Photoelectric Effect

I. EQUIPMENT LIST

* Photoelectric Apparatus
* Five color filters: 635 nm (red), 570 nm (yellow), 540 nm (yellow/green), 500 nm (deep green), 460 nm (blue).

II. BACKGROUND INFORMATION

The photoelectric effect is a phenomenon where electrons are emitted from a metallic surface when a beam of light shines on the surface. The ejected electrons are called photoelectrons. They can be collected as a current in a completed circuit.

Here are some specific characteristics of the effect:

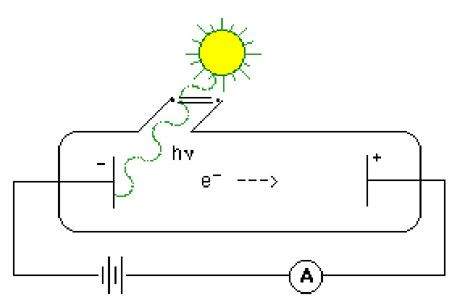
a) The current produced by the photoelectric effect is directly proportional to the intensity of light shining on the surface of the metal.
b) The maximum kinetic energy of the ejected photoelectrons depends only on the highest frequency the incident radiation.
c) For each metal there is a definite cutoff frequency below which no photoelectrons are emitted.
d) The effect occurs as soon as the light shines on the surface.

In 1905 Einstein successfully explained the photoelectric effect by assuming that light was made up of discontinuous, concentrated packages of energy called photons and that the absorption of a photon produced the emission of a photoelectron. Max Planck had theorized that e-m radiation from a heated object would be given by packets of energy, where the energy of each packet is given by a constant multiplied by the frequency of the wave-packet. Einstein used Planck's idea to describe the photons, and showed that there was a minimum energy required to produce photoelectrons for a given metal (called the work function) and by conservation of energy the electron would obtain kinetic energy from the excess energy in the photon (above the work function). The photoelectric current can be stopped by applying a reverse voltage which will reduce the kinetic energy of the electrons. The maximum voltage needed to reduce the current to zero stops the most energetic electrons.

The energy of the photon is given by:

$$E = h\,f\ ,$$

where *h* is Planck's constant and *v* is the frequency of the light.

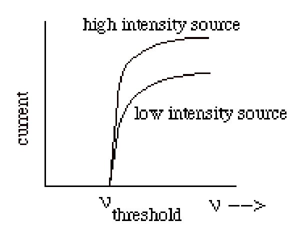


Einstein showed that the relationship between the photon energy, the work function (Φ) of the material is given by, and the maximum kinetic energy of the photoelectrons,

$$h\,f = \Phi + K_{max},$$

where the work done by the electric force to stop the most energetic electrons is

$$W = \Delta K_{max} = e\,V$$



Equipment information
The Photoelectric Effect Cell contains vacuum phototube which can be permanently fatigued if it produces high currents over a period of time; for this reason, do not allow intense light into the cell. The Photoelectric apparatus comes with an aperture cover to cover the opening into the cell.

A. Please keep the aperture opening covered at all times except when collecting data.
B. Please keep the light source facing the ceiling at all times except when collecting data
C. Make sure the apparatus is off when finished collecting data. The light should be off and the amplifier system should be off.

The cutoff filters, transmit light of wavelengths down to a certain limit but no light from below this limit. The filters are affected by moisture, fingerprint oils, and by light over a period of time.

D. Handle the filters by the edges only.
E. Do not expose them to intense light for long periods of time.
F. Place them back in their container when not being used.

III. EXPERIMENTAL PROCEDURE

In this experiment the ammeter shown in the simplified circuit diagram on page 1 is built into the photoelectric apparatus.

1. Get a photoelectric apparatus, and a small box (5) of Filters.
2. Make sure there is a cover over the tube of the receiving box. This is to protect the phototube for external light until taking measurements.
3. Plug in the photoelectric apparatus into the AC outlet and turn on the apparatus. Let it warm up for about five minutes. The currents you are measuring are very small and you want the equipment to come to equilibrium to minimize noise currents.
4. The device has a built-in variable voltage source and meter.
5. The device has a built-in ammeter on the top that measures in nano-amps.
6. Move the light to the 25 cm mark.
7. The apparatus comes with a set of five filters. For each filter, you will find the decelerating voltage at which the current becomes zero. Take data for voltages around that value. (Use the most sensitive current setting)

The remaining steps should be completed each time a new filter is used.
This lab works best when there is as little ambient light as possible in the room. Make sure all shades are closed.

8. With the cover over the photocell apparatus turn the voltage scale fully counterclockwise. Check the current reading.
9. Put the voltage direction switch to negative and the display mode to switch to “current”, and the current multiplier at “x 0.001”.
10. Insert the red filter.

11. Turn the **VOLTAGE** knob coarsely and observe the change in current with change in voltage. Using the fine adjustment, adjust the accelerating voltage to decrease the photocurrent to zero. *Note:* The minimum value for the photocurrent might not be zero but slightly negative.

Once you've determined this point, record the voltage indicated. Record the stopping potential for zero current and slightly negative current. You will need to switch the meter between voltage and current.

12. Have your lab partner repeat the process and get an average value. *Note:* you can repeat step 11 and select a different starting point, such as .3, then .4, etc.

13. Repeat for the remaining filters.

V. CALCULATIONS

Plot V vs f.
Use the graph to evaluate h and Φ. Show your work.
Compare with theoretical values by calculating the percent difference.

VI. CONCLUSION/QUESTIONS

1. What is the longest light wavelength that will produce photoelectrons for your cathode?

2. Suppose the current drawn by your tube was 10^{-6} A when 400 nm light was incident on your metal plate.
   a. How many photoelectrons per second are ejected from the metal plate?
   b. What is the kinetic energy of the photoelectrons?

3. Calculate the amount of energy contained in a photon (a quantum of visible light) of wave length 590 nm. Suppose that a source of yellow light is sending out radiation of this single wave length at the rate of one watt. How many photons are emitted each second?