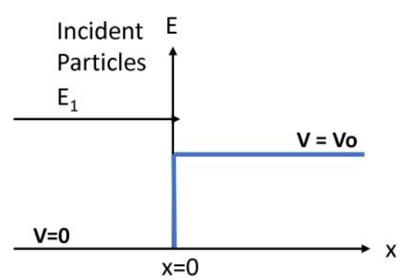
ECE 3030 Spring 2025 HOMEWORK ASSIGNMENT NO. 2
Due: Monday, January 27th 11:59 pm upload to Carmen 3030 SpeedGrader

1. (20 pts) The work function of a material refers to the minimum (threshold) photon energy E = hυ needed to remove an electron from the material, *i.e.*, the photoelectric effect. (a) Calculate the minimum wavelength of light needed to remove an electron from platinum, which has a 5.65 eV work function. (b) Repeat for lithium, which has a 2.90 eV work function. (c) If the light wavelength λ decreases for an energy above threshold, are more or less electrons excited and ejected? (d) For a photon energy above threshold, then does the number of electrons increase or decrease as the light intensity increases? Does the energy threshold change? (Note the 1 eV = 1.6×10^{-19} J = 1.6×10^{-12} erg conversion factors.
2. (15 pts) (a) For an electron with a de Broglie wavelength λ = h/p equal to the GaAs a_0 = 5.65 Å lattice spacing, determine the electron kinetic energy $E = p^2/2m$ in eV and the momentum p = mv in gm-cm/sec.
3. (10 pts) (a) An electron is in a one-dimensional quantum well with a width of 1.7 nm. What is the minimum uncertainty in its momentum along the width direction of the well? (b) A free electron's energy is measured with an uncertainty no greater than 2 eV. Determine the minimum uncertainty in the time over which the measurement is made.
4. (10 pts) An electron is bound in a one-dimensional well with a width of 17 Å. (a) Calculate the first three energy levels that the electron may occupy. (b) If the electron drops from the third to the lowest energy level, what is the wavelength of a photon that might be emitted?
5. (15 pts) The general solution to the QM kinetic + potential energy equation for a traveling wave/particle is $\psi(x) = A_1e^{jk_1x} + B_1e^{-jk_1x}$ (for +x and -x going directions) where $k_1 = [2m(E-V)/\hbar^2]^{1/2}$. For the step potential shown here, E_1 >V=0 and particles are traveling in the +x direction from -x. Incident wave/particle energy $E_1 > 0$. For x < 0, what is k_1 equal to in terms of E and V? What is ψ(x<0) equal to? Now do the same for x>0. What are k_2 and ψ(x>0) equal to? Now set ψ(x<0) equal to ψ(x>0) at x=0. And set dψ(x<0)/dx equal to dψ(x>0)/dx at x=0. Finally, with these 2 equations, solve for B_1, A_2, and B_2, in terms of A_1. Do the waves/particles travel faster for x> 0 or x<0? Are there reflected waves/particle for x< 0 and for x>0?



6. (15 pts) Consider an electron with a kinetic energy of 3.3 eV incident on a step potential function of height 4.0 eV. Determine the relative probability │ψ(x)*ψ(x)│ of finding the electron at a distance (a) 5 Å beyond the barrier, (b) 10 Å beyond the barrier, and 40 Å beyond the barrier compared with the probability of finding the incident particle at the barrier edge.
7. (15 pts) (a) Estimate the tunneling probability of a particle with an effective mass of 0.067 m_0 (an electron in GaAs), where m_0 is the mass of an electron, tunneling through a rectangular barrier of height V_0 = 0.8 eV and width 15 Å. The particle kinetic energy is 0.20 eV. (b) Repeat part (a) for a particle with 1.08 m_0 effective mass (an electron in silicon). Which tunnels less?

   15 pt. bonus: A certain semiconductor device requires a tunneling probability not to exceed $T = 5 \times 10^{-6}$ for an electron with energy E = 0.08 eV to tunnel through a rectangular barrier with a barrier height of V_0 = 0.8 eV. What is the minimum barrier width that will limit this probability, *i.e.*, leakage current?