(a) is same at each point on the surface (b) increases as $x^2 + y^2$ increases
(c) decreases as $x^2 + y^2$ increases (d) is $zero$.

(viii) A uniform magnetic field is acting along the positive Z axis. The value of vector potential (A) at a distance r from the Z axis has the magnitude
(a) 2Br (b) Br (c) $\frac{Br}{2}$ (d) $\frac{B}{2r}$

(ix) A square loop of side a is rotating about the X axis with an angular velocity $\vec{\omega} = \omega_0 \hat{\imath}$ in the presence of a constant magnetic field $\vec{B} = B_0 \hat{\jmath}$. The induced emf in the loop will be
(a) $B_0 a^2 \omega_0 Sin\omega_0 t$ (b) $B_0 a^2 \omega_0 Cos\omega_0 t$
(c) $B_0 a^2$ (d) $B_0 a^2 \omega_0$

(x) Which of the following force law represents a central force?
(a) $\vec{F} = \frac{Kcos\theta}{r}\hat{r}$ (b) $\vec{F} = \frac{Kcos\theta}{r}\hat{\theta}$
(c) $\vec{F} = \frac{K}{r}\hat{r}$ (d) $\vec{F} = \frac{K}{r}\hat{\theta}$.

Group – B

2. (a) A scalar field is given by the function $\Psi(x, y, z) = x + y^2 - z$. Evaluate the directional derivative of the field along the direction of the vector $\vec{a} = 2\hat{\imath} + 2\hat{\jmath} - \hat{k}$ at a point (1, 1, 2). [(CO1)(Evaluate/HOCQ)]

(b) A vector field is given as $\vec{A} = z\hat{\imath} - 2x\hat{\jmath} + y\hat{k}$. Modify this vector field for cylindrical polar coordinates and hence determine the components A_ρ, A_φ, and A_z. [(CO1)(Create/HOCQ)]

(c) 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, evaluate the value of $\vec{\nabla} \times \vec{\nabla}(r^2)$. [(CO1)(Evaluate/HOCQ)]

3 + (3 + 3) + 3 = 12

3. (a) A car moves with a constant acceleration $\vec{f}$. Identify the type of reference frame for an observer sitting in the car. Write down the five term acceleration formula of a particle as seen from the rotating coordinate frame of reference. [(CO2)(Remember/LOCQ)]

(b) Deduce Kepler's 3rd law (law of periods) starting from the consideration of central force. [(CO2) (Create/HOCQ)]

(c) Explain the fact that the orbit of a planet moving under the influence of a central force is confined in a plane. [(CO2) (Analyze/IOCQ)]

(d) A particle is moving with velocity v horizontally along longitude towards north in the northern hemisphere on the earth surface. Show that, due to Coriolis force, particle will be deflected towards eastward direction.
[(CO2) (Apply/IOCQ)]

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

Group – C

4. (a) Construct the differential equation of motion of a forced harmonic oscillator. [(CO3) (Create/HOCQ)]

   (b) A massless string suspended from a rigid rod carries a mass of 450 gm at its lower end. It is observed that the system oscillates with time period of 0.5 sec and the amplitude of oscillation reduces to half of its initial value in 40 sec. Evaluate the (a) relaxation time, (b) quality factor, (c) logarithmic decrement. [(CO3) (Evaluate/HOCQ)]

   (c) Show that $g(x,t) = a\ sin\pi t\ sin\frac{2\pi}{3}x$ represents a classical wave. Find its velocity. [(CO3) (Remember/LOCQ)]

   (d) Compare the steady state trajectories (displacement as a function of time) of an object having a simple harmonic oscillation, damped harmonic oscillation and a forced harmonic oscillation. [(CO3)(Create/HOCQ)]

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

5. (a) Determine the state of polarization for the light vector $\vec{E} = \cos(\omega t - kz)\hat{\imath} + \cos\omega t - kz + \pi 4\hat{\jmath}$. Justify with the help of relevant diagram. [(CO6)(Evaluate/HOCQ)]

   (b) A step index optical fibre has a core of refractive index 1.50 and cladding of refractive index 1.40. If the fibre is used in a water environment, find its numerical aperture and acceptance angle. (Given: Refractive index of water is 1.33) [(CO6)(Apply/IOCQ)]

   (c) Define stimulated emission and population inversion in LASER. Find the relationship between Einstein A and B coefficient in lasing action. [(CO6) (Remember/LOCQ)]

   (d) A circularly polarized light is given by $\vec{E}(z,t) = 2\ sin\frac{2\pi}{3}(z-t)\hat{\imath} + 2cos\frac{2\pi}{3}(z-t)\hat{\jmath}$. Identify proper retardation plate that can transfer it to a linearly polarized light along the line $y = \frac{3}{2}x$. [(CO6)(Apply/IOCQ)]

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

Group – D

6. (a) The electric field at a field point (0, 2, 0) due to two point charges both having 1C charge and placed at points (1,0,0) and (2,0,0) is given by $\vec{E} = \frac{1}{4\pi\varepsilon_0}\vec{\alpha}$. Find $\vec{\alpha}$. [(CO4) (Evaluate/HOCQ)]

