NATIONAL OPEN UNIVERSITY OF NIGERIA
PLOT 91, CADASTRAL ZONE, NNAMDI AZIKIWE EXPRESSWAY, JABI - ABUJA
FACULTY OF SCIENCES
DEPARTMENT OF PHYSICS
2024_1 EXAMINATION

COURSE CODE: PHY 309
COURSE TITLE: QUANTUM MEHANICS 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

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

$$\begin{pmatrix} 1 \\ -\sqrt{2} \\ -1 \end{pmatrix} \; and \; \begin{pmatrix} 1 \\ \sqrt{2} \\ 1 \end{pmatrix}$$ **7marks**

1c. Replace the following classical mechanical expressions with their correspondingquantum 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: $r = 2sin\theta cos\emptyset$ **5marks**

b. Solve the following second-order linear differential equation subject to the specified boundary conditions:
$\frac{d^2x}{dt^2} + k^2(t) = 0$,where x(t=0) = L, and$\frac{dx(t=0)}{dt} = 0$. Assume $x(t) = e^{\alpha t}, with\ \alpha\ unknown$ **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 $\varphi(x, t) = \varphi_o e^{-i\omega t}$. **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 <x>. **12marks**

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

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

5(a). Describe the algorithm to prove the finiteness of a regular language L. ***(6marks)***

b) Explain the term Finite in respect to automaton and with the aid of a diagram, show the following (i) transition state, ii) start state iii) Final State.***(9 marks)***

6 a) When is a grammar said to be ambiguous and in what state is language is said to be recursively enumerable **(9 marks)**

b) State the Types of PDAs ***(6 marks)*** 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**