(c) Write the semi-empirical mass formula for calculation of the binding energy of a nucleus. Calculate the binding energy per nucleon for the zinc isotope $^{64}Zn_{30}$. The values of coefficients are :

a_1 = 14.1 MeV, a_2 = 13.0 MeV, a_3 = 0.595 MeV, a_4 = 19.0 MeV, a_5 = 33.5 MeV. (5,5,5)

[This question paper contains 8 printed pages.]

05.01.2024(M)

Your Roll No..............

Sr. No. of Question Paper : 4928 G

Unique Paper Code : 42227929

Name of the Paper : Elements of Modern Physics

Name of the Course : **B.Sc. (Prog.) Physical Science : DSE**

Semester : V

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.
3. Question No. **1** is compulsory.
4. **All** questions carry equal marks.
5. Non-programmable scientific calculators are allowed.

1. All parts are compulsory. (3×5=15)

(a) Monochromatic light of wavelength 3000 Å is incident on a surface of area 4 cm^2. If the intensity of the incident light is 15×10^{-2} W/m^2, determine the rate at which photons strike the surface.

(b) Determine the wavelengths of the first two spectral lines of Lyman series of hydrogen. (Rydberg constant = 1.097×10^7 m^{-1}).

(c) Derive the expressions for momentum and energy operators starting from the expression for the wavefunction of a free particle.

(d) Find the lowest energy of an electron confined to move in a one-dimensional infinite potential box of length 2Å. (Given m = 9.11×10^{-31} kg, h = 1.054×10^{-34} Js)

(e) Show that the density of nuclear matter is independent of the mass number A of nuclei. Obtain an estimate of this density.

If the energy of the electron is less than the height of the barrier ($E < V_0$)

(a) Write the time-independent Schrodinger equation and its solution for the two regions and explain the meaning of each term.

(b) Define penetration depth. Calculate the penetration depth for a 5 eV electron approaching a step barrier of 10 eV.

(c) A particle of energy E is incident on a potential step of height V_0 = 10 eV. Calculate the reflection coefficient R and the transmission coefficient T when E = 5 eV and 15 eV. (5,5,5)

7. (a) Discuss Gamow's theory of α-decay.

(b) Find the energy released, when two $^2H_1$ nuclei fuses together to form $^4He_2$ nucleus. The binding energy per nucleon of $^2H_1$ and $^4He_2$ is 1.1 MeV and 7.0 MeV, respectively.

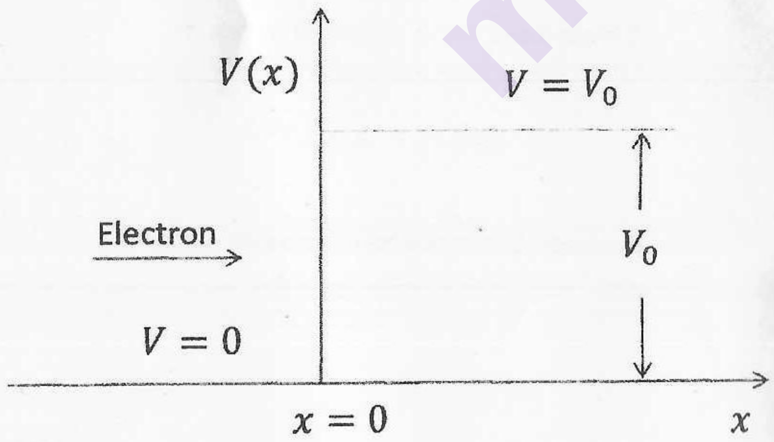
(c) Prove the following relation for the case of a particle undergoing relativistic motion :

$$\lambda = \frac{hc}{\sqrt{K(K + 2m_0c^2)}}$$

The symbols have their usual meaning. (5,5,5)

6. An electron of energy 'E' approaches a step barrier potential of height V_0 from the left as shown.

Here, $V(x) = \begin{cases} 0 & for \ -\infty < x \leq 0 \\ V_0 & for \quad 0 \leq x \leq \infty \end{cases}$



2. (a) Which aspects of the photoelectric effect cannot be explained by classical physics?

(b) Consider a photon that scatters from an electron at rest. If the Compton wavelength shift is observed to be triple the wavelength of the incident photon and if the photon scatters at 60°, calculate the wavelength of the incident photon.

(c) State the postulates of Bohr's atomic model. Derive the expressions for the radius of n^{th} Bohr orbit and the velocity of electron in the n^{th} orbit. (5,5,5)

3. (a) A beam of electrons is incident normally on a double slit. Draw the expected and observed patterns on the screen when both slits are open. How does the linear superposition principle help in understanding the observed pattern?

(b) An electron has the speed of 600 ms^{-1} with an accuracy of 0.005%. Calculate the minimum uncertainty in determining its location.

(c) Calculate the time required for 10% of a sample of thorium to disintegrate. Take the half-life of thorium to be 1.4×10^{10} years. (5,5,5)

4. (a) An object's one-dimensional motion is described by the wavefunction

$$\psi(x) = \begin{cases} Ax, & 0 < x < 1 \\ 0, & \text{elsewhere,} \end{cases}$$

where A is the normalization constant. Determine A and calculate the probability of finding the particle in the region x = 0 to x = 0.5?

(b) Using Heisenberg's uncertainty principle find an estimate for the ground state energy of an electron confined in an infinite potential well of width L.

(c) Assume that the electron in a hydrogen atom is replaced by a muon of mass $m \approx 200\ m_e$, where m_e is the mass of an electron. Determine the change in the wavelength of the H_α line of Balmer series. Assume $m << m_p$, where m_p is the mass of a proton. (5,5,5)

5. (a) State the conditions for a physically acceptable wavefunction. Discuss about its physical significance.

(b) Define probability current density. For a 1-dimensional wave function given by

$$\psi(x, t) = A(x)e^{i\varphi(x,t)}$$

evaluate the probability current density.