The Photoelectric Effect Part I: Initial Observations, Circuit Review

1. Open the PhET simulation titled "Photoelectric Effect" located here: https://phet.colorado.edu/en/simulations/photoelectric. You can also just search for "PhET photoelectric effect." Click on the "play" button and select "RUN CHEERPJ BROWSER-COMPATIBLE VERSION" from the pop-up window.

2. Initially, there is no light shining on the left metal plate (made of sodium), and the battery's voltage is set to zero. What is the potential difference between the two metal plates? What is the current in the circuit? Why?

3. Drag the slider to the right to increase the voltage of the battery. Describe what happens to the plates.

4. After this change happens, when is the potential difference between the two metal plates? What is the potential difference between the right plate and the positive end (right) end of the battery? What is the current in the circuit?

Reminder: Current is measured in amperes, where 1 ampere is equal to 1 coulomb/second. In other words, it is the measure of the amount of electric charge that crosses a surface per second. This depends on both the number of charges moving and the average speed of those charges *in the metal wires of the circuit*.

Everything up until now has been review of Physics 212 concepts. Shining light onto the left plate is what will bring us into Modern Physics territory.

5. Return the battery slider to zero. This is like saying there is no battery at all. Now increase the intensity of the light shining onto the left plate to 40%. What happens? What is the current in the circuit?

6. In the tube, do the liberated electrons move at a constant velocity, or do they accelerate? Look closely!

7. Just after they are emitted from the left plate, do the liberated electrons all move at the same velocity relative to one another? Look closely!

8. Predict: Do you think all intensities of light will liberate electrons? Explain.

9. Predict: Do you think all wavelengths of light will liberate electrons? Explain.

To collect data, use the prepared spreadsheet, *phys301-pe.xlsx* for each of the parts below. The graphs will automatically populate when data is entered into the tables.

Part II: Current vs. Intensity (keep battery/applied voltage at zero)

1. Use the intensity slider to turn the intensity back to 0%. Now turn the intensity up to a very small percentage, such as 5%. The current reads 0.000 A. There are two possibilities: the current is zero, or the current is less than 0.0005 A. Which do you predict is true? Why did I choose that particular value to ask you about?

2. Collect current readings at intervals of every approximately 15% increase in intensity in your Excel spreadsheet.

3. Examine the relationship of current as a function of intensity. Is it linear? Is it proportional? Explain why, in terms of the physics, you see this relationship.

4. Given your answer to the previous question, do you change your answer to the first question in this part? At a small percentage, was the current really zero, or just a very small number?

Part III: Current vs. Applied (Battery) Voltage

1. Place the intensity slider to 50%. Describe, physically, what happens when you increase the voltage applied from the battery (move the slider to the right).

2. Describe, using the laws of physics, what happens when you change the direction of the voltage applied from the battery (move the slider to the left, so its value is negative and the battery flips directions).

3. Collect current measurements for the voltages listed in your Part III table. Repeat this with the intensity at 100%.

4. Explain the shape of this graph. See hints below.
    a. Why is the current zero until a certain voltage (the "stopping potential" ΔV_s)?

    b. Does the stopping potential depend on intensity? Why or why not?

    c. Why does the current increase for a bit?

    d. Why does the current remain constant after a certain voltage?

    e. Why is the maximum current higher with higher intensity?

Hints: Recall our Physics 212 model for the flow of electrons through a circuit. Once our electrons hit the right place, they enter the metal wire, where they are constantly bouncing with atoms in the circuit's metal; the properties of the metal set the drift velocity of the particles. Recall that current is a function of both the speed and ***number*** of electrons.

Part IV: Maximum Electron Kinetic Energy vs. Frequency

Be sure the battery voltage is back at 0.00 V, and the Target is still set to Sodium. Under "Graphs," select the Electron Energy vs. Light Frequency graph. Zoom in until the vertical axis is scaled from 0 to just above 8 eV (electron-volts).

Notice that the liberated electrons do not all move at the same speed. A liberated electron's energy – kinetic energy, that is – depends on its speed. We are interested in the *maximum* kinetic energy an electron could have. This corresponds to the fastest electrons in your simulation.

1. Does the intensity of the light change the maximum kinetic energy of the liberated electrons? Test it, then explain why or why not.

To take data that we can use in Excel, we will use a seemingly backwards process, because the slider to change the light is marked in units of wavelength (and we can easily read that value instead of estimating frequency between grid lines).

1. Find the wavelength of light that corresponds to a maximum electron kinetic energy of 2 eV. Record this in the Column A of your Part IV table. *For now, ignore the line that reads f* (Hz) = 0.

2. Calculate, by hand, the frequency in Hz corresponding to this wavelength. Pay attention to units!

3. Enter this as a formula for the Column B of your table. Click and drag to apply the formula to the rest of the rows in this table.

4. Repeat the process for the wavelength corresponding to 4, 6, and 8 eV, respectively. The graph will automatically populate with data points for your maximum kinetic energy (in eV) on the vertical axis vs. frequency (Hz) on the horizontal axis.

5. What is the nature of the relationship between K_{max} and frequency? Is it linear? Is it proportional?

6. Let's find an equation for K_{max} as a function of *f*. Use Column D to create a modeled equation. You can use the spaces about your table for the constants for slope m and intercept b. Write your equation below. Don't forget units!

7. If you repeated this experiment with a different metal, do you predict that the slope would change? Do you predict that the intercept would change?

8. Repeat the experiment using Zinc. Write your modeled equation below. Don't forget units!

9. Did the slope change? Did the intercept change?

10. What is the significance of the intercept? What is the significance of the slope? We'll cover this more as a class together – try your hand at an explanation now.

Print your spreadsheet and attach it to this handout for your future reference. Double-check that it is automatically set to fit onto one page.