NATIONAL OPEN UNIVERSITY OF NIGERIA
PLOT 91, CADASTRAL ZONE, NNAMDI AZIKIWE EXPRESSWAY, JABI - ABUJA
FACULTY OF SCIENCES
DEPARTMENT OF PURE AND APPLIED SCIENCES
SEPTEMBER, 2020_1 EXAMINATION

COURSE CODE: **PHY 309**
COURSE TITLE: **QUANTUM MECHANICS I**
CREDIT UNIT **3**
TIME ALLOWED **(2 HRS)**

INSTRUCTION: ***Answer question 1 and any other four questions***

QUESTION 1

(a) (i) Check whether the following vectors are linearly independent:
$2i + 3j - k$, $-i + j + 3k$ and $-3i + 2j + k$ [3marks]
(ii) Find the inner product of the vectors ix^2+2 and $2x-3i$ $0 \leq x \leq 0$ [4marks]
(b) Write conditions that apply for a bound state [2 marks]
(c) Differentiate eigenvalues from eigenstates [2 marks]
(d) Write down Planck's formula with the assumption that radiant energy could only be emitted or absorbed in quanta. [3 marks]
(e) Find the change in wavelength if a photon is scattered at an angle of 23^0 after its collision with an electron initially at rest. [4marks]
(f) Write the formula guiding photoelectric effect. [2 marks]
(g) State Heisenberg's uncertainty principle. [2 marks]

QUESTION 2

(a) Show that the set $\left[\begin{pmatrix}1\\0\\1\end{pmatrix},\begin{pmatrix}1\\1\\0\end{pmatrix},\begin{pmatrix}1\\2\\1\end{pmatrix}\right]$ is linearly independent. [6 marks]

(b) Show that is $\left(\bar{i}+\bar{j},\bar{i}-\bar{j}\right)$ a set of basis vectors in 2- dimensional space [3 marks]

(c) Normalise each vector in the set $\left[\begin{pmatrix}1\\2\\3\end{pmatrix},\begin{pmatrix}-2\\0\\4\end{pmatrix},\begin{pmatrix}1\\2\\1\end{pmatrix}\right]$ [3 marks]

QUESTION 3

(a) Given the matrix $\begin{bmatrix}3 & -2\\1 & 2\end{bmatrix}$, find the corresponding eigenvectors and the eigenvalues.

[8 marks]

(b) Write the (i) Stefan-Boltzmann formula for the total radiant energy emitted by a blackbody per unit surface area per unit time. [2 marks]

(ii) Rayleigh and Jeans predicted formula for radiation emitted by a blackbody per unit time, per unit area. [2 marks]

QUESTION 4

(6. (a) Discuss (i) Blackbody radiation [4 marks]

(ii) Photoelectric effect [4 marks]

(b) Find the maximum kinetic energy with which an electron is emitted from a metal of work function 3.2×10^{-39} J when a radiation of energy $E = 3.313 \times 10^{-39}$ J falls on it, given that the work function is 3.2×10^{-39} J. [4 marks]

QUESTION 5

(a) State Bohr's postulates in theory of the hydrogen atom. [2 marks]

(b)What are the conditions that must be fulfilled for any function to satisfy time-independent Schroedinger equation? [2 marks]

(c)By solving the time-dependent Schroedinger equation for a free particle ($V = 0$), find the condition imposed on the angular frequency and the wave number. [4 marks]

(d) State 4 postulates of quantum mechanics. [4 marks]

QUESTION 6

(a) Let the total wave function of the particle in the potential well be where $\Psi = Dx$ where D is a normalisation constant. Find the probability that the particle is in state 0, 1, 2 and 5 given that

$$\psi_n(x) = \sqrt{\frac{2}{L}} \sin \frac{n\pi x}{L}$$ [6 marks]

(b) Normalise the eigenfunction $\psi(x) = A \exp\left(\frac{-m\omega x^2}{2\hbar}\right)$ Hence, find the probability that the particle subjected to a harmonic oscillation lies in the range $0 \leq x \leq \frac{1}{2}$ [6 marks]