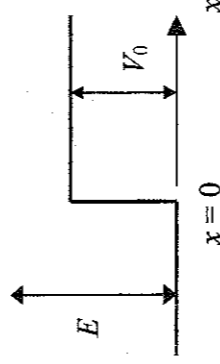


1. (10%) What is the special theory of relativity, and which are the two principles it is based on?
2. (10%) Suppose two photons, one with energy E_1 , and the second with energy E_2 , approach each other along the x axis. What is the corresponding rest energy of the system? (speed of light= c)
3. (10%) What is the meaning of the particle-wave duality? How does this concept apply to (a) light (b) electrons?
4. (10%) Explain briefly the following terms: (a) Stark effect (b) Zeeman effect.
5. (10%) Assuming that the emission of a photon of the wavelength accompanies the transition of an electron from the $n = 2$ level to the $n = 1$ level of a one-dimensional infinite quantum well is λ . What is the width L for the quantum well? (Planck constant/ $2\pi = \hbar$, electron mass= m)

6. (14%) Consider a beam of electrons traveling to the right along the x -axis with energy E . As shown in the following figure, the potential energy is $V = 0$ for $x < 0$,



- but at $x = 0$ there is a potential "step," and the potential energy increases to (positive) V_0 for $x > 0$. Assuming that $E > V_0$, (a) calculate the reflection and transmission coefficients, and (b) show that flux is conserved.
7. (6%) What are the total angular momentum values that are obtained in the addition of (a) $\ell = 2$ and $s = 1/2$? (b) $\ell = 1$ and $s = 3/2$? (c) $s_1 = 2$ and $s_2 = 1/2$? Where ℓ and s are the quantum numbers of orbital angular momentum and spin, respectively.
 8. (10%) What is uncertainty principle? Use the uncertainty relation to estimate the ground state energy of a particle in a one-dimensional potential given by $V(x) = ax^4$.
 9. (10%) The energy difference between the $\ell = 0$ and $\ell = 1$ rotational levels, with ℓ the rotational quantum number, in the CO molecules is measured to be ΔE experimentally. Assume the masses of C and O are m_1 and m_2 , respectively. Find the equilibrium separation r_0 of the CO molecule.
 10. (10%) (a) Which of the following atoms are bosons: ^{85}Rb , ^{87}Rb , ^{133}Cs , ^{23}Na , ^6Li , ^7Li ? (b) Which of the following particles are fermions: electron, proton, photon, neutron, ^{40}K , quark?