Photoelectric Effect Homework Activity

Learning Goals: To be able to explain how the photoelectric effect experiment works and why a photon model of light is necessary to explain the results.  To be determine how to calculate the wavelength of light, the work function of the metal, or the stopping potential, if given the other two.

The following table of **work functions for metals** may be helpful for some of the problems in this homework:

| Aluminum | 4.08 eV | Cesium | 2.1 eV | Lead | 4.14 eV | Potassium | 2.3 eV | Uranium | 3.6 eV |
|---|---|---|---|---|---|---|---|---|---|
| Beryllium | 5.0 eV | Cobalt | 5.0 eV | Magnesium | 3.68 eV | Platinum | 6.35 eV | Zinc | 4.3 eV |
| Cadmium | 4.07 eV | Copper | 4.7 eV | Mercury | 4.5 eV | Selenium | 5.11 eV | | |
| Calcium | 2.9 eV | Gold | 5.1 eV | Nickel | 5.01 eV | Silver | 4.73 eV | | |
| Carbon | 4.81 eV | Iron | 4.5 eV | Niobium | 4.3 eV | Sodium | 2.28 eV | | |

To answer the following questions, you should use the Photoelectric Effect simulation .

1. (1 pt) Suppose you set up the experiment so that the plate is ejecting electrons. Predict which of the following changes to the experiment could increase the maximum initial kinetic energy of the ejected electrons. (Select all that apply) Then test your prediction.

☐ A. Increasing the intensity of the light beam

☐ B. Decreasing the intensity of the light beam

☐ C. Increasing the wavelength of light

☐ D. Decreasing the wavelength of light

☐ E. Increasing the frequency of light

☐ F. Decreasing the frequency of light

☐ G. Increasing the voltage of the battery

☐ H. Decreasing the voltage of the battery

☐ I. Replacing the target with a material that has a larger work function

☐ J. Replacing the target with a material that has a smaller work function

2. (1 pt) Suppose now you set up the experiment so that the light intensity is non-zero but the plate is NOT ejecting electrons. Predict which of the following changes to the experiment could make the plate start ejecting electrons? (Select all that apply) Then test your prediction.

☐ A. Increasing the intensity of the light beam

☐ B. Decreasing the intensity of the light beam

☐ C. Increasing the wavelength of light

☐ D. Decreasing the wavelength of light

☐ E. Increasing the frequency of light

☐ F. Decreasing the frequency of light

☐ G. Increasing the voltage of the battery

☐ H. Decreasing the voltage of the battery

☐ I. Replacing the target with a material that has a larger work function

☐ J. Replacing the target with a material that has a smaller work function

3. (0.5 pts) What causes the electrons to be ejected from the left plate in this simulation?

⊙ A. The force exerted on the electrons by the battery

⊙ B. The beam of light shining on the plate
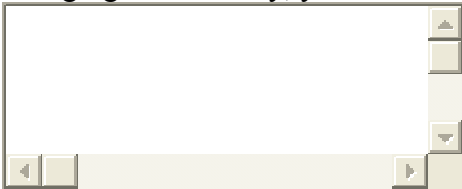
⊙ C. Both A and B.

⊙ D. Neither A nor B.

4. (essays) These essays are designed to help you understand how the observations from the photoelectric effect experiment lead to and make sense only with a photon model of light. The following are some key experiments from the photoelectric effect. For each, explain

1. what you observe
2. what conclusions you can draw about light and why, and
3. how it is or is not consistent with what you would expect to observe if light matched the classical wave model and with what you would expect to observe if it matched the photon model of light.

a. (essay) Light is shining on a metal and electrons are being emitted. You turn the intensity down very very low.
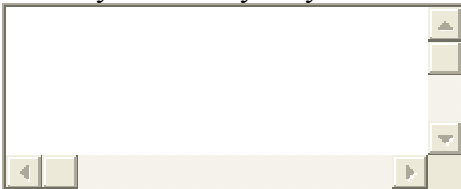
b. (essay) Light is shining on a metal plate and electrons are being emitted. Without changing the intensity, you make the wavelength longer and longer.

5. (0.25 each) If you have the experiment set up so that electrons are being emitted from the metal plate, which of the following are true and false?
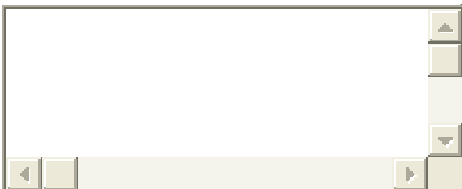
☐ **True** ☐ **False**   As long as conditions do not change, all emitted electrons have the same initial kinetic energy.

☐ **True** ☐ **False**   The work function for the metal is different for different electrons.

☐ **True** ☐ **False**   The energy of the photons hitting the plate must be less than the work function of the metal.

☐ **True** ☐ **False**   The electrons emitted with the largest initial kinetic energy are those that were the least tightly bound in the metal.

6. (essay) Explain what the phrase - 'the work function for sodium' - means in a way that would make sense to a non-science person.

7. In the photoelectric effect experiment, the graph of current vs battery voltage for a metal with light of a particular frequency shining on it looks like the curve below. This graph represents **current vs voltage** for **200nm light** shining onto **Cadmium (Cd)** which has **a work function of 4.07 eV**.


