Light:
Light Emission and Lasers

Names:

We'll again be working with "PhET" website sims: **http://phet.colorado.edu/new/index.php** .

1) **Models of the atom: Absorption and emission of photons.**
Find and open the simulation: models of the hydrogen atom.

A. Turn the spectrometer and white light source on, and then observe when photons are absorbed by the box and emitted by the box. (It may help to either speed up or slow down the simulation (for more absorption/emission events, it helps to run fast, but for more clarity, it might help to run slow down until you're used to observing).

When photons are absorbed, are all the absorbed photons the same color?

When photons are emitted, do they always have the same color as the originally absorbed photons?

When photons are emitted, do they always have the same direction as that of the absorbed photons?

B. When you turn the spectrometer on, notice that it records the color of the emitted photons, regardless of what direction the emitted photons travel in after the emission process. Turn the speed to fast, and then allow the spectrometer take data for at least three minutes. Make observations about the emitted photons according to color, energy, and number of photons of different energies.

Draw the spectrometer results below and then explain the image.

C. The de Brogie model of the atom is a fairly refined model that shows lot conceptually without being TOO complex. Switch to the de Broglie model and reset the spectrometer. Also note that since the electrons are in orbitals, you can click on an extra feature called the "electron energy diagram." Run the simulation with a white light source.
   What do you notice about the energy transition when the atom absorbs a photon?

   Are all the absorbed photons always the same wavelength?

   What do you notice about the energy transition when the atom emits a photon?

   Are all the emitted photons always the same wavelength?

   Are all emitted photons the same wavelength as the photon absorbed that caused the last energy transition?

   More subtle (and may require the "monochromatic light source"): when absorption events occur from the ground state, what is the energy of the absorbed photons?

Notes: The Bohr model is similar to the de Broglie model, but your text talks about the electrons in orbitals having standing wave characteristics, and this model shows that well.

The lifetime of an excited state is the amount of time it stays in the upper state before decaying to a lower energy state. Here, all states have about the same lifetime, and I doubt that is truly the case in the hydrogen atom… but I didn't bother to look up the lifetime of the states.

This simulation is also specific to the hydrogen atom (in "unperturbed" form). It has certain distinct absorption and emission characteristics. The absorption and emission of all atoms is determined by their energy states… which are MOSTLY defined by the nature of the atom itself, but can be "perturbed" (or shifted) by the environment the atom is in (what atoms it may be bonded too, etc.) Interestingly, only the unperturbed hydrogen atom can be modeled exactly using quantum mechanics (but some approximation techniques are pretty good for other atoms, or even for whole molecules).

Continue the activity to learn about how all this makes a difference in laser technology….

2) **Laser medium basics.** Find and open the "Lasers" simulation.

A. Pumping a two state system.

This simulation uses an "optical pump" as an energy source for a laser. Turn the light source on a medium level with the preset wavelength. What do you observe about the emitted photons? (Are they spontaneous emissions, stimulated emissions or both… and how can you identify this?)

When you change the intensity of the light source to a very low level, what do you notice about the emitted photons?

When you change the intensity of the light source to a very high level, what do you notice about the emitted photons?

When you have the intensity at a medium level but decrease the lifetime, what do you notice about emissions?

When you have the intensity at a medium level but increase the lifetime, what do you notice about emissions?

When you tune the light to a color that has a lower energy than the preset color, what do you observe?

When you tune the light to a color that has a higher energy than the preset color, what do you observe?

B. Pumping a three state system.

When you change to a three state system, can you still only pump electrons to a higher energy level with the red light or is there another light energy that works now? Explain.

What characteristics do you observe about the emission events when you pump with the additional color? (Are all emissions the same color, are they stimulated, spontaneous, etc.?)

Click on “display photons emitted from upper state.”) What transition do these photons represent, and what region of the spectrum are these photons in?

When you increase the lifetime of the upper state what happens to the emission events?

When you in increase the lifetime of the lower state what happens to the emission events?

C. Making a laser with a three state system.

Your text talk about how it’s ideal to have a four-state system when making a laser, but a three state system isn’t bad. Put all your learning together and find conditions that make a good laser. Describe them below. (“Good” equals continually running with decent “in the green” lasing power.)

When you switch the view from photons to waves, what is special about the wave in the laser?

How can you change the color emitted from the laser?

How can you change the color of the light that is used to “pump” the laser?

Bonus Challenge (1 pt): I can make a laser that burns out (of course I used to build lasers for a living)! When lasers “burn” they actually damage an optic in the system. Optics can’t be kept perfectly clean (even in high vacuum), and it’s dirt on the optics (including the surfaces of the laser medium if it’s a solid) that can absorb energy from the EM radiation and heat up enough to burns a pit in the optic.