PHYSICS – I
(PHY1001)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

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

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) The shape of the orbit of a particle moving under the influence of central force when the $E > 0$ is
(a) hyperbola (b) parabola (c) ellipse (d) straight line

(ii) For a given central force $\vec{F} = F(r)\hat{r}$ which of the following statement is false?
(a) The orbit is confined in a plane (b) $\vec{r} \cdot \vec{F} = 0$
(c) $\vec{r} \times \vec{F} = 0$ (d) The angular momentum is conserved.

(iii) A damped oscillator is acted upon by an external force $F = F_0 cos\omega t$. If ω_0 is the natural frequency of oscillation, the frequency of oscillation of the system at steady state is
(a) ω_0 (b) ω (c) $\omega - \omega_0$ (d) $\omega + \omega_0$

(iv) Damping constant γ resembles the dimension of *
(a) length (b) mass (c) time (d) frequency

(v) The curve representing the relation between relaxation time and damping factor is a
(a) straight line (b) parabola (c) hyperbola (d) cubic parabola

(vi) A light vector represented by $\vec{E}(x,t) = 2\cos(kx - \omega t)\hat{j}$ is
(a) circularly polarized (b) unpolarized
(c) elliptically polarized (d) plane polarized

(vii) When the liquid is introduced between the lens and the plate, the diameters of the rings
(a) decreases (b) increases (c) remains same (d) none of these

(viii) The eigenvalue of a quantum observable is
(a) complex (b) real (c) purely imaginary (d) bicomplex

(ix) If ψ_1 and ψ_2 are two eigenstates of the Hamiltonian corresponding to two different eigenvalues $c_1\psi_1 + c_2\psi_2$ is
(a) aneigen state (b) is not an eigenstate
(c) may be an eigenstate (d) may not be an eigenstate.

(x) For a particle in a box $0 \leq x \leq a$ the expectation value of position is
(a) Independent of the dimension of the box
(b) Independent of the eigenstate
(c) Dependent on the eigenstate
(d) Dependent on the energy value

Fill in the blanks with the correct word

(xi) If the orbit equation is given $r = \frac{12}{3+\cos\theta}$, the shape of the orbit is _____.

(xii) Quality factor of a forced oscillating system is independent of _____ frequency.

(xiii) Two coherent sources in Newton's ring experiment are obtained by division of _____.

(xiv) $[H, A] = 0$ and$H\psi = E\psi$ implies $HA\psi =$ _____.

(xv) $\left[X,\ P_x{}^2\right] =$ _____.

Group - B

2. (a) Show that for a particle moving in a central force field, the areal velocity is constant. *[(CO6)(Remember/LOCQ)]*

(b) Develop Kepler's 3rd law (law of periods) starting from the consideration of central force? *[(CO4)(Remember/LOCQ)]*

(c) Explain the fact that the orbit of a planet moving under the influence of a central force is confined in a plane. *[(CO1)(Apply/IOCQ)]*

(d) The orbit of a planet rotating around the sun is given by $r = \frac{5}{3+2\cos\theta}$. Evaluate the eccentricity of the orbit and minor axis of the orbit. *[(CO1)(Apply/IOCQ)]*

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

3. (a) How does the eccentricity of the orbit depend on the energy of the particle moving under the influence of inverse square central force? *[(CO6)(Analyse/HOCQ)]*

(b) Write and explain the conditions under which a particle moving under central force have different shapes of orbit? *[(CO4)(Remember/LOCQ)]*

(c) Find out the general expression for the radial and transverse component of velocity and acceleration of a particlein a plane polar coordinate system. *[(CO4)(Remember/LOCQ)]*

(d) Find the conditions for which the central force given by $\vec{F} = \frac{r(r-1)}{(r^2+1)}\hat{r}$ is attractive towards the origin. *[(CO1)(Remember/LOCQ)]*

