Physics 390: Homework 6

This homework is due the Monday after winter break, **Monday March 9**.

1. A free particle of mass m with wave number k_1 is traveling to the right. At $x = 0$ the potential jumps from zero to V_0 and remains at this value for positive x.

   (a) If the total energy is $E = \hbar^2 k_1^2/2m = 2V_0$, what is the wave number k_2 in the region $x > 0$? Express your answer in terms of k_1 and V_0.

   (b) Calculate the reflection coefficient R at the potential step.

   (c) What is the transmission coefficient T?

   (d) If one million particles with wave number k_1 are incident upon the potential step, how many particles are expected to continue along in the positive x direction after passing the step? How does this compare with the classical prediction?

2. A world's largest particle accelerator, the Large Hadron Collider in Geneva, is about to come on-line again, after being shutdown for the past year for an upgrade. The accelerator creates beams of protons that are used to test quantum theory. The beams of particles that we considered in class were made of electrons, but the theory we developed can be used for beams of protons too.

   Consider a beam of protons, each having kinetic energy 30 MeV. The particles approach a potential step of 20 MeV.

   (a) What fraction of the beam is reflected and what fraction is transmitted?

   (b) How would the answer change if the particles had been electrons?

3. A 10 eV electron is incident on a potential barrier of height 25 eV and width 1 nm.

   (a) Use Equation 6-76 to calculate approximately the probability that the electron will tunnel through the barrier.

   (b) Repeat the calculation for a width of 0.1 nm.

4. A wall is two meters high and half a meter thick.

   (a) About how much potential energy will a human being of mass 60 kg gain if they climb on top of the wall? You can assume the acceleration due to gravity is $9.8\,\mathrm{ms}^{-2}$.

   (b) How much kinetic energy will the same human being have if they run at the wall at $4\,\mathrm{ms}^{-1}$?

   (c) Hence calculate a rough estimate of the probability that this person could tunnel quantum-mechanically through the wall and appear on the other side. (Hint: You should get a *very* small number.)

5. Problem 7-2 in Tipler & Llewellyn. An acceptable method of solution for this problem is to write a computer program or use a spreadsheet. (If you take this route, you must turn in a copy of your program and its output, or your spreadsheet, to get full credit.)