Real Observation
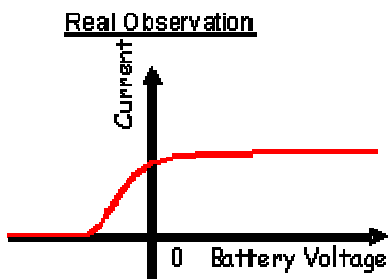
a. (essay) Explain your reasoning for why this curve has the shape that it does. In your answer, you should address: Why is current level at V>0, why does current go to zero at some negative voltage and what determines that voltage, and why does current start

decreasing steadily at V<0?

b. (0.75 pt) What is the stopping potential in this situation (in eV)? (Remember stopping voltage is expressed as a positive number).

c. In the graphs below, the gray curve is always the same and represents the situation you explained in part a (the current vs voltage for 200nm light shining onto Cadmium (Cd) which has a work function of 4.07 eV). The red curves now represent the current vs voltage after a change in the experiment.
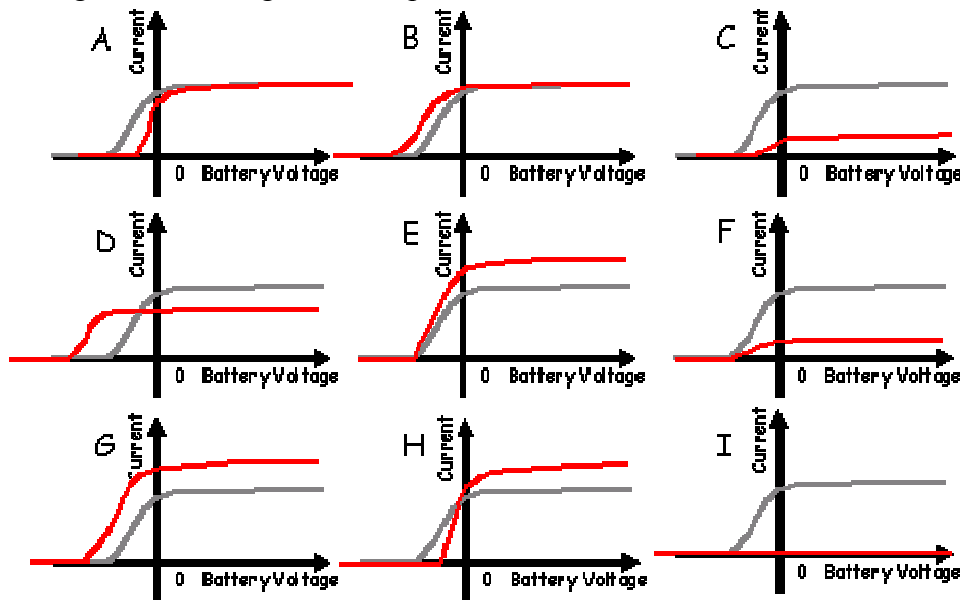


i. (0.5 pt each) If you decrease the wavelength of the light shining onto the metal, what happens to the voltage where the current goes to zero...

☐ becomes a larger, negative number

☐ becomes a smaller, negative number

☐ is unchanged

(essay) Briefly explain your reasoning behind this answer:

ii. (0.5 pt) Which graph would represent this decrease in wavelength?

iii. (0.5 pt) Which graph would represent an increase in the intensity? [dropdown]

iv. (0.5 pt) Which graph would represent an increase in wavelength to 290nm?
[dropdown]

v. (0.5 pt) Which graph would represent an increase in wavelength to 500 nm?
[dropdown]

vi. (0.5 pt) Which graph would represent a switch to sodium? [dropdown]

d. (0.5 pts) What change or combination of changes would you need to explain the change observed in Graph H above? (check all that apply)

☐ decrease in wavelength

☐ increase in wavelength

☐ decrease in intensity

☐ increase in intensity

8. (1pt) You have a colored spot light, but you don't know its precise wavelength. To find out the wavelength you shine your light on a sodium target placed in a circuit as shown in the simulation. You look up the work function of sodium and find that it is 2.3 eV. If you set the battery voltage to -0.5 V, you find that the most energetic electrons nearly reach the right plate, but turn around just before they get there. What is the wavelength, in nm, of the colored light that you used? (You can answer this question either by doing a calculation or by using the simulation. To get practice for answering the next question, we recommend that you use both methods and check that they give the same answer.)

[text box]

9. (1 pt + **4 pts for LONG ANSWER WRITE UP**.) Your long answer will be graded using the following rubric:

1. **Identifying the physical principles or key ideas (expressed in words) that apply to the problem and your strategy for approaching the problem:** (2 if correct, 0 if irrelevant principle/ideas, 1 if have both some relevant and some irrelevant principles/ideas.)
2. **Including a useful picture that is helpful in solving the problem (include information that help you think about what is happening!)** (2 for a useful picture, 1 for a picture that is not particularly useful, 0 for a non-useful picture or no picture)
3. **Explaining (in words) the reasoning that goes along with the equations/math you are doing.** (2 for correct explanation, 1 for mostly correct or incomplete explanations, 0 for incorrect explanations)
4. **Showing the details of your solution (equations/math)** (2 for correct equations/solution, 1 for mostly correct or incomplete equations/solution, 0 for incorrect equations/solution)
5. **Clarity of solution.** (2 if good, 1 if difficult but can be figured out, 0 if incomprehensible. If 0 here, all the others will be left blank.)

You have a plate of metal, but you have no idea what kind of metal it is. You come up with the brilliant idea of measuring the work function of this metal by using it as the target in a photoelectric effect experiment. You can perform this experiment virtually by selecting '???' as the target in the simulation. What is the work function, in eV, of the mystery metal?

[                    ]

10. (0.25 pt) What is the mystery material?

- ☐ Sodium (Na)
- ☐ Calcium (Ca)
- ☐ Cadmium (Cd)
- ☐ Aluminum (Al)
- ☐ Silver (Ag)
- ☐ Platinum (Pt)
- ☐ Magnesium (Mg)
- ☐ Nickel (Ni)
- ☐ Selenium (Se)
- ☐ Lead (Pb)