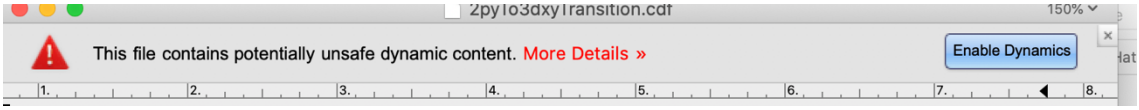
Absorption and emission of light – what's going on with the electron?

For this worksheet you will need to install the (free) Wolfram CDF Player on your computer or look on with another student who has it installed (https://www.wolfram.com/products/player/legacy-cdf.cgi).

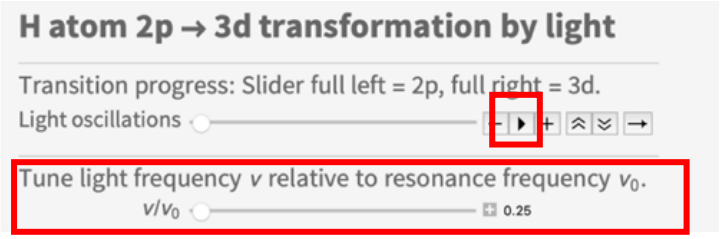
Part 1: the red line

After you've installed the wolfram player, download or open the CDF simulation that is posted at:
http://quantum.bu.edu/CDF/101/2pyTo3dxyTransition.cdf
Click "Enable Dynamics" so that the simulation will run on your device.



1. Start by tuning the light frequency all the way to the left so that v/v_0 is set to 0.25 (see screenshot to the right).

   Once the frequency has been set, press the play button (▶)



   a. What do the arrows moving back-and-forth (left-to-right) represent in the simulation?

   b. What does the red dot in the middle of the simulation area represent?

   c. The blue dumbbell shape represents a hydrogen atom electron wave (the 2p wave, to be precise). What happens to this wave when the simulation is run and the frequency is too low (0.25)?

2. Reset the Transition Progress slider (top slider) all the way back to the left. Then, re-tune the light frequency so that the simulation is run at the resonant frequency of the electron wave (i.e., $v = v_0$ or $v/v_0 = 1.0$).
   a. Press play again. What do you observe? What is happening to the electron wave?

   b. At the end of this simulation, the electron wave has changed. It is now a 3d electron wave. Is the process you observed in (a) absorption or emission? How do you know?

   c. Is the process that you observed in (a) instantaneous or gradual?

   d. The energy change of the process can be modeled using the formula $E_n = -\frac{2.18\text{ aJ}}{n^2}$ where n is the number of loops in the electron wave. For 2p, $n = 2$. For 3d, $n = 3$. Based on this, what is the **energy change** ($\Delta E = E_{\text{final}} - E_{\text{initial}}$) in attojoules (aJ) for the electron wave during the process in (a)?

e. As you saw in the simulation, the electron wave has gained energy during this process. The light has lost the exact same amount of energy that the electron has gained (in d). What is the wavelength and color of this light?

f. This amount of energy – the energy that electron has gained from the light – has a name. What is the name of this *quantity of energy* that the light transfers?

Part 2: simulating absorption of light by an electron

Run the simulation at http://quantum.bu.edu/CDF/101/1sTo2pTransition.cdf

3. The initial and final states of the electron wave in this simulation are 1s ($n = 1$) and 2p ($n = 2$).
   a. In your own words, describe what is happening when the light is resonant with the change in the electron.

b. What would happen if the frequency of the light (and, hence, the energy of the light) were higher than the resonant frequency? Check your intuition using the simulation by setting the ratio of frequencies to 3-4 times the natural resonant frequency. What happened?

c. What is the photon energy, wavelength, and color of the light in the simulation when the light is in resonance with the electron wave?

d. Explain what the word *photon* means.