

## Section 13: Modern Physics II (Quantum Mechanics)

### 1. Quantum Numbers

For the  $n = 3$  energy level in a hydrogen atom, what are the possible values for the quantum numbers  $l$  (orbital) and  $m_l$  (magnetic)? How many distinct electron states exist for  $n = 3$ ?

### 2. Energy Scaling

State the general dependence of energy  $E$  on the principal quantum number  $n$  (i.e.,  $E \propto n^?$ ) for:

- a) A particle in a one-dimensional infinite potential well.
- b) An electron in a hydrogen atom.

### 3. Photon Energy

Calculate the energy (in eV) of a photon with a wavelength of 500 nm. Use the formula  $E = \frac{hc}{\lambda}$  where  $h = 4.1357 \times 10^{-15}$  [eVs] and  $c = 3.0 \times 10^8$  m/s.

### 4. Quantum Well Energy

An electron is in a 1D infinite potential well of width  $L = 0.5$  nm. It is in the  $n = 2$  state. What is the energy of the electron in eV?

### 5. Quark Model

What is the quark composition of a proton and a neutron? Use this to verify their electric charges (u quark charge =  $+2/3$  e, d quark charge =  $-1/3$  e).

### 6. Radioactive Half-Life

The half-life of Cobalt-60 is 5.27 years. If a sample initially contains 100 grams of Cobalt-60, how much will remain after approximately 21 years?

### 7. Alpha Decay

Give a specific, balanced nuclear equation for an alpha decay process, starting with Uranium-238 ( ${}_{92}^{238}\text{U}$ ).

### 8. Beta Decay

Give a specific, balanced nuclear equation for a beta-minus decay process, starting with Carbon-14 ( ${}_{6}^{14}\text{C}$ ).

### 9. Pair Annihilation

An electron and a positron, each with a rest mass of  $0.511\text{MeV}/c^2$ , annihilate each other, producing two photons of equal energy. What is the energy (in MeV) and wavelength of each photon?

### 10. Wavefunction Probability

For a particle in a 1D box of length  $L$ , the wavefunction for the ground state is  $\Psi(x) = \sqrt{2/L} \sin(\pi x/L)$ . Calculate the probability of finding the particle in the region  $0 \leq x \leq L/4$ .