4 + 3 + 3 + 2 = 12

Group - C

4. The motion of a damped oscillator is given by the equation $\ddot{x} + Ke^{\sigma\dot{x}} + \omega_0^2 x = 0,\ K, \sigma > 0$.
   (i) Considering σ to be very small linearize the equation and find the dimension of K and σ. *[CO3 Apply/IOCQ]*
   (ii) Find the condition of weakly damped oscillation. Find the origin about which the damped oscillation is taking place. *[CO3(Apply/IOCQ)]*
   (iii) Find the relaxation time of the system. *[(CO3)(Evaluate/HOCQ)]*

(6 + 4 + 2) = 12

5. (a) Write down the expression of the amplitude of a forced harmonic oscillator under external periodic force in its steady state explaining all terms. Draw the amplitude resonance plot with angular frequency of the external force for two different damping constants. Show that at velocity resonance, the maximum velocity is inversely proportional to damping factor. *[(CO3)(Analyse/HOCQ)]*

   (b) The dynamics of a system undergoing forced oscillation is given by the equation of motion:

$$4\frac{d^2x}{dt^2} + 6\pi\frac{dx}{dt} + 10\pi^2 x = 5cos\alpha\pi t, \alpha > 0$$

   Estimate the values ofα , for which amplitude and velocity resonance is possible. Find the Q-factor of the system. *[(CO4)(Remember/LOCQ)]*

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

Group - D

6. (a) Illustrate creation of elliptically polarized light from plane polarized light. *[(CO3)(Understand/LOCQ)]*

   (b) Using a diagram, explain Brewster's law. *[(CO2)(Understand/LOCQ)]*

   (c) Calculate the polarizing angle for a light wave passing from air to glass. Given that the refractive index of air is 1.00 and the refractive index of glass is 1.50. *[(CO3)(Apply/IOCQ)]*

   (d) Calculate the thickness of a quarter wave plate (QWP) required for an operating wavelength $\lambda = 0.589\ nm$ when it is made of calcite with $\mu_e = 1.4864$ and $\mu_o = 1.66584$. *[(CO3)(Apply/IOCQ)]*

3 + 3 + 3 + 3 = 12

7. (a) Find out whether $\psi(y,t) = Ae^{(ky-\omega t)}$ represents a classical wave or not. *[(CO2)(Remember/LOCQ)]*

   (b) Obtain the expression for the diameter of n^{th} dark ring in Newton's ring experiment. *[(CO4)(Remember/LOCQ)]*

   (c) If the diameter of fourth dark ring in Newton's ring experiment is 2.52 mm and it is illuminated by a light of wavelength 6000 A, then find out the radius of curvature of the plano-convex lens. *[(CO3)(Remember/LOCQ)]*

(d) When a transparent liquid is poured between the air gap in Newton's ring experimental setup, the diameter of the fifth ring decreases from 2.7 mm to 2.32mm. What is the refractive index of the liquid? *[(CO3)(Remember/LOCQ)]*

3 + 4 + 2 + 3 = 12

Group - E

8. (a) Considering H as the Hamiltonian of a system and an observable A with no explicit time dependence establish the Heisenberg equation of motion : $\frac{\partial \langle A \rangle}{\partial t} = \frac{2\pi i}{h}[H, A]$ and explain the notion of conservation principle in view of this equation. *[(CO4)(Understand/LOCQ)]*

(b) Establish the relation $[A, BC] = [A, B]C + B[A, C]$. Using this relation Show that if [A, B]=1, $[A, B^2] = 2B$ *[(CO4)(Understand/LOCQ)]*

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

9. (a) The state of a quantum system is given by $\psi = \frac{1}{\sqrt{3}}\psi_1 + \sqrt{\frac{2}{3}}\psi_2$, where, ψ_1 and ψ_2 are normalized eigenstates. Find the probability of finding the system in the respective eigenstates. *[(CO1)(Remember/LOCQ)]*

(b) Considering the unitary time evolution and Hamiltonian H as the generator of time evolution develop time dependent Schroedinger equation. *[(CO1)(Apply/IOCQ)]*

(c) Show that z^n is an eigen function of the operator $z\frac{d}{dz}$ and find the eigenvalue. *[(CO2)(Understand/LOCQ)]*

4 + 4 + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	61.5	26	12.5