eMATH

Photoelectric Effect

Purpose:

To explore how the kinetic energy of a photoelectron ejected from a metal is a function of the frequency of the incident light, and the type of metal.

Background:

When light strikes a metal, one of three things may happen:

1. If the frequency of the incident light is less than the threshold frequency ($f < f_0$), no electrons are ejected from the surface of the metal, even if the intensity of the incident light is increased.
2. If the frequency of the incident light is equal to the threshold frequency ($f = f_0$), electrons are ejected from the surface of the metal but have no kinetic energy. If the intensity of the incident light is increased, the number of electrons ejected from the metal increases.
3. If the frequency of the incident light is greater than the threshold frequency ($f > f_0$), electrons are ejected from the metal and have kinetic energy. If the intensity of the incident light is increased, the number of electrons ejected from the metal increases.

The kinetic energy of the photoelectrons is expressed by the formula:

$$E_{k_{\max}} = hf - W,$$

where W is the work function of the metal and can be expressed as

$$W = hf_0$$

The formula for the kinetic energy of the photoelectrons is in the form of the equation of a straight line: $y = mx + b$.

$$E_{k_{\max}} = hf - W$$
$$y = mx + b$$

The purpose of this eMATH is to see the relationship of the kinetic energy equation and the straight-line equation, and to determine the physical quantities of:

a. Threshold frequency (f_0)
b. Planck's constant (h)
c. Work function (W)

Instructions:

1. Download and open the accompanying Excel spreadsheet. This spreadsheet has a table that shows the work function of several different common metals. You will pick a few of these metals and use them to plot the graph of the kinetic energy of the photoelectrons as a function of the frequency of the incident light.

2. Use the drop-down selection boxes to choose the three metals to compare. A graph of the kinetic energy of the photoelectrons as a function of the frequency of the incident light will be plotted for these metals.

3. Make a note of the *x*-intercept, the *y*-intercept, and the slope of the line for all three metals.

Analysis:

1. What part or parts of the electromagnetic spectrum does the incident light represent?

2. Look at the lines on the graph. Determine the slope of each of these lines by positioning the pointer over the line near one end. After a moment, the values for the line at this location will be displayed. This will be one set of values to use for the slope. Do this again near the other end of the same line to get the other set of points. Use these points to determine the slope.

3. What physical constant does the slope of your line represent?

4. The other lines are parallel to each other. What can be said about the slopes of all the lines? Why?

5. Place the pointer over one of the lines where it intercepts the *x*-axis. Make a note of this "x" value. Can you determine what the significance of this frequency is? (Hint: What is the corresponding energy value at this position?) Multiply this "x" value by Planck's constant. It should equal the work function of a metal. Verify that the work function of the metal for this line is the same as the value you determined.

6. Now look at the point where the lines intercept the *y*-axis. This will be a negative energy. What physical value does it represent?

7. Experiment with producing different lines by using the work functions of other metals. Can you find which metal produces a line furthest to the right? What determines the position of the line?