Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Photoelectric Effect Simulation

1. Go to the PhET website. Choose >Play with sims >Physics >Light & Radiation > Photoelectric Effect.
2. Set the intensity to 50%.
	* What is the current? \_\_0.071\_\_\_\_\_\_
	* Define intensity for this simulation. In this simulation changing the intensity changes the rate of photon production. Increased intensity means increased # of photons per time.
	* Does every electron “kicked out” out of the metal cross the gap between plates? YESWhy/why not?

Each electron has sufficient kinetic energy when the potential difference is 0.

1. Leave the intensity at 50% and the wavelength at 400 nm. Change the voltage to -3.00 volts.
	* Explain what this change in potential difference means in this model. Making the potential difference negative changes the charges on the plates/changes the direction of electric field
	* Why is there no current? The electrons are attracted by the positive plate/repelled by the negative plate. With this electric field strength, the electrons don’t have sufficient energy to overcome the electric field and cause a current.
	* Predict: Will increasing the intensity at the same wavelength and potential difference cause a current to flow? NO Why or why not? (use sim to check prediction) No matter how many electrons are ejected, none have sufficient energy to cross the gap causing a current. Increasing the rate of photon production increases the rate of electron ejection. Although the rate of electron ejection increases, none of the electrons have sufficient kinetic energy to cause a current to flow.
	* Is the work function still met (at 400 nm, -3.00 V and 50% intensity)? What is your evidence? YES. Electrons are still ejected from the metal, so the work function is met.
	* Predict: What setting can you change to cause a current? (explain two answers, then use sim to check prediction). (1) I can increase the energy of each photon by decreasing the wavelength. This results in the electrons having sufficient kinetic energy to cause a current. (2)I can increase the potential difference (any p.d. over -0.7 V will allow a current to flow when wavelength is 400 nm and sodium is used in this sim). Note that “I can change the metal,” is not a valid answer. Sodium is the default metal—if the settings remain λ=400 nm, calcium is the only other metal with a low enough work function for electron ejection-but electrons will not cause a current with this p.d.)
2. Click to open all three graphs. Use sodium as your metal. Set the potential difference to 2.00 volts and the wavelength to 345 nm (in the UV region).
	* Slide the intensity from 0%-100%. Sketch the Current vs. Intensity graph. Explain this graph. (this means define the axes and use the model to support the relationship shown on the graph)

The y-axis is current (the rate of electron flow). The x-axis is intensity (rate of photon production). Each photon has sufficient energy to meet the work function/kick an electron out of the metal. At this p.d. each electron has sufficient kinetic energy to cross the gap causing a current to flow. Therefore each photon causes one electron to flow and increasing intensity causes a linear increase in current.

* + Return the intensity to 50%. Slide the wavelength across the spectrum. Sketch the graph of Energy vs. Frequency below. Explain this graph. Additionally, show a calculation for the slope of this graph. What does the slope represent? What does the y-intercept represent? Write the equation for this graph.

The y-axis is the kinetic energy of the electron (this is the photon energy minus the work function). The x-axis is the frequency of each photon. The x-intercept is the threshold frequency.

Slope: the points (1.5 x1015, 4) and (3 x 1015, 10) are easy points to read from this graph. Slope calculation:

 $\frac{ \left(10-4\right)}{\left(3.0-1.5\right) ×10^{15 }} = \frac{6}{1.5 ×10^{15}} =4 × 10^{15} eV∙s$

4 x 1015 eV·s is Planck’s constant (convert to J·s and get 6.63 x 10-34 J·s) The slope represents Planck’s constant.

The y-intercept represents the work function. $y=mx+b$ for this graph can be written:

$$Kinetic Energy of electron =\left(Plank^{'}s constant\right)\left(photon frequency\right)+ ϕ$$

EK = hf - $ϕ$

y = mx + b

$Φ$ represents the work function which is the y-intercept (a negative value—the quantity of energy required to remove the electron from the metal)

Explanation of graph: Once the work function is achieved, an increase in the energy (frequency) of photons results in a linear increase of kinetic energy in the electrons.

* + Return the wavelength the 345 nm. Slide the potential difference from -8.00 volts to +8.00 volts. Sketch the graph of Current vs. Voltage below. Explain the graph. What does the x-intercept represent? What is stopping voltage a measure of?



The y-axis represents the current (rate of flow of electrons). The x-axis represents the potential difference/voltage/electric field strength.

The x-intercept is the stopping voltage (stopping potential) which is a measure of the minimum voltage that produces a current.

Stopping voltage is a measure of the kinetic energy of the electrons. Once the stopping voltage is exceeded, increasing the voltage increases the current linearly. With increasing voltage, an increasing number of electrons have enough kinetic energy to cause a current to flow (“cross the gap”). At a current of 3.5 on this graph, increasing the voltage does not increase current. This is because every electron to be ejected from the metal will “cross the gap” for a positive voltage. (Analogy: on a hill every ball released will roll down the hill—downhill represents the direction of the electric field-every free electron will move toward the positive plate)

1. Determine which of the metals has the greatest work function. Outline your method below including what variables you held constant and how you changed other variables. Check your answer with 2 other students.

Platinum. One possible method: At a constant settings for voltage, student slides the frequency/wavelength slider and observes the graph of energy vs. frequency. The graph with the lowest y-intercept has the greatest work function.

1. Find a student with a different method and have them explain their thinking to you. They can use the model to show you their process. Ask them at least one question about their process to push their thinking. Initial their paper here\_\_\_\_\_\_ when they have given an adequate explanation. Be sure to explain your process to another student and have them initial above on this paper.
2. Figure out the work function for the unknown metal (????). Use the internet to determine one possibility for this metal. Check your answer with two other students.

The metal begins ejecting electrons at a wavelength of 330 nm.

 $f= \frac{v}{λ}= \frac{3 × 10^{8}}{330 × 10^{-9} } =9.1 × 10^{14} Hz$

$$E=hf=\left(6.63 ×10^{-34}J·s\right)\left(9.1 × 10^{-14} Hz\right)=6 × 10^{-19} J$$

$$\left(\frac{6 × 10^{-19} J}{1.6 × 10^{-19} J eV^{-1}}\right) \~ 3.8 eV$$

An internet search may give the following metals with work functions around 3.8 eV:

Zn, Tl, U, Hf, As

Students may also notice that the graphs for Zn and ????? are the same and conclude that ????? is zinc. (or that the same current is produced for Zn and ???? for identical settings)

1. Write your own question that could be answered using this simulation. Have a fellow student show you how to use the simulation to answer your question. When the student has demonstrated sufficient knowledge of the photoelectric effect, initial their paper here\_\_\_\_\_\_. Be sure to answer someone else’s question and get their initials as well.