   (b) Calculate the electric potential and field at $\left(25, \frac{\pi}{3}\right)$for a dipole of charges ±2C placed at (2,0,0) and (-2,0,0) with origin at the centre of the dipole. [(CO4)(Apply/IOCQ)]

   (c) A charge of 5C is placed at (0,-2, 0) near a grounded infinite conducting plane y = 0. Obtain the potential and electric field at (1,-4, 2) using image method. And also find the total induced charge on the infinite conducting plane. [(CO4)(Create/HOCQ)]

4 + 2 + (4 + 2) = 12

7. (a) Two concentric, cylindrical, conducting surfaces of infinite length have inner and outer radii as R_i and R_o. The inner cylinder is grounded while the outer cylinder has a uniform surface charge density σ_0. Find out the potential and electric field at any point between the cylinders. [(CO4)(Evaluate/HOCQ)]

   (b) If polarization $\vec{P} = \chi\epsilon_0\vec{E}$, then express the electric displacement vector in term of the electric field $\vec{E}$. [(CO4)(Evaluate/HOCQ)]

   (c) Show that the vector field $\vec{E} = x\hat{\imath} - y\hat{\jmath}$ can represent an electrostatic field in vacuum. [(CO4)(Understand/LOCQ)]

   (d) Find the electric field $\vec{E}$ at any point (r, θ), where potential is $\varphi(r, \theta) = r^2 cos\theta$. [(CO4)(Remember/LOCQ)]

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

Group – E

8. (a) Explain the fact that a steady current represents a magnetostatic field. Show that the vector field given by $\vec{B} = \frac{\mu_0\alpha}{4\pi}\left(-x\hat{\jmath} + y\hat{k}\right)$ represents a magnetostatic field. Find the corresponding current density. [(CO5)(Create/HOCQ)]

   (b) Find the value of magnetic moment of a circular loop of radius R and carrying a current IIalong the counter- clockwise sense. [(CO4)(Remember/LOCQ)]

   (c) The vector potential due to a current carrying system is given by $\vec{A} = k((x - y)\hat{\imath} + (y + z)\hat{\jmath} + z\hat{k}$. Show that the magnetic field produced by the system is zero along the line $y = x$. [(CO5) (Understand/LOCQ)]

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

9. (a) Show that $\vec{E} = \hat{k}\sin(y - t)$ and $\vec{B} = \hat{\imath}\sin(y - t)$ constitute a possible electromagnetic field. That is, show that they satisfy Faraday's law. [(CO6) (Analyze/IOCQ)]

   (b) A semi-circular loop of radius 'a' is rotating with its diameter as the axis of rotation (along Z axis) in presence of a constant magnetic field $\vec{B} = -B_0\hat{\imath}$. Its angular velocity is $\vec{\omega}$. Estimate the induced current as a function of time t if the resistance of the loop is R. [(CO6) (Create/HOCQ)]

   (c) For linear isotropic material, show that the relation between magnetic susceptibility (χ) and permeability (μ) is $\mu_0(1 + \chi) = \mu$. [(CO5)(Understand/LOCQ)]

   (d) A current carrying circular loop (with the centre at the origin) on YZ-plane has the magnetic moment $\vec{m} = m\hat{\imath}$. The vector potential $\vec{A}$ due to it at a field point $\vec{r}$ is given by $\frac{\mu_0}{4\pi}\frac{\vec{m}\times\vec{r}}{r^3}$. Find the magnetic field at a point P $(1, 2, 1)$ due to this loop. [(CO6) (Create/HOCQ)]

3 + 3 + 2 + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	42%	15%	43%

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. Analyze the nature of central forces and rotating frame phenomenon to understand basic space science and real world applications understand basic space science and real world applications.
3. Interpret the different types of oscillatory motion and resonance.
4. Apply fundamental theories and technical aspect in the field of electricity and magnetism in solving real world problems in that domain 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 use materials for scientific and technological use.
6. Develop Analytical & Logical skill in handling problems in technology related domain.

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

Department & Section	Submission Link
BT	https://classroom.google.com/c/NDA2MTYzNjI3MjE4/a/NDY4Mjc3MTgwNzEx/details
CE	https://classroom.google.com/c/NDEwNjU3Njg0ODQ2/a/NDc1MTUzNTc5NTg0/details
CHE	https://classroom.google.com/c/NDA2MDQwODE2MTky/a/NDc1MTQ1MTkyMzQ0/details
CSE (AI&ML)	https://classroom.google.com/c/NDA2MTU2NTUyODY5/a/NDc0ODQ5MDQ5ODM5/details
CSE (DS)	https://classroom.google.com/c/NDA2MTYzNjI3MTQ0/a/NDY4Mjc2NTA3OTM1/details
EE	https://classroom.google.com/c/NDA2MDQwODE2MTMx/a/NDc1MTQzNzM2Nzky/details
ME	https://classroom.google.com/c/NDA2MTM0MTk4OTQ1/a/NDc0ODUzOTUwOTI3/details