[This question paper contains 4 printed pages.]

Sr. No. of Question Paper : 2351 **F-4** **Your Roll No.....**

Unique Paper Code : 2221401

Name of the Course : **B.Sc. (H)**

Name of the Paper : Elements of Modern Physics

Semester : IV

Duration : 3 Hours Maximum Marks : 75

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt **five** questions in all. Question No. **1** is compulsory.
3. **All** questions carry equal marks.
4. Use of non-programmable scientific calculators is allowed.

1. Attempt any **five** questions

   (a) What are the outcomes of Davisson and Germer experiment? Explain how these results directly confirm the De Brogie hypothesis of matter wave?

   (b) The wave function for a particle moving along the positive x-direction is given as $\psi(x, t) = A\exp\left\{i\left(\frac{px}{\hbar} - \frac{Et}{\hbar}\right)\right\}$. Using this derive an expression for momentum and kinetic energy operator in one dimension.

   (c) Normalize the wave function given below to find the constant 'A' for the Gaussian wave packet given as

$$\psi(x) = A\exp\left(-\frac{\alpha^2 x^2}{2}\right)\exp(i\,k\,x) \text{ given that } \int_{-\infty}^{\infty}\exp\left(-\alpha^2 x^2\right)dx = \sqrt{\frac{\pi}{\alpha}}.$$

(d) How do we explain the emission of Beta- particles from radioactive nuclei even though they are not contained in them? What kind of observations on the energy spectrum of Beta-rays led 'Pauli' to propose the neutrino hypothesis in 1930?

(e) A positron and an electron with negligible kinetic energy meet and annihilate one another, producing two γ-rays of equal energy. What is the wavelength of these γ-rays.

(f) Determine the approximate density of a nucleus.

(g) Describe the function of moderator and control rods in a nuclear reactor giving example of each. (5×3)

2. (a) Give an account of Einstein's explanation of Photoelectric effect on the basis of quantum theory. (5)

(b) The Photoelectric threshold for a certain metal is 3600A° when source is placed at 1m from target. Determine the maximum energy in eV of the electron ejected by the radiation of wavelength 2000A°. What will be the effect (qualitatively) on energy and number of ejected photoelectron when source is shifted to 25cm? (3,2)

(c) Show that the de Broglie wavelength for an electron accelerated from rest through a large potential difference, V, is

$$\lambda=\frac{12.27}{V^{1/2}}\left(\frac{Ve}{2m_e c^2}+1\right)^{-1/2}$$

where λ is in angstroms (Å), m_e is the rest mass of electron and V is in volts. (5)

3. (a) Give the statement of Heisenberg's uncertainty principle for position and momentum measurement. Show how the gamma ray microscope thought experiment validates the principle. (2,4)

(b) How does the uncertainty principle rule out the possibility of electron being inside the nucleus? (4)

(c) Show that electron-positron pair cannot be created by an isolated photon. (5)

4. (a) Determine which of the following wave functions is a physically acceptable solution of the Schrodinger wave equation:

(i) tan x,

(ii) sin x,

(iii) 1/x,

(iv) exp $(-x^2/2)$,

(v) exp(ikx) (5)

(c) A particle of mass 'm' is confined in a field free region between impenetrable walls at x = 0 and x = a. Assuming that it does not lose energy in collisions with the walls:-

(i) Obtain an expression for the normalized wave function.

(ii) Draw the wave function for the first and second value of integer 'n'.

(iii) Show that the stationary energy levels of the particle are given by

$$E_n = \frac{n^2 \pi^2 \hbar^2}{2ma^2}$$

(iv) Identify the most probable location of the particle for this state. (10)

5. (a) Consider a particle of energy $E < V_0$ moving from left to right, towards a step potential function of height V_0 represented by the equations

$V = 0$ for $-\infty \leq x \leq 0$,

$V = V_0$ for $0 \leq x \leq \infty$.

(i) Write the Schrodinger wave equation and its physically acceptable solution in the two regions.

(ii) Use these equations to work out the reflection and transmission coefficients for $E < V_0$.

(iii) What is mechanical tunneling? (12)

(b) Determine the probability of finding a particle of mass 'm' between x = 0 and x=L/10, if the particle is described by the normalized wave function:

$$\psi_n(x) = \sqrt{\frac{2}{L}} Sin \frac{n\pi x}{L}$$ for $0 \leq x \leq L$ and is in the n=3 state. (3)

6. (a) Write three properties of nuclear forces. (3)

(b) Write the semi-empirical mass formula for a nucleus of mass number 'A', containing 'Z' protons and 'N' neutrons explaining each term used in the expression. (5)

(c) Calculate binding energy in (MeV) per nucleon for (i) $_5B^{10}$ with mass number 10.0161 amu (ii) $_{14}Si^{29}$ with mass number 28.9857 amu. Using this calculation name the atom which is more stable. Given that mass of proton is 1.0081 amu and mass of neutron is 1.0089 amu. (7)

7. (a) Sun generates its energy by fusing 4 protons to make $a^4{}_{He}$ nucleus with approximate release of 26 MeV of energy. The power output from the Sun is 4×10^{26} W. Find the life of Sun assuming that Sun contains roughly 10^{57} protons. (5)

(b) Calculate the total energy released if 1.00 kg of ^{235}U undergoes fission, taking that each fission reaction produces 208 MeV. (5)

(c) What are cosmic rays? What are the possible origins of cosmic rays? (5)