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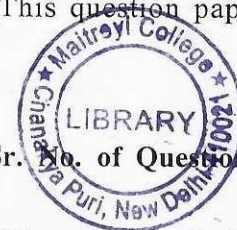
$$m_e = 9.1 \times 10^{-31} \text{ kg}$$

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

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

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

[This question paper contains 8 printed pages.]



08.01.2024 (M)

Your Roll No.....

Sr. No. of Question Paper : 4979

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

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

$$m(^{23}_{11}\text{Na}) = 22.989770 \text{ u.} \quad (5,5,5)$$

Constants :

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

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

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

- (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 $V(x) = \alpha^2 x^2$ is

$$\psi(x) = \exp\left(-\sqrt{\frac{m\alpha^2}{2\hbar^2}}x^2\right), \alpha \text{ being a constant. Find}$$

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

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

- (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 $\phi = 60^\circ$ 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)

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

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

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

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

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.