

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) Which of the following force law does not represent a central force?
 (a) $\vec{F} = k \cos^2 \theta \hat{r}$ (b) $\vec{F} = k r \hat{r}$
 (c) $\vec{F} = \frac{k}{r^2} \hat{r}$ (d) $\vec{F} = \frac{k}{r^3} \hat{r}$
- (ii) For an orbit equation given by $r = e^\theta$, the force law is
 (a) proportional to r^3 (b) proportional to r^2
 (c) proportional to $1/r^3$ (d) a constant
- (iii) 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
- (iv) 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) $\omega + \omega_0$
- (v) A function $x(t) = A \sin^2 \omega_0 t$ represents
 (a) SHM about a point $x = \frac{A}{2}$ with time period $\frac{\pi}{\omega_0}$
 (b) SHM about a point $x = \frac{A}{2}$ with time period $\frac{2\pi}{\omega_0}$
 (c) SHM about a point $x = 0$ with time period $\frac{\pi}{\omega_0}$
 (d) SHM about a point $x = 0$ with time period $\frac{2\pi}{\omega_0}$
- (vi) A half wave plate introduces a phase difference
 (a) $\frac{\pi}{2}$ (b) $\frac{\pi}{5}$ (c) 2π (d) π

- (vii) In a series L-C-R circuit connected with sinusoidal, the discharge of the capacitor is oscillatory if
- (a) $R = 2\sqrt{LC}$ (b) $R = 2\sqrt{\frac{L}{C}}$
(c) $R = \sqrt{LC}$ (d) $R = \sqrt{\frac{L}{C}}$
- (viii) A light vector represented by $\vec{E}(x, t) = 2 \sin(kx - \omega t)\hat{j} + 3 \cos(kx - \omega t)\hat{k}$ is
- (a) circularly polarized (b) unpolarized
(c) elliptically polarized (d) plane polarized
- (ix) The solution of time dependent Schroedinger equation is a
- (a) real function (b) complex function
(c) purely imaginary function (d) elliptic function
- (x) If $\int (A\psi)^* \phi dx = \int \psi^* B \phi dx$ B is called
- (a) transpose (b) inverse (c) adjoint (d) conjugate

Fill in the blanks with the correct word

- (xi) In absence of a central force the planet will move in a _____.
- (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) $[X, P_x^2] =$ _____
- (xv) Eigenstate of a quantum observable corresponding to two different eigenvalues are _____

Group - B

2. (a) Write Kepler's laws of planetary motion. [[CO3](Analyse/LOCQ)]
(b) For a particle moving under the influence of a central force field, show that, (i) the total energy remain conserved (ii) upon the withdrawal of the force, it starts to follow a rectilinear path. [[CO4](Remember/HOCQ)]
(c) The equation of the orbit of a particle moving under the influence of a central force is given by $r = \frac{12}{3 + \cos \theta}$. Justify the nature of the orbit and also find the semi-major axis of the orbit. [[CO2](Evaluate/HOCQ)]
- 3 + (3 + 3) + (1 + 2) = 12**
3. (a) Find out the general expression for the radial and transverse component of velocity and acceleration of a particle in a plane polar coordinate system. [[CO4](Remember/LOCQ)]
(b) 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)]
(c) Prove that the speed v of a particle moving in an elliptical path in an inverse square force is given by $v^2 = \frac{K}{m} \left(\frac{2}{r} - \frac{1}{a} \right)$ where a is the semi-major axis.

[[CO3](Analyse/HOCQ)]

- (d) Is the $\vec{F} = \cos \theta \hat{r}$ a central force? Explain using the help of definition of central force.

[[CO1](Apply/IOCQ)]

3 + 2 + 5 + 2 = 12

Group - C

4. The motion of a damped oscillator is given by the equation $\ddot{x} + Ke^{\sigma\dot{x}} + \omega_0^2x = 0$, $K, \sigma > 0$.

- (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) A particle performing forced oscillation has the following equation of motion:

$$100\ddot{x} + 6\pi\dot{x} + 16\pi^2x = 50 \cos 3\pi t.$$

- (i) Find out the amplitude of steady state oscillation.

- (ii) Find out the phase difference between the driving force and the velocity in steady state oscillation.

- (iii) Calculate the frequencies corresponding to the amplitude and the velocity resonance.

[[CO3](Analyse/HOCQ)]

- (b) Write down the differential equation of a series LCR circuit driven by a sinusoidal voltage $V(t) = V_0 \cos \omega t$.

- (i) Compare the differential equation with a mechanical system undergoing forced vibration with the force $f(t) = f_0 \cos \omega t$.

- (ii) Find out the condition for which the current and the voltage are $\frac{\pi}{2}$ out of phase.

[[CO1](Analyse/HOCQ)]

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

Group - D

6. (a) Discuss the steps to convert a circularly polarized light into a plane polarized light.

[[CO3](Create/HOCQ)]

- (b) Differentiate between retardation plates made of positive crystal and negative crystal.

[[CO4](Remember/LOCQ)]

- (c) Find the state of polarization of the light vector represented by $\vec{E}(z, t) = \sin(kz - \omega t)\hat{i} + \cos(kz - \omega t)\hat{j}$.

[[CO2](Remember/LOCQ)]

- (d) Find out whether $\psi(y, t) = Ae^{(ky - \omega t)}$ represents a classical wave or not.

[[CO2](Remember/LOCQ)]

3 + 3 + 3 + 3 = 12

7. (a) Using a diagram, explain Brewster's law.

[[CO2](Understand/LOCQ)]

- (b) 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)]

- (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 Å, 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 + 3 + 3 + 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 : $\frac{d\langle A \rangle}{dt} = \frac{2\pi i}{h} [H, A]$ 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. The quantum state of a particle confined within $0 \leq x \leq \infty$ is given by $\psi(x) = A\sqrt{x}e^{-2x+i\omega t}$.
- (i) Evaluate the normalization constant and the probability density.
- (ii) Find the expectation value of $\frac{1}{x}$.
- (iii) Find the point where the probability density is maximum. [[CO5](Evaluate/HOCQ)]
[(3 + 3) + 3 + 3] = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	42.7	12.5	44.8