Some Relevant Formulae, Constants and Identities

\[ \Delta \lambda = \frac{\hbar}{m_c}(1 - \cos \theta) \]
\[ \hbar c = 1.99 \times 10^{-25} \text{J.m} = 1240 \text{ eV.nm} \]
\[ \lambda = \frac{\hbar}{p}; \quad \Delta x \Delta p \geq \frac{\hbar}{4\pi}; \quad \Delta E \Delta t \geq \frac{\hbar}{4\pi} \]

Bohr radius for ground state H atom, \( a_0 = \frac{\hbar^2}{m k e^2} = 0.529 \text{ Å} \)

Quantized orbit in Hydrogenlike atom \( r_n = \frac{n^2 a_0}{Z} \)

Energy in Hydrogen atom \( E_n = \frac{-k e^2}{2a_0} \left( \frac{1}{n^2} \right) = \left( \frac{-13.6 \text{ eV}}{n^2} \right) \)

Coulomb's constant \( k = 8.988 \times 10^9 \text{N.m}^2/\text{C}^2 \)

Planck's constant \( \hbar = 6.626 \times 10^{-34} \text{J.s} = 4.136 \times 10^{-15} \text{eV.s} \)

1 J = 1.60 \times 10^{-19} \text{ eV}, Electron rest mass = 9.1 \times 10^{-31} \text{ Kg} = 0.511 \text{ MeV/c}^2

Proton rest mass = 1.673 \times 10^{-27} \text{kg} = 938.3 \text{ MeV/c}^2

Speed of light in vacuum \( c = 2.998 \times 10^8 \text{m/s} \)

Electron charge = 1.602 \times 10^{-19} \text{ C}
**Problem 1: Quantum Cowboy** [10 pts]

A bullet weighing 12g leaves a rifle at a speed of 150 m/s in the horizontal direction. (a) What is the wavelength of this bullet? (b) If the vertical (direction perpendicular to bullet’s flight) position of the bullet is known to an accuracy of 0.001 cm, what is the minimum uncertainty in its vertical momentum? (c) If the accuracy of the bullet were determined only by the uncertainty principle, by how far, vertically, might the bullet miss a pinpoint target 300 m away? It would be helpful to first draw a diagram of the setup.

**Problem 2: Seeing Is Believing** [10 pts]

Suppose we wish to test the possibility that electrons in the Hydrogen atom move in circular orbits (as postulated by Bohr) by “viewing” them by shining light (photon) on it (a) From the “resolving power” standpoint, which of the two photon wavelengths, $\lambda=10^{-11}$ m or $\lambda=10^{-6}$ m would appear more appropriate and why? (b) What is the energy $E$ of the appropriately chosen photon? (c) How much energy $E_e$ would such a photon transfer to a free electron in a head-on Compton collision? (d) What does this tell you about the possibility of verifying the orbital motion by “viewing” an atomic electron at two or more points along its “circular” path? Can this be accomplished? Justify your assertion in 3 sentences or less.