Photoelectric Effect Lab Simulation

We are going to use a computer simulation to study several details of the photoelectric effect. One member of your lab group must have a computer with a web browser connected to the internet and follow the steps below to use the program. These steps do not require downloading Java.

1. Using Google Chrome or Microsoft Edge, go to the Phet simulations home page: https://phet.colorado.edu/en/simulations/category/new
   You could do a search for "phet," and this website should be at the top of the list.

2. Click on the search icon (magnifying glass) in the upper right-hand corner of the web page. Type "photoelectric effect" in the search bar. Double click on "photoelectric effect" in the list of simulations (not activities).

3. Click the "play" arrow on the simulator to run it using your browser and select "Run CheerpJ Browser-Compatible Version." This seems to work best in most cases. If you know that you have java installed on your computer, you could instead download and run the .jar file.

4. If you want the simulation window to fill most of your screen, change your screen resolution to 1280 x 800 or 1024 x 768. On a Windows computer, do this by right clicking anywhere on the screen, choose "display settings," and scroll down to the resolution option. Before doing this, make a note of your current screen resolution so that you can easily change back to that after you finish using the simulation program.

5. On the next page, are some activities students can do using the simulator to explore the properties of the photoelectric effect. Feel free to modify them as needed for your class.

Part 1 – Simulation Practice

1. Light shines from the lamp and hits the surface of a metal.
   a. You can choose from several different metals. Select Sodium.
   b. You can adjust the intensity (brightness) of the light. Set it to 50%.
   c. You can adjust the wavelength (or frequency) of the light. This determines its color. Set it to 600 nm. Later, we will need to use the following equation to convert wavelength (λ) into frequency (f):
      $f = c / \lambda$, where $c = 3x10^8$ m/s (the speed of light)
   d. In the simulator, wavelength is measured in nanometers (nm) which are very tiny. In the metric system, 1 nm = $1x10^{-9}$ m = 0.000000001 m.

2. If the light hitting the metal contains enough energy, it will eject some electrons from the surface.
   a. If electrons are ejected from the metal and hit the other side, a current will be detected. Scientists can't actually see the individual electrons leave the surface of the metal, but they can measure current and infer that it is caused by emitted electrons.
   b. The energy carried by a wave is proportional to its frequency. So, waves with a higher frequency (or shorter wavelength) carrier more energy than waves with a lower frequency (or longer wavelength). The equation is: $E = h f$, where $h = 4.14x10^{-15}$ eVs
      i. Note: The electron-volt (eV) is a unit of energy. It represents the work done on an electron in accelerating it through a potential difference of one volt. You can convert electron volts into Joules, using: 1 eV = $1.602x10^{-19}$ J.
   c. The energy of the wave should also increase as its intensity (brightness) increases. For waves, intensity is proportional to amplitude. We don't need that specific equation for this experiment.
   d. In the particle model of light, intensity (brightness) would be the number of particles hitting the surface per second. The brighter the beam, the more particles present. Under "options" you can select "show photons" if you want to see the light as a beam of particles.

3. How does the wavelength (or frequency) of the incident light affect the energy of the ejected electrons?
   a. Set the intensity of the light to 50%.
   b. Starting at around 600 nm, lower the wavelength of the light until you see an electron get ejected from the surface of the sodium. Record this wavelength.
   c. Calculate its frequency in Hz using the equation from above ($f = c / \lambda$).
   d. Calculate its energy in eV using the equation from above ($E = h f$).
   e. Check the box to display the "electron energy vs. light frequency" graph. Observe what happens as you change the wavelength.

4. How does the intensity of the incident light affect the current?
   a. Check the box to display the "current vs. light intensity" graph. The current will reflect the relative number of electrons that are being ejected per second.
   b. Select a wavelength in the red portion of the spectrum (greater than 539 nm). Vary the intensity of the light and observe any changes in current.
   c. Select a wavelength in the blue portion of the spectrum (a little less than 539 nm). Vary the intensity of the light and observe any changes in current.
   d. Select a wavelength in the UV portion of the spectrum (a lot less than 539 nm). Vary the intensity of the light and observe any changes in current.

5. How does the battery voltage affect the current?
   a. In this experiment, the battery allows us to stop the moving electrons. We can determine how much kinetic energy an ejected electron has by measuring the voltage required to stop it.
   b. Check the box to display the "current vs. battery voltage" graph. Once again, the current will reflect the relative number of electrons that are being ejected per second.
   c. Select a wavelength of 400 nm and set the intensity to 50%. Vary the voltage and observe any changes in current. What voltage value prevents any ejected electrons from getting to the other side? This is called the "stopping voltage." Record the voltage when the current is first reduced to zero.
   d. What is the stopping voltage if the incident light has a wavelength of 200 nm?
   e. Describe what happens if you select a wavelength of 600 nm.

Part 2 – Further Investigations

Now that we have practiced using some of the features of the simulation, each group should repeat the above experiments (steps 3, 4, and 5 from part 1) for a different metal. Since you are using a new metal, in step 4 you should replace the 539 nm wavelength reference with your new result from step 3. Also, you may have to adjust the wavelengths for step 5 based on your new metal. You should pick a wavelength higher than your result from step 3, one a little lower than your result from step 3, and one a lot lower than your result from step 3.

Groups 1 & 6 – Zinc
Groups 2 & 7 – Copper
Groups 3 & 8 – Platinum
Groups 4 & 9 – Calcium
Groups 5 & 10 – ?????

Part 3 – Design your own Investigation

If time permits, you can design your own experiment to test a particular aspect of the Photoelectric Effect.