THE PHOTOELECTRIC EFFECT

The goal of this activity is illustrate the photoelectric effect, and to measure Planck's constant. Taking the actual data for this lab only takes a few minutes, so take your time to make sure you understand what is going on!

Step 1: Turn on the apparatus. Turn the 'light intensity' knob up to full. Now wait 5-10 minutes for the apparatus to warm up. While it is warming up, read the following and answer all questions.

The photoelectric effect was the first dramatic evidence that light, although a wave, comes in discrete packets of energy called photons. Einstein won the Nobel prize in 1905 for suggesting this solution. The photoelectric effect occurs when light is shone onto a piece of metal, causing electrons to be ejected from the metal.

We now formulate the energy of a photon in terms of Planck's constant:

$$\textit{Energy of a photon} = hf$$

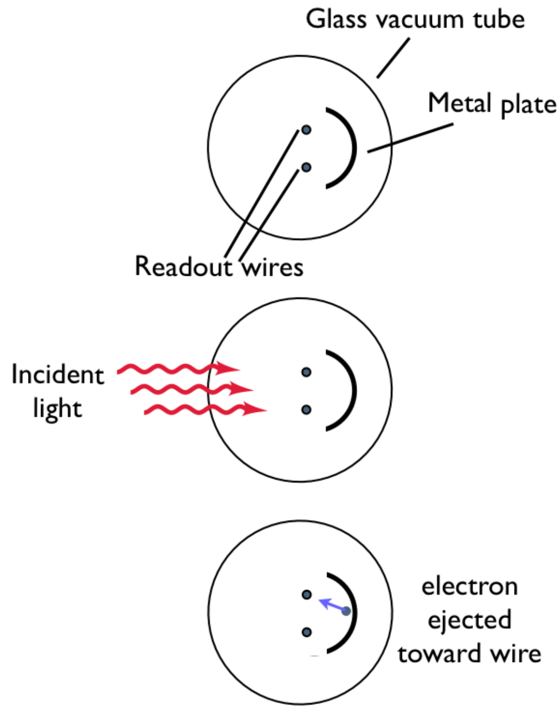
where f is the frequency of the photon in Hz, and h is Planck's constant, with a modern accepted value of 6.63×10^{-34} Js.

In addition, we define the *work function* of the metal, W, to be the energy required to knock an electron out of the metal. That is:

$$\text{Energy(initial)} = \text{Energy(final)}$$

$$hf - W = KE$$

the kinetic energy of the electron that is ejected is equal to the energy of the photon, minus the energy that is 'wasted' trying to get the electron free.



In the experiment we are doing today, we have a setup as shown in the figure. Light shines on the metal plate. This causes electrons to be ejected. Some of those electrons will fly towards the readout wires. When they hit, a small amount of electricity flows through the wires. We measure this flow with an ammeter - a electrons hitting the wires is shown as positive current, while electrons leaving the wires is shown as negative current.

To measure the KE of the electron, we use a decelerating voltage. An electron that starts at a place with some voltage V_i and ends up at a place with voltage V_f gains energy:

$$\Delta E = q\,(V_f - V_i) = -e\,\Delta V$$

Given this, answer the following questions before you begin:

Question 1: What voltage (negative or positive) do we need to put on the wire to stop the electrons?

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Question 2: Assume that an electron flies off the plate, directly toward the wire with kinetic energy 1.0 eV. What voltage would we need to put on the wire to keep this electron from hitting?

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Question 3: Electrons fly off the plate in all directions. What voltage would we put on the wire (negative or positive) to make more of them hit the wire?

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Question 4: If more electrons hit the wire, will the current increase or decrease? Is the current negative or positive?

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Question 5: If we see the opposite current, what does that mean? (Hint - some of the light hits the wire, too.)

Step 2: Observe how the voltage and current work.

(A) Switch the 'current multiplier' to 100x. Turn the voltage control knob all the way to the left (off). Remove the blackout filter from the box. Flip the readout switch to 'current'. Put the red (635 nm) filter into the port.

(B) Align the light so it shines directly to the left at the port. Use the side screws to secure it. What happens to the current as you increase the brightness of the light? Crudely sketch it below:

(C) Make sure that current is proportional to quantity of light, by moving the light source. To move the light, loosen aluminum screw under light bulb, move the light, then tighten the aluminum screw again. Try three or four different positions, and sketch the current as a function of distance. What shape is this curve?

(D) Turn the brightness knob all the way up. Now, flip the switch to measure voltage. Play with the voltage controls to see how they control the voltage on the readout wires. Make a note below - do you understand this?

(E) Flip to measuring at current. Sketch how the current changes as you change the voltage. Try both positive and negative voltages. (You will have to flip back and forth to see how changing the voltage affects the current.)

Have the instructor look at your sketches before you continue.

Step 3: Find the electron KE at each wavelength.

Move the light to the 25 cm mark.

The apparatus comes with a set of five filters. The filters are 635 nm (red), 570 nm (yellow), 540 nm (yellow/green), 500 nm (deep green), 460 nm (blue).

For each filter, find the decelerating voltage at which the current becomes zero. (Use the most sensitive current setting!) Record your results in a table.

Step 4: Graph the results.

Use graphing software or graph paper to plot the KE of photoelectrons against the frequency of light. Use convenient units, not necessarily SI. (Note you will need to convert the values taken in step 4.) Label each point with the color of the filter. Find the best fit line through the points.

Step 5: Interpret the data.

From your data, find:

Planck's constant (*h*): __________________ Js

The work function of the metal (*W*): ___________________eV. Note that the work function is the energy required to just barely knock an electron out of the metal - it's the value of hf where KE = 0. (It's the x-intercept, not the y-intercept.)

Compute how well your value of *h* agrees with the accepted value.

What are the possible reasons for the discrepancy? (Note: "human error" and "random error" are not acceptable answers.)