Module 3

QUANTUM MECHANICS – NUMERICAL PROBLEMS

SET – 1

- Elementary charge $q = 1.6 \times 10^{-19}$ C
- Speed of light c in vacuum = 3×10^{8} m/s
- Mass of electron $m_e = 9.1 \times 10^{-31}$ kg
- Mass of proton $m_p = 1.67 \times 10^{-27}$ kg
- Planck's constant $h = 6.63 \times 10^{-34}$ J-s
- Reduced Planck's constant $\hbar = h/2\pi = 1.05 \times 10^{-34}$ J-s

1. Calculate de' Broglie wavelengths of (i) cricket ball of mass 150 gm thrown at a speed of 150 km/hr and (ii) electron orbiting in hydrogen atom at a speed of 10^6 m/s. Comment on your results.
2. What is de' Broglie wavelength of a neutron having energy 1 MeV. Use $m_n = m_p$. By how much potential difference a proton has to be accelerated in order to have the same de' Broglie wavelength?
3. Find kinetic energy of an electron whose de' Broglie wavelength is the same as that of 100 keV photon.
4. An electron and a proton have the same kinetic energies. Compare their de' Broglie wavelengths. Given $m_p = 1800\, m_e$.
5. Estimate de'Broglie wavelength of an electron and hence its speed in the 1st Bohr orbit. Given radius of 1st Bohr orbit $a_0 = 0.5$ Å.
6. Calculate uncertainty in the determination of momentum of an electron confined to a quantum well of size 1 nm. What is the percentage uncertainty in the momentum if its mean speed is 10^6 m/s?
7. Determine uncertainty in the measurement of momentum of a marble of mass 10 gm confined to a box of dimensions 50 cm. What is the percentage uncertainty in the momentum if it is moving with a speed of 20 cm/s. Is it significant as compared to the result of preceding example? What can you say about the measurement?
8. Determine the minimum energy possessed by a nucleon using uncertainty principle.
9. Calculate the percentage uncertainty in the measurement of momentum of a neutron having energy 20 MeV confined to a region of width equal to (i) 10 nuclei (ii) 10 atoms. Comment on the results.
10. The frequency of radiation emitted from any source is never sharp at a singular value but it has a small spread. Using uncertainty principle, show that this spread of typically a few megahertz.
11. Uncertainty principle indicates that electrons cannot pre-exist in the nucleus like protons or neutrons. But, in radioactive elements during β-decay, electrons do come out from the nucleus during the process described by neutron disintegration process: $\mathrm{n}_0^1 \to \mathrm{p}_{+1}^1 + \mathrm{e}_{-1}^0 + \bar{\nu}\,_0^0$. Show using the uncertainty principle again that electron comes out of the nucleus almost spontaneously as soon as it is generated and doesn't stay there.
