

Pre-class Assignment for physics Complete before 1 pm on Tuesday January 24

Associated reading: *Quantum*, ch. 1 - 4

1. Blackbody radiation

- a) Go to <http://phet.colorado.edu/en/simulation/blackbody-spectrum> and Run Now!
- b) The initial temperature is 4800 K (should be blue type in the white box). You can change the temperature by typing in the box, or even easier, moving the slider up and down.
- c) Decrease and increase the temperature. Use the zoom in and zoom out buttons on the horizontal and vertical axes as needed.
- d) What do you notice happens to the position of the peak as the temperature changes?
- e) More specifically, does the height of the peak increase or decrease as the temperature increases? What does the height correspond to physically? Give both a technical term and an everyday description.
- f) More specifically, does the location of the peak move to the left or to the right as the temperature increases? What does the horizontal location of the peak correspond to physically? Give both a technical term and an everyday description.
- g) Go to <http://lectureonline.cl.msu.edu/~mmp/applist/blackbody/black.htm> This is similar to the previous site, but allows you to more easily obtain numerical results.
- h) The initial temperature is 4000 K. You can change the temperature by sliding the red bar in the thermometer on the right hand side up and down. Increase and decrease the temperature and confirm that the spectrum behaves similarly to what you saw in the previous simulation.
- i) Fill out the following table. You might not be able to get exactly the target temperatures, but get as close as you can and record the actual temperature you set. The column $P(T)/P(1000\text{ K})$ records the ratio of the power emitted by the blackbody at temperature T to the power emitted by the blackbody at temperature $T = 1000\text{ K}$. The last row is the product of the temperature T and the peak wavelength (λ_{max}). I've done the first row for you - confirm the first row to make sure you are doing the measurements and calculations correctly.

| Set this | | "measure" these | | Calculate this |
|------------------------|------------------------|-----------------------------|-------------------------|-------------------------------------|
| Target Temperature (K) | Actual Temperature (K) | λ_{max} (nm) | $P(T)/P(1000\text{ K})$ | $\lambda_{\text{max}} * T$ (nm · K) |
| 1000 | 1009 | 2871 | 1.03 | 2896839 |
| 2000 | | | | |
| 4000 | | | | |
| 6000 | | | | |
| 8000 | | | | |

- j) What do you notice about the values you obtain by calculating $\lambda_{\text{max}} * T$? This relationship is known as "Wien's displacement law".
- k) (optional) Plot λ_{max} vs. T (make an x-y scatter plot with λ_{max} on the vertical axis and T on the horizontal axis). Fit a power function to the data (in Excel, add a Power trendline) and display the equation and R^2 value.
- l) (optional, but encouraged) Plot $P(T)/P(1000\text{ K})$ vs. T . Fit a power function to the data and display the equation and R^2 value. This relationship is known as the "Stefan-Boltzmann law".

2. Photoelectric effect

- a) Go to <http://phet.colorado.edu/en/simulation/photoelectric> and Run Now!
- b) Check the boxes to turn on the bottom two graphs (you won't need Current vs battery voltage).
- c) Slide the wavelength slider all the way to the right, into the IR (which stands for infrared), all the way to 850 nm. Set the intensity all the way to 100%
- d) Decrease the wavelength in steps of 50 nm (so down to 800, then 750, then 700, etc.) until you notice something happening. Between what two wavelengths (in steps of 50) do you notice something happening between the two vertical plates? What do you notice? See if you can narrow down the range for which something begins to happen to within 5 nm.
- e) The particles you notice are electrons. Since they were ejected from the (left) plate due to the interaction with light, they are sometimes called photo-ejected electrons, or just photo-electrons. Can you see where the name "photoelectric effect" came from?
- f) Keep the intensity to 100%, and change the wavelength all the way from the longest wavelength (850 nm) down to the lowest wavelength (100 nm) using the slider. Draw/copy the graph of Electron energy vs light frequency; include the units.
- g) Keep the wavelength at the lowest wavelength (100 nm). Change the intensity from 100% all the way down to 0%, slowly, in steps of 20%. What do you notice happening to the photo-electrons?
- h) Keep the wavelength at the lowest wavelength (100 nm). Change the intensity from 100% all the way down to 0%, using the slider. Draw/copy the graph of Current vs light intensity (there aren't any provided units, which you should outrage you. Outrage, I say!).
- i) Set the wavelength to 600 nm. Change the intensity from 100% all the way down to 0% using the slider. Do you notice anything happening between the vertical plates?
- j) (optional, but recommended) Change the Target from Sodium to a different metal. See what changes.
- k) (optional) Play with the different choices in the Options menu.
- l) (optional) A slightly different version of this simulation is available at http://www.kcvs.ca/site/projects/physics_files/photoelectric/photoelectricEffect.swf This version doesn't have the graphs, but there are more metals available under Options, and the material under Resources is very rich reading.

3. Rutherford scattering

- a) Go to http://www.kcvs.ca/site/projects/physics_files/rutherford/thomson_model.swf This applet allows you to visualize what Rutherford believed would happen when he conducted his famous gold-foil experiment by interacting positively charged alpha particles (an alpha particle is the nucleus of a helium atom) with Thomson's "plum-pudding" model of an atom, where the positive charge is uniformly distributed throughout the spherical volume occupied by the atom. (Note that Au is the chemical symbol for gold). Click Auto-fire to see what happens to the trajectories of alpha particles launched at a gold atom, if Thomson's model for the atom is correct.
- b) Go to http://www.kcvs.ca/site/projects/physics_files/rutherford/scattering2.swf This applet simulates what Geiger and Marsden, working under Rutherford, actually observed. Click Auto-fire.

4. Hydrogen atom

- a) Go to <http://phet.colorado.edu/en/simulation/hydrogen-atom> and Run Now!
- b) Turn on the spectrometer by clicking on the box.
- c) Turn the knob to Prediction (what the model predicts) by clicking on the knob.
- d) The first model is the Billiard Ball model. Shine white light on the Box of Hydrogen by clicking on the red button with the white O. What do you notice?
- e) Choose the Plum Pudding model, still with white light shining on the Box of Hydrogen. What do you notice?
- f) Choose the Classical Solar System model. What do you notice? You might want to turn off the light and choose the Classical Solar System model again. What do you notice?
- g) Choose the Bohr model, without the white light turned on. What do you observe?
- h) Now, turn on the white light and watch for a while. Pay close attention. What do you observe?
- i) Keep this going, but also click on Show electron energy level diagram. It's difficult to look at the atom and the energy level diagram at the same time, but do your best. What do you observe?