$m_e = 9.1 \times 10^{-31}$ kg

$m_n = 1.6749 \times 10^{-27}$ kg $= 1.00866$ u

$m_p = 1.6726 \times 10^{-27}$ kg $= 1.00728$ u

$R = 1.097 \times 10^{7}$ m^{-1}

[This question paper contains 8 printed pages.]

08.01.2024 (M)

Your Roll No.....

Sr. No. of Question Paper : 4979 **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) A metal whose work function is 4.2 eV is irradiated by radiation of 2000 Å wavelength. Find the maximum kinetic energy of emitted electrons.

(b) Estimate the minimum uncertainty in the velocity of a proton confined in a nucleus of radius 10^{-14} m.

(c) A wave function of a particle is given by $\psi(x) = Ae^{-kx}$ over the domain $0 \leq x \leq \infty$ (Assume $\psi(x) = 0$ outside this domain.), where A and k are constants. Find the normalization constant A in terms of k.

(d) The wavefunction associated with a particle is given as $\psi(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{3\pi x}{L}\right)$ in region $0 \leq x \leq L$, and $\psi(x) = 0$ otherwise. Calculate the probability of finding the particle in interval $\frac{L}{3} \leq x \leq \frac{2L}{3}$.

(b) One gram of ^{226}Ra has an activity of 1 curie. From this fact determine the half life of ^{226}Ra. How much time will it take to decay 0.75 g of ^{226}Ra?

(c) The nucleus $^{23}_{10}Ne$ decays by negative beta-emission. Determine the maximum kinetic energy (in Joule) of the electrons emitted. Given that :

$m(^{23}_{10}Ne) = 22.994466\ u$

$m(^{23}_{11}Na) = 22.089770\ u.$ (5,5,5)

Constants :

$h = 6.62 \times 10^{-34}$ J.s

$c = 3 \times 10^{8}$ m/s

$e = 1.6 \times 10^{-19}$ C

P.T.O.

(c) Calculate the de Broglie wavelength for a proton of kinetic energy 70 MeV. (5,5,5)

6. (a) For following wavefunction

$$\psi(x, t) = A(\sin kx + iB\cos kx)e^{-i\omega t}$$

where A, B, k, ω are real constants. Calculate probability density and probability current density.

(b) The time-independent wave function of a particle of mass m moving in a potential $V(x) = \alpha^2x^2$ is

$\psi(x) = \exp\left(-\sqrt{\frac{m\alpha^2}{2\hbar^2}}x^2\right)$, α being a constant. Find the energy of the system. (10,5)

7. (a) What is positive beta decay and negative beta decay? Explain giving examples.

(e) Write salient features of nuclear forces.

2. (a) Show that the de Broglie wavelength associated with electron which is accelerated from rest through a potential difference V volt (non-relativistic case) is

$$\lambda = \frac{12.3}{\sqrt{V}}\text{Å}.$$

(b) A photon of energy 3 keV collides with an electron initially at rest. If the photon emerges at an angle 60°, calculate the angle at which the electron recoils.

(c) In a typical Davisson-Germer experiment, the first maxima in the diffraction pattern of 54 eV electrons was observed at $\phi = 60°$ from an unknown target, where ϕ is the angle between the incident and scattered beams. Determine the lattice constant D of the target. (5,5,5)

P.T.O.

3. (a) What is energy-time uncertainty principle? Discuss the gamma ray microscope thought experiment and explain how it validates Heisenberg's uncertainty principle.

(b) Calculate series limit wavelengths corresponding to Balmer and Paschen series of hydrogen spectra. (10,5)

4. (a) A particle of mass m is confined in a one dimensional infinitely rigid box having potential

$$V(x) = \begin{cases} \infty & x < -L/2 \\ 0 & -L/2 \le x \le L/2 \\ \infty & x > L/2 \end{cases}$$

Find the wave functions associated with the particle and its energy E.

(b) When light of given wavelength is incident on a metallic surface, the stopping potential for the photoelectrons is 3.2 V. If a second light source

whose wavelength is double that of the first is used, the stopping potential drops to 0.8 V. Calculate the work function and the cut-off frequency of the metal. (10,5)

5. (a) A particle of mass m and energy $E < V_0$ travelling along x-axis has a potential barrier defined by

$$V(x) = \begin{cases} 0 & x < 0 \\ V_0 & 0 < x < L \\ 0 & x > 0 \end{cases}$$

Write Schrodinger equations and their solutions for three regions, explain each term of the solutions.

(b) The transmission probability of an electron across a potential barrier of 10 eV is equal to 0.8%. If the width of the potential barrier is 0.6 nm, calculate the energy of incident electron using the approximate formula.