Phys 2053: Homework VI

due February 25, 2016 by 5 pm

1-D Potential Exercise - PhET simulation
Use the Java installation in the Clippinger Computer Lab in the directory JavaS. To access it, log into one of the Linux computers and open an xterm window. Type "*cd*" to go to the main directory, and then "*cd JavaS*" to enter the directory with the Java simulations.

To run the simulation, type
java -jar quantum-tunneling_en.jar
and a window with the simulation will pop up.

1. Free Particle
Let's start with something familiar: the free particle. Choose the appropriate potential and a particle of known kinetic energy.

1. Describe the stationary wave function ϕ.
2. Vary the energy and describe the change in ϕ. Explain why this change occurs.
3. Change the potential and describe and explain the resulting change in ϕ.
4. Now make a wave packet and let it evolve several fs (femto seconds). Look at the magnitude as well as the real part of ϕ and describe the changes. Do the wave function wave fronts move at the same speed as the packet?
5. Describe the difference between the behavior of a plane wave and a wave packet.

2. Step Potential
Now create a step potential and a deBroglie particle.

1. Set $E \geq V$ and adjust the step so that $V = 0$. Increase the step (still $V \leq 0$) and describe and explain the change in ϕ.
2. Keep $E \geq V$ and $V \geq 0$. Given an energy value (which can pick and show), calculate and verify the (relative) amplitudes of the incident, reflected, and transmitted stationary wave functions, and the transmission and reflection probabilities. You can choose to show the summed or separated incident wave parts.

3. Look also at the imaginary parts of ϕ. Describe and explain the difference between the imaginary and real parts (the word you likely will need is *phase*).

4. Increase the step so that $V \geq E$. What happens? Compare the real and imaginary parts of ϕ. Is it similar to the case $E \geq V$? Describe and explain.

5. Compare the difference in behavior between a plane wave and a wave packet.

3. Barrier Potential

Now create a barrier potential. Start with quite a broad barrier.

1. With $E \geq V$, describe how ϕ varies over and beyond the barrier, and explain why.

2. Now set $E \leq V$ and describe the change. What is T?

3. Can you make $T \geq 0$? Under which conditions, keeping $E \leq V$?

4. Construct yourself a barrier like Fig. 3.6 in Morrison. Determine the ratio of the amplitudes E/A and verify your expression with the output from the program. You may want to choose a barrier of 0.8 eV and a width of 1 nm. Choose as electron energy 0.6 eV.

5. Successively increase the width of the barrier until there is no transmission anymore. Plot the transmission coefficient as function of barrier width. Can you relate your graph to the analytic expression for the transmission coefficient?

6. Compare the difference in behavior between a plane wave and a wave packet when they scatter from the barrier potential.

The entire project is worth 12 pts.