Physics 465: Computing Project 6 (due 10/13)

October 4, 2011

Designing a "qubit" for a Quantum Computer

A "qubit" is a physical quantum mechanical system that can somehow be restricted to be in a superposition of only two basis states. This week we're going to design a qubit using the finite square well as the basis for our design.

Suppose you have a simple setup where you can store a single electron on a 1-D strip of conductor with a potential of V_0 in between two 1-D strips each at ground (0.0 V) potential as shown in Fig 1. The horizontal strip on the top contains a single free electron, while the conductors below have free charges that produce the voltage that creates the potential energy of the "well".

For the sake of argument, let's assume that the voltage on the center conductor is around +0.1V. This makes the potential energy there (for electrons!) -0.1 eV. In order to make a working qubit, you'll need to adjust the width w of your central conductor so that there are exactly two bound states. Once this has been done you will be able to simulate the behavior of the qubit under various circumstances. After we get this working, we can use it, in principle, as one component in a simple quantum computer! (Time permitting, we'll have a chance to do this later in the semester.)

Determining the width of the Central Conductor

Use your knowledge of the bound states of the finite square well to estimate the width necessary to ensure that there are exactly 2 bound states available to an electron in the potential well. Report the width you decide to use in your simulation along with some justification for that choice.

Build the two available bound state wavefunctions as arrays in Python

Construct $\psi_1(x)$ and $\psi_2(x)$ as arrays in python. Use the relationships from the text to find k_1, k_2, κ_1 and κ_2 for your design. Use these to fill the $\psi_1(x)$ and $\psi_2(x)$ arrays

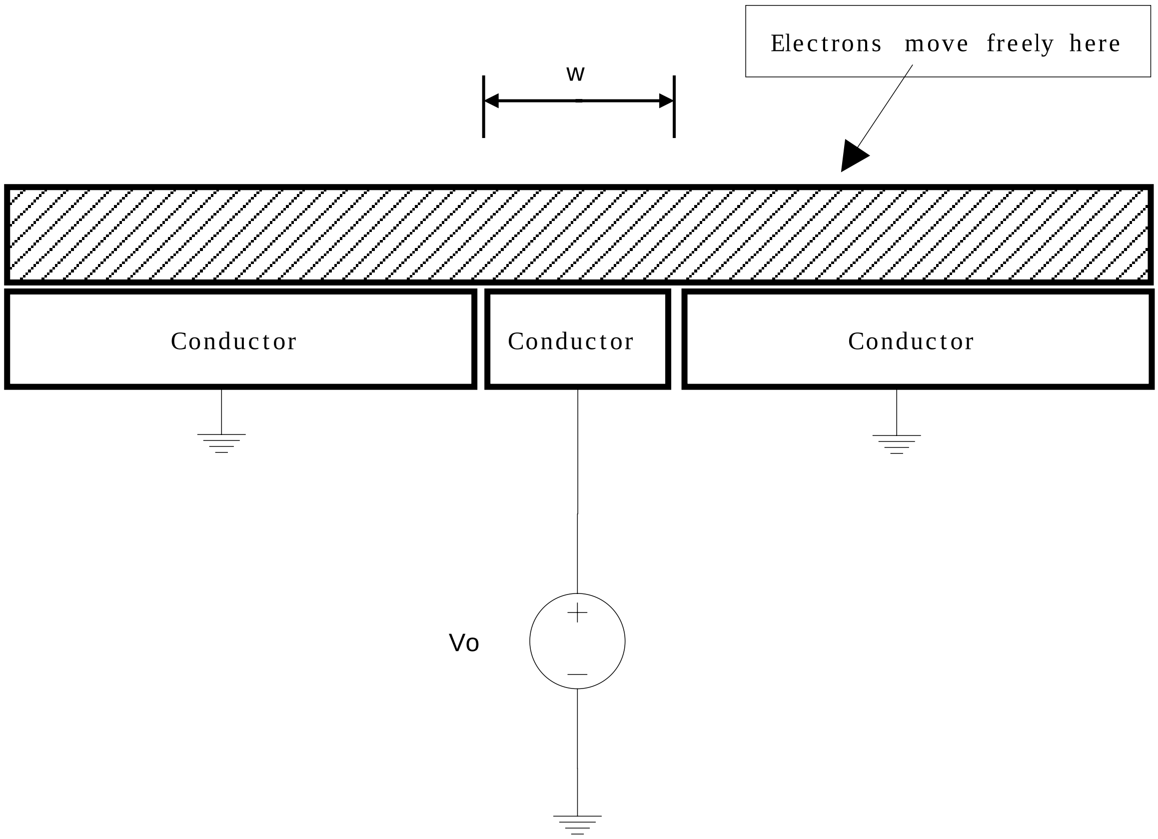

Figure 1: Simple Electron Containment System

with values. Hint: Be sure they are normalized, and that they satisfy the boundary conditions at $x = +a$ and $x = -a$.

