



NATIONAL OPEN UNIVERSITY OF NIGERIA
PLOT 91, CADASTRAL ZONE, NAMDI AZIKIWE EXPRESSWAY, JABI - ABUJA
FACULTY OF SCIENCES
DEPARTMENT OF PHYSICS
2024 1 EXAMINATION

COURSE CODE: PHY 309
COURSE TITLE: QUANTUM MECHANICS I
CREDIT UNIT: 3
TIME ALLOWED: 3 HRS
INSTRUCTION: Answer question 1 and any other three questions

- 1a. Define vector space, Orthogonality and Orthonormality 9marks
1b. show that the following vectors are mutually orthogonal

$$\begin{pmatrix} 1 \\ 0 \\ -1 \end{pmatrix} \text{ and } \begin{pmatrix} 1 \\ \sqrt{2} \\ 1 \end{pmatrix}$$
$$\begin{pmatrix} 1 \\ -\sqrt{2} \\ -1 \end{pmatrix} \text{ and } \begin{pmatrix} 1 \\ \sqrt{2} \\ 1 \end{pmatrix}$$

7marks

- 1c. Replace the following classical mechanical expressions with their corresponding quantum mechanical operators.

- i. $K.E = \frac{mv^2}{2}$ in three-dimensional space
- ii. $P = mv$, a three-dimensional Cartesian vector
- iii. y - component of angular momentum: $L_y = zp_x - xp_z$.

9marks

- 2a. Transform the following functions accordingly from spherical polar to Cartesian coordinates: $r = 2\sin\theta\cos\phi$ 5marks

- b. Solve the following second-order linear differential equation subject to the specified boundary conditions:

$$\frac{d^2x}{dt^2} + k^2(t) = 0, \text{ where } x(t=0) = L, \text{ and } \frac{dx(t=0)}{dt} = 0. \text{ Assume } x(t) = e^{\alpha t}, \text{ with } \alpha \text{ unknown}$$

10marks

- 3a. Define coherent and incoherent scattering 4marks

- b. The wave function $\varphi(x, t)$ satisfies the time dependent Schrodinger equation of a free particle. Show that $H = \frac{-\hbar}{2m}\nabla^2 + V$ represent the Hamiltonian operator. Where $\varphi(x, t) = \varphi_0 e^{-i\omega t}$.

11marks

- 4a. Given the matrix $\begin{bmatrix} 2 & 4 \\ 1 & 3 \end{bmatrix}$, find the corresponding eigenvectors and eigenvalue. 8marks

- b. For the Hermitian matrix 4a, show that the Eigen functions can be normalized and that they are orthogonal. 7marks

- 5a. State the Correspondence Principle 3marks

- b. $\Psi(x) = A(ax - x^2)$ for $|x| \leq a$. Normalise the wavefunction and find $\langle x \rangle$. 12marks

- 6a. States the postulates of Quantum Mechanics 4marks

- b. A particle trapped in the well
$$V \begin{cases} 0, & 0 < x < a \\ \infty, & \text{elsewhere} \end{cases}$$

is found to have a wave function $\frac{i}{2}\sqrt{\frac{2}{a}}\sin\frac{\pi x}{a} + \sqrt{\frac{2}{3a}}\sin\frac{3\pi x}{a} - \sqrt{\frac{2}{16a}}\sin\frac{3\pi x}{a}$

- (a) If the energy is measured, what are the possible results and what is the probability of obtaining each result?
- (b) What is the most probable energy for this particle?
- (c) What is the average energy of the particle? **11marks**

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