Registration Number:

Date & Session

ST. JOSEPH'S COLLEGE (AUTONOMOUS), BENGALURU -27
B.Sc. (PHYSICS) – V SEMESTER
SEMESTER EXAMINATION: OCTOBER 2023
(Examination conducted in November /December 2023)

PH5123: INTRODUCTION TO CLASSICAL MECHANICS AND QUANTUM MECHANICS (for current batch students only)

Time: 2 Hours **Max Marks: 60**

This paper contains two printed pages and three parts

PART-A

Answer any FOUR questions **(4 x 8 =32)**

1. State D'Alembert's principle and hence obtain an expression for Lagrange's equation for conservative systems. (8)

2. Demonstrate that homogeneity of space leads to the conservation of linear momentum and homogeneity of time leads to the conservation of energy. (8)

3. Describe the G.P. Thomson experiment with theory, to confirm the existence of matter waves. (8)

4. (a) Derive an expression for probability current density in terms of wave function.
   (b) Mention any two conditions for potential barrier penetration to take place. (6+2)

5. Write the Schrodinger's equation for a particle in a one-dimensional box and solve it to obtain the energy eigenvalues. (8)

6. (a) For a dynamical system write the quantum mechanical operator and expectation values for the (i) energy and (ii) momentum.
   (b) If the Schrodinger equation for a hydrogen atom is
   $$\frac{1}{r^2}\frac{\partial}{\partial r}\left[r^2\frac{\partial\Psi}{\partial r}\right]+\frac{1}{r^2\ \sin\theta}\ \frac{\partial}{\partial\theta}\left[\sin\theta\ \frac{\partial\Psi}{\partial\theta}\right]+\frac{1}{r^2 sin^2\theta}\ \frac{\partial^2\Psi}{\partial\emptyset^2}+\frac{2m}{\hbar^2}\ (E-V)\ \psi=0$$
   Using the method of separation of variables obtain the differential equation governing the azimuthal part. (4+4)

PART-B

Answer any FOUR questions **(4 x 5 =20)**

7. Assume a particle is subjected to forces $F_{x,,}$ F_Y, $F_{Z.}$. If the generalized coordinates are assumed to be cylindrical coordinates ie (ρ, θ, z) such that x = $\rho\cos\theta$, $y = \rho\sin\theta$, and z = z, find the generalized force components.

8. Using the Euler-Lagrange equation, find the equation of the curve that will have the shortest distance between two points.

9. The position and momentum of 1 keV electron are simultaneously determined. If its position is located within 0.4nm, what is the percentage uncertainty in its momentum?

10. A beam of electrons having energy 16 eV is incident on a step potential of height 9 eV. Calculate the reflection and transmission coefficient.

11. Calculate the zero-point energy and spacing of the energy levels in a one--dimensional oscillator of frequency 2 kHz.

12. Find the probability that a particle is found between 0.4 ℓ and 0.6 ℓ, if the wavefunction is $\Psi(x) = A \sin\left(\frac{\pi x}{\ell}\right)$ for $0 < x < \ell$ and $\Psi(x) = 0$ outside.

PART-C

Answer any FOUR questions **(4 x 2=8)**

13. Explain whether the principle of virtual work can be applied to a ball-rolling down an inclined plane.

14. Can the number of generalized coordinates be greater than the cartesian coordinates of a system of particles subjected to some constraints? Explain

15. An electron and a proton have the same value of de Broglie wavelength. Compare their kinetic energy.

16. What is the degeneracy of the first excited state for an electron trapped in a 3D box?

17. If two quantum mechanical operators commute, what does it imply?

18. What is basic principle behind the working of Tunnel diodes.?