So... what are we supposed to do?

Your mission is to produce three deliverables:

1) A graph of the real part of $\Psi(a,t)$ when $\Psi(x,0) = \psi_1(x)$. With my design I ended up with Fig. 2 for this part, and my wavefunction initially looked like Fig. 3.

2) A graph of the real part of $\Psi(a,t)$ when $\Psi(x,0) = \psi_2(x)$. With my design I ended up with Fig. 4 for this part, and my wavefunction initially looked like Fig. 5.

3) A graph of $\langle x \rangle$ when $\Psi(x,0) = \frac{1}{\sqrt{2}}(\psi_1(x) + \psi_2(x))$. With my design I ended up with Fig. 6 for this part, and my wavefunction initially looked like Fig. 7.

If your numbers look very different, please ask!

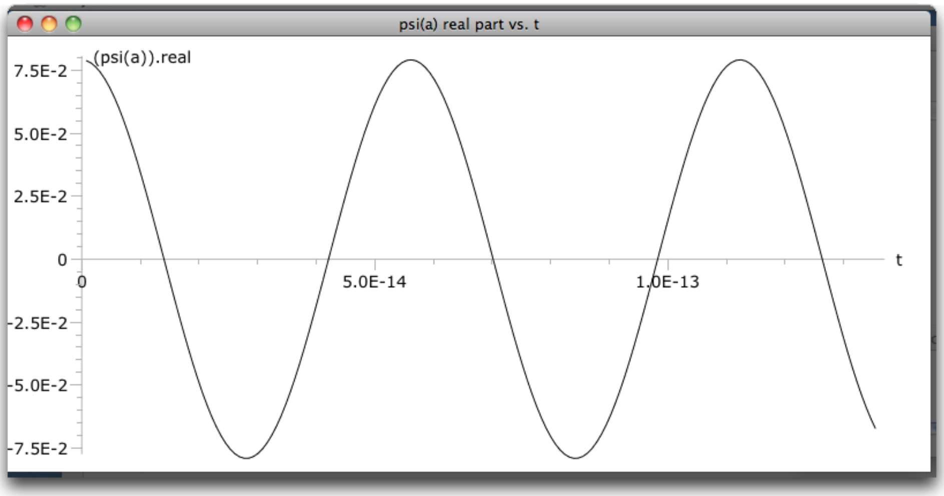

Figure 2: Real part of $\Psi(a,t)$ with only state ψ_1

Questions

1) Use your knowledge of the finite square well to predict the frequencies displayed in Fig. 2, Fig. 4 and Fig. 6. Compare your theoretical predictions to your computational results as shown in your graphs.

2) Explain why ω_2 appears to be *lower* that ω_1 for this finite square well.

3) If we wanted to use a laser to bump your qubit from state 1 to state 2, what wavelength of light should we use? Explain.

