Short Answers (5 points each):

1. How many quantum numbers are required to describe a particle trapped in a three-dimensional box?

2. Describe the key difference between a classical particle crossing a small \((E > V_0)\) step in potential energy compared with the quantum mechanical description.

3. What is the energy of photons in light with wavelength \(\lambda = 620\) nm?

4. Explain the physical meaning of the threshold frequency in the photoelectric effect.

5. Neutron stars are super hot. Would they appear redder or bluer than our Sun?

6. Estimate the de Broglie wavelength of a neutron at room temperature \((E = 0.03\text{eV})\).

7. Two electrons, one with energy 6 eV and one with energy 8 eV strike a potential barrier of height 30 eV and width 2 nm. Which electron is more likely to penetrate the barrier?

8. Sketch the wave function representing a beam of mono-energetic electrons passing a step in potential energy, with \(E > V_0\).

Quantitative Questions (20 points each):

9. Describe quantitatively why it would be difficult to referee a hockey game if Planck’s constant was 50 J s. (mass of a puck = 0.16 kg, width of goal = 1.8 m)

10. The wave function for a free electron, i.e., one on which no net force acts, is given by \(\psi(x) = A \sin (2.5e10 x)\), where \(x\) is in meters. What is the electron’s momentum and kinetic energy?

11. An electron is trapped in a potential well described by \(U(x) = \frac{1}{2} m \omega^2 x^2\) with a wave function given by \(\psi(x) = A x \exp(-ax^2)\). Use the Schrödinger equation to solve for \(a\) in terms of \(m\), \(\omega\), and \(h\). What is the energy of the electron?