Name of the Department	:	Physics
Name of Course	:	B.Sc. Prog. _CBCS_DSE
Semester	:	V- Semester
Name of the Paper	:	Elements of Modern Physics
Unique Paper Code	:	42227929
Question Paper Set Number	:	Set-A

Duration: 3 Hours   Maximum Marks: 75

All questions carry equal marks. Attempt any four of the following questions.

Q1(a) Obtain an expression for the change in wavelength of a photon when it is Compton scattered by a free electron. In the graph of intensity of scattered photons versus wavelength, we can observe two peaks at two wavelengths, one at the wavelength of the incident photon and the other at a longer wavelength. Explain why we observe these two peaks. How does Compton Effect differ from Photoelectric Effect?
(b) X-ray of wavelength 2.78 Å are scattered from a thin Aluminium foil. Scattered X-rays are observed at an angle of 60º from the incident beam. Calculate the wavelength of the scattered X- rays and the kinetic energy of the recoil electron.

Q2(a) Explain how Davisson-Germer experiment establishes the wave nature of electrons. Is light a wave or a particle? Support your answer by citing specific experimental evidences.
(b) In a scattering of 4 eV protons from a crystal, the fourth order maximum of the intensity is observed at an angle of 35º. Estimate the crystal's planar separation.

Q3(a) The Bohr theory of Hydrogen atom is based on several assumptions. Discuss these assumptions and their significance. Do any of these assumptions contradict classical Physics? Derive the expressions for (i) the radius of the nth orbit (ii) the energy of the electron in the nth orbit in the Bohr's model of Hydrogen atom.
(b)(i)Find the shortest and longest wavelength of the Paschen Series. (ii) Calculate the wavelength of the H_δ line of the Balmer series.

Q4(a) State Heisenberg's uncertainty relation for position and momentum. Use the uncertainty principle to show that electrons cannot exist inside a nucleus.
(b) In a double slit experiment with a source of mono-energetic electrons, detectors are placed along a vertical screen parallel to the x-axis to monitor the diffraction pattern of the electrons emitted from the two slits. When only one slit is open, the amplitude of the electrons on the screen is

$$\psi_1(x,t) = A \exp[-i(kx-\omega t)]/\sqrt{1+x^2}$$

and when the only the other slit is open the amplitude is

$$\psi_2(x,t) = B \exp[-i(kx+3\pi x-\omega t)]/\sqrt{1+x^2}$$

(i) Calculate the normalization constants A and B.
(ii) Calculate the intensity detected on the screen when both slits are open and a light source is used to determine which of the slits the electron went through.
(iii) Calculate the intensity when both slits are open and no light source is used.
(iv) Justify your answers given in (ii) and (iii).

Q5. (a) Solve the Schrodinger's equation for a particle in a one-dimensional box of length L and obtain the energy eigenvalues and energy eigenfunctions. Show that energy eigenfunction obtained is not eigenfunction of momentum.

(b) Plot the wavefunction

$$\Psi(x) = \begin{cases} 1 - x^2, & x < 0 \\ x+2, & x \geq 0 \end{cases}$$

Can this be the solution of Schrodinger's equation? Give reason.

(c) Suppose that the solution to Schrodinger's equations for some potential give rise to three wavefunction $\psi_1(x)$, $\psi_2(x)$ and $\psi_3(x)$ of the forms

$$\psi_1(x) = A\exp(2kx), \qquad -\infty \leq x \leq 0$$

$$\psi_2(x) = Bx^3 + Cx + D, \qquad 0 \leq x \leq L$$

$$\psi_3(x) = 0, \qquad x \geq L$$

Type equation here.

(i) Determine the values of B, C and D in terms of A. (Note: Do not apply continuity condition on $\frac{d\psi}{dx}$ at x= L)

(ii) Derive an expression that A, B, C and D must satisfy that the solution be normalized.

Q6(a) Electron does not exist inside a nucleus but electron is released during beta decay. Comment on this. A nucleus such as $^{226}_{88}Ra$ that is initially at rest undergoes alpha decay. Which has more kinetic energy after the decay, the alpha particle or the daughter nucleus? Prove your answer with relevant equations.

(b) Two samples of the same radioactive nuclide are prepared, each having the same size. Sample A has thrice the initial activity of sample B. How does the half-life of A compare with the half-life of B? After each sample has passed through six half-lives, what is the ratio of their activities?

(c) Copper, as it occurs naturally, consists of two isotopes, $^{63}_{29}Cu$ and $^{65}_{29}Cu$. Which isotope will be more abundant? Given the atomic masses of the two isotopes to be 62.95 u and 64.95 u.

Constants:

h= 6.6×10^{-34} J.s

m_e= 9.1×10^{-31} Kg

m_n= 939.55 MeV= 1.00866 u

m_p= 938.26 MeV = 1.00728 u