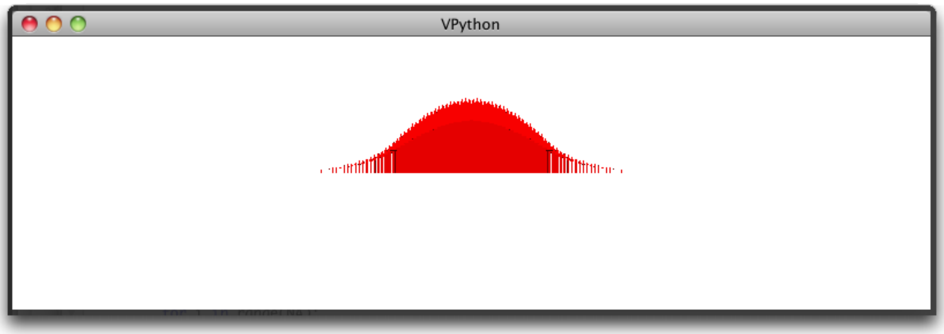

Figure 3: Arrows for $\Psi(a, 0)$ with only state ψ_1

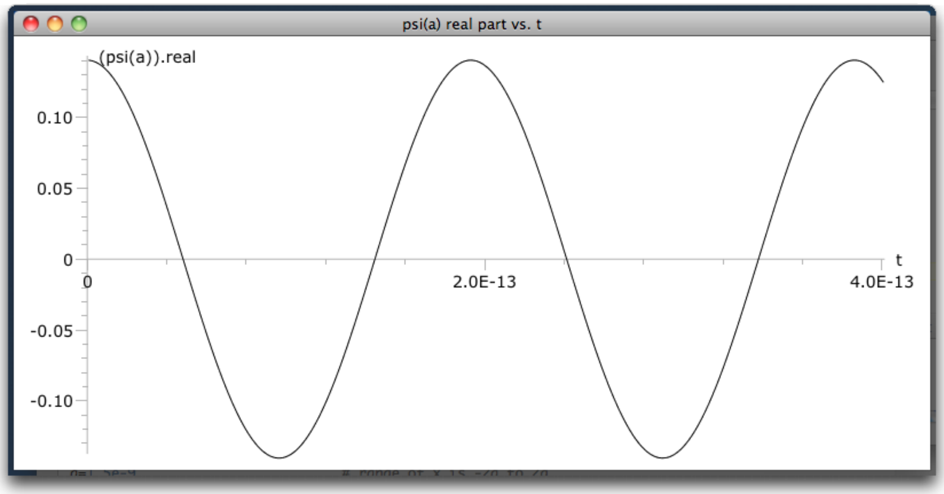

Figure 4: Real part of $\Psi(a, t)$ with only state ψ_2

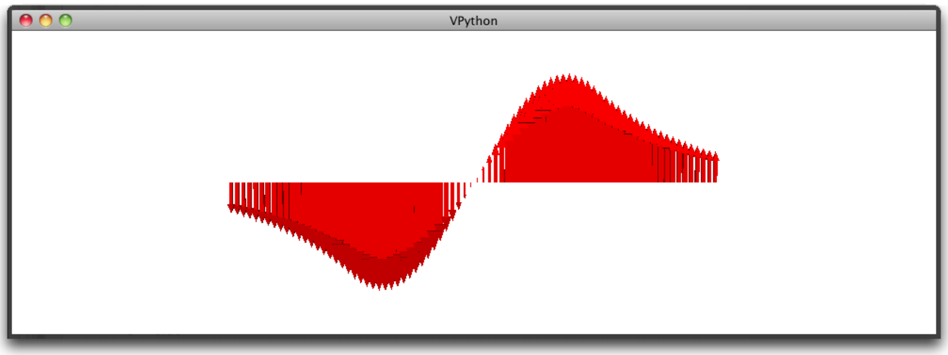

Figure 5: Arrows for $\Psi(a, 0)$ with only state ψ_2

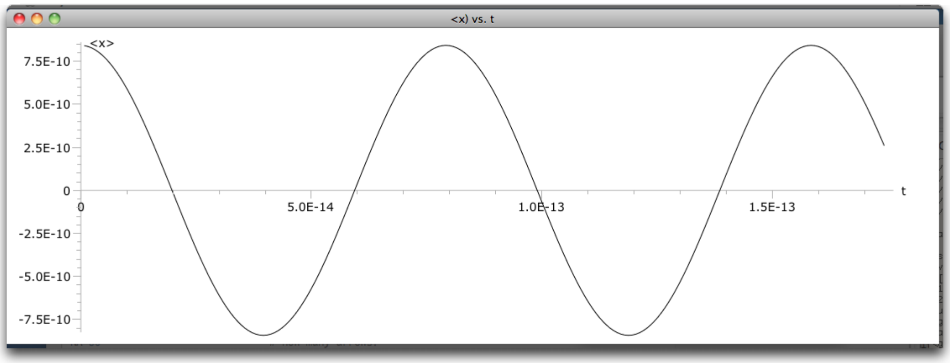

Figure 6: $\langle x \rangle$ in equal superposition state

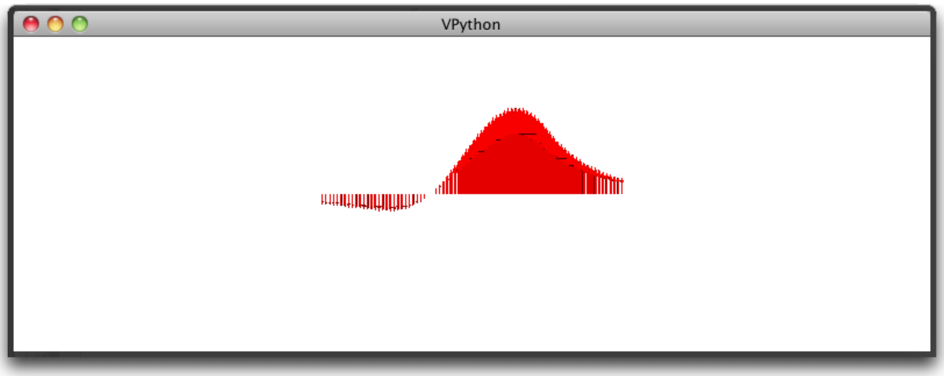

Figure 7: Arrows for $\Psi(a, 0)$ with superposition of ψ_1 and ψ_2