A12

FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI
SCHOOL OF SCIENCE
DEPARTMENT OF PHYSICS

2014/2015 RAIN SEMESTER EXAMINATION **DATE:**
PHY 306: MODERN PHYSICS II **TIME: 3 HOURS**

INSTRUCTIONS

Answer any five questions.

Take: Electron charge = 1.60×10^{-19} C
Electron mass = 9.11×10^{-31} kg
Proton mass = 1.67×10^{-27} kg
Permittivity of free space = 8.85×10^{-12} $CN^{-1}m^{-1}$
Velocity of light = 3.0×10^{8} ms^{-1}
Planck's constant = 6.63×10^{-34} Js

Question 1.

(a) An excited atom gives up its excess energy by emitting a photon of characteristic frequency. The average period that elapses between the excitation of an atom and the time it radiates is 3.0×10^{-8}s. Find the inherent uncertainty in the frequency of the photon.

(b) An electron is in a box 0.20nm across, find its permitted energies corresponding to n = 1, 2, 3 and 4.

(c) If the electron in (1b) above is replaced with a 13g marble and the width of the box increased to 12cm, what are the permitted energies corresponding to n = 1, 2, 3 and 4.

(d) Compare the results obtained in (1b) and (1c) above and briefly discuss the physical implications.

Question 2.

(a) State four conditions that ψ must meet in order to be an acceptable wave function.

(b) Using the one-dimensional wave function of an unrestricted particle given as $\Psi = Ae^{-(i/\hbar)(Et - px)}$, derive the time-independent Schrodinger equation. Hence, express the derived equation in three dimensions.

(c) The wave function for a free electron is given by $\psi(x) = A\sin(2.5\times10^{10}x)$ where x is in meters. Compute the total energy of the electron.

$\psi(x) = A\sin(2.5\times10^{10}x) = A\sin\frac{2\pi x}{\lambda}$

$\psi(x) = \frac{2\pi x}{\lambda} = 2.5\times10^{10}$

$\frac{2\pi}{\lambda} = 2.5\times10^{10}$

but $E = \frac{p^2}{2m} + V$

Question 3.

(a) Suppose that an electron moving in a thin metal wire could be measured while in its ground state. What would be the probability of finding it somewhere in the region 0<x<L/4?

(b) What would be the probability of finding it in a very narrow region $\Delta x = 0.01L$ wide centered at x=5L/8?

(c) Show that the expectation value of the momentum of a particle trapped in the one-dimensional infinite square well is zero at all states.

$\boxed{\psi(x,t) = A\sin\left(\frac{\pi x n}{a}\right)\cos\frac{2\pi t}{T}}$

$\psi(x,t) = A\sin\frac{2\pi x}{\lambda}\cos\frac{2\pi t}{T}$

Question 4.

(a) Briefly discuss two applications of quantum mechanical tunnel effect.

(b) Electrons with energies of 1.0eV and 2.0eV are incident on a barrier 10.0eV high and 0.50nm wide. Calculate their respective approximate transmission probabilities.

(c) Sketch and explain briefly the first three harmonic oscillator wave functions.

$\boxed{\psi(x) = A\sin 2\pi x}$

$\lambda = \frac{2\pi}{2.5\times10^{10}}$

$E = p^2 + V$

Question 5.

(a)(i) State Pauli's exclusion principle

(ii) what is its implication if two electrons have the same set of the four quantum numbers in a given atom?

(b) Using the principle in (a) above, calculate the number of sub-shells and the total number of electrons in the M-shell of a given atom.

(c) What do you understand by the terms; Symmetric and Anti-symmetric wave functions?

(d) Given two states as ψ_1 and ψ_2; write the equations for the linear combinations of these states for a symmetric wave function and anti-symmetry wave function.

Question 6.

(a) What do you understand by the terms Fermions and Bosons?

(b) Explain the Zeeman's effect.

(c) What do the following mean: (i) Normal Zeeman's effect and (ii)Anomalous Zeeman's effect?

(d) Calculate the Bohr magneton, μ_β, for an electron.