SCHOOL OF ENGINEERING AND TECHNOLOGY
D.C. COURT JUNCTION, DIMAPUR
END-TERM EXAMINATIONS, FEB–JUNE 2023 (BACK PAPER)

Course: Code:	GIT02	Semester:	I	Total:	60 Marks
Course: Name:	Engineering Physics-I			Time:	3 hours

(Write only the question number on the answer script)

Part – A

Q.1. Answer the following questions $10 \times 1 = 10$

a. According to quantum mechanics, the lowest energy of a simple harmonic oscillator with mass m and spring constant C is

(a) $h\sqrt{\frac{C}{m}}$ (b) $\frac{h}{4\pi}\sqrt{\frac{C}{m}}$ (c) $h\sqrt{\frac{m}{C}}$ (d) $\frac{h}{4\pi}\sqrt{\frac{m}{C}}$.

b. A man is standing on a disc at a distance of $3m$ from the disc's origin. The disc itself is rotating at constant angular speed of $3\ rad/s$. The speed of the man with respect to the ground is __9__ m/s.

c. If Δp is the uncertainty in the momentum and Δx is the uncertainty in the position of a particle, Heisenberg's uncertainty principle states that

(a) $\frac{\Delta p}{\Delta x} \geq \frac{h}{4}$ (b) $\frac{\Delta x}{\Delta p} \geq \frac{h}{4\pi}$ (c) $(\Delta p)(\Delta x) \geq \frac{h}{4}$ (d) $(\Delta p)(\Delta x) \geq \frac{h}{4\pi}$.

d. According to quantum mechanics, the set of values of the total energy of a particle bound inside a potential is

(a) finite (b) continuous (c) discrete (d) empty.

e. Suppose a force $\vec{F} = 2\hat{i} + \hat{j} - \hat{k}$ N acts on particle at a displacement of $\vec{r} = -\hat{i} + \hat{j} + 3\hat{k}$ m from the origin. The torque of the particle around the origin is (give the vector expression)

(a) $-4\hat{i} + 5\hat{j} - 3\hat{k}$ N m (b) $4\hat{i} - 5\hat{j} + 3\hat{k}$ N m (c) $-4\hat{i} - 5\hat{j} + 3\hat{k}$ N m (d) $4\hat{i} + 5\hat{j} - 3\hat{k}$ N m.

f. In Newton's rings experiment, the central interference fringe is

(a) rectangular (b) dark (c) bright (d) pentagonal.

g. A ball of mass 3 kg is moving in the positive X direction with a speed of $2\ m/s$. Soon, it collides with a ball of mass 1 kg also moving in the positive X direction with a speed of $1\ m/s$. Suppose that after collision the two balls stick together and continue moving in the positive X direction. Their joint speed is __1.5__ m/s.

h. In a quantum mechanical simple harmonic oscillator, compared to the probability of finding it near the classical endpoints of its motion, the probability of finding a particle in the ground state near the equilibrium position is

(a) greater (b) lesser (c) equal (d) unrelated.

i. In quantum mechanics with a time independent Hamiltonian, the energy of a stationary state, also known as an eigenstate, is

(a) infinite (b) decreasing with time (c) increasing with time (d) constant with time.

j. In Young's double slit experiment, the central interference fringe is

(a) bright (b) dark (c) fuzzy (d) discontinuous.

Part – B

$5 \times 4 = 20$

Q.2. Answer any five questions

a. Consider Young's double slit experiment where the slits are 0.4 mm apart and the screen is 4 m away from the slits. The third bright fringe is at a distance of 2 cm from the central or the zeroth fringe. Find the wavelength of the light.

b. Find the moment of inertia of a thin hollow cylinder of mass M, radius R and length L around its own axis.

c. State the Gauss divergence theorem in vector calculus. Do not forget to define all the terms.

d. The de Broglie wavelength of a proton of mass 1.67×10^{-27} kg is 10^{-13} m. What is its speed? Take the value of Planck's constant as $h = 6.6 \times 10^{-34}$ J s.

e. Find the distance between the third bright ring and the dark ring just outside it for a Newton's rings experiment with a plano convex lens of radius of curvature R using coherent monochromatic light of wavelength λ.

f. State Stokes' theorem in vector calculus. Do not forget to define all the terms too.

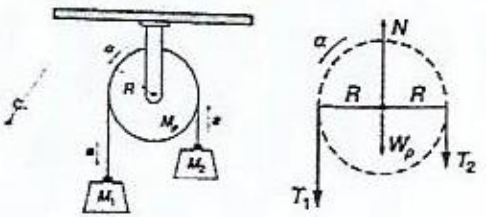
Part – C

Q.3. Answer any five questions

$5 \times 6 = 30$

a. Find the centre of mass of a water molecule H_2O. For simplicity assume that the two hydrogen-oxygen bonds subtend an angle of 120°, each bond has a length of 9×10^{-9} m and the oxygen atom is 16 times heavier than a hydrogen atom.

b. Consider a simple pendulum consisting of a bob of mass 2 kg suspended from a light string of length 1 m. The pendulum is oscillating in a plane. The maximum angle from the vertical attained by the bob during the course of its oscillation is $\frac{\pi}{60}$ radians. What is the bob's speed at the bottommost point of its trajectory? You can take the gravitational acceleration to be $g = 9.8\, ms^{-2}$.



Draw the force diagram for masses M_1 and M_2. Assume that the rope does not slip on the pulley. The torque diagram for the pulley is given for your convenience. Recall that the moment of inertia of the disc shaped pulley is given by $I_p = \frac{M_p R^2}{2}$. Find the acceleration a for the arrangement shown.

d. A rubidium atom in a rubidium vapour lamp can radiate at any time after it is excited from its lowest energy or ground state. The average excited atom has a lifetime of about 10^{-9} s., i.e., some time during this period it emits a photon and is deexcited i.e. comes back to its ground state.

(a) What is the minimum uncertainty ΔE in the energy of the excited state of the atom?

(b) Almost all the excited rubidium atoms give out photons at a wavelength of around $\lambda = 10^{-7}$ m. What is the fractional uncertainty in the frequency of the photon, also called the natural fractional width of the rubidium emission line?

Take the value of Planck's constant as $h = 6.6 \times 10^{-34}$ J s and the speed of light as $c = 3 \times 10^8$ m/s.

e. Consider the time independent potential

$$V(x) = \begin{cases} V_0 & x < 0 \\ V_0 & x > a \\ 0 & 0 \le x \le a. \end{cases}$$

In other words, the particle is in a potential well ranging from $x = 0$ to $x = a$ with walls of finite height V_0.

Suppose the particle has total energy $E < V_0$ i.e. the particle is a bound particle.

(i) Draw a diagram of the potential function showing the two types of regions neatly.

(ii) Write down the time independent Schrodinger equation in the region outside the well i.e. in the region $x < 0$ and $x > a$. Also write down its general solution.

(iii) Write down the time independent Schrodinger equation in the region inside the well i.e. in the region $0 \le x \le a$. Also write down its general solution.

1. Suppose monochromatic coherent light of wavelength $\lambda = 600$ nm is passed through a narrow slit. A Fraunhofer diffraction pattern is formed on a screen 6 m away.

   (a) The distance on the screen between the centres of the first dark fringes on either side of the central bright fringe is 10 mm. What is the width a of the slit?

   (b) Let I_0 denote the intensity of the central bright fringe. What is the intensity at a point 20 mm away from the centre of the pattern?