Lab #8
The Photoelectric Effect

1. Objectives

To show that the energy of photoelectrons depends on the frequency of the incident light and to determine Planck's constant.

2. Theory

The apparatus consists of a phototube in which photoelectric emission can occur. The tube is connected to a variable DC voltage source. Light from a mercury source is allowed to shine through a window of the phototube and falls on a semi-cylinder coated with potassium. This is called the ***emitter***. Along the axis of the emitter is a wire called the ***collector***. When the collector is made a few volts positive with respect to the emitter, electrons that are emitted are attracted to it and will return to the collector via an external wire (see circuit diagram), thus creating a ***photocurrent***.

The photocurrent is very small and must be amplified by a few thousand times before it can be measured by the multimeter. There is voltage control knob which allows you to vary the voltage between the emitter and the collector. As you turn the knob clockwise, you make the collector more negative, thus repelling more electrons before they can reach the collector. At one point, you will reach a point where all the photoelectrons are repelled before they can reach the collector. This point is called the ***stopping voltage***. The work done by this stopping voltage will decrease the maximum kinetic energy of the electrons leaving the emitter. The maximum kinetic energy of a photoelectron is given by:

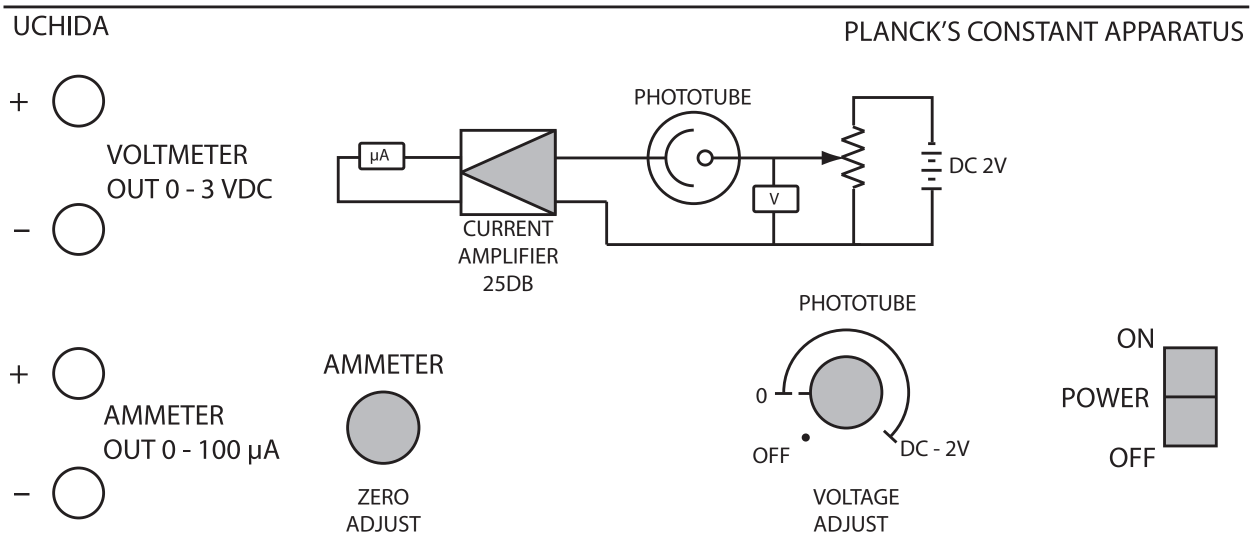
$$eV_{\text{stop}} = K_{\max} = hf - \phi$$

$$V_{\text{stop}} = \frac{hf}{e} - \frac{\phi}{e}$$

where $e = 1.6 \times 10^{-19}$ C is the charge of one electron, V_{stop} the stopping voltage (in Volts), $h = 6.626 \times 10^{-34}$ J s Planck's constant, f the frequency of incident light, and ϕ, the work function of the emitter. This equations shows that if the work function is greater than the incident photon's energy, the electron cannot escape from the metal.

In this experiment you will measure the stopping voltage as light of different frequencies fall on the phototube. Colored filters select frequencies from the mercury spectrum emitted by an intense mercury lamp.

Filter	Wavelength
V-058	579.1 nm
V-054	546.1 nm
V-Y43	435.8 nm
UV-39	385.5 nm



Schematics of the Planck's constant apparatus.

3. Procedure

a) Connect the + (red) and – (black) voltmeter leads to the + and – terminals marked on the front of the apparatus. Set the voltmeter to DCV 2 volts.

b) Do the same thing for the microammeter, am multimeter set to read DCA 200 μA.

c) Turn the filter wheel so that the desired filter covers the window of the phototube. Then put the mercury lamp in front of the filter wheel and turn it on.

d) ***Make sure that the voltage dial is set to OFF*** and then turn on the power by flipping the switch to ***ON***. There will usually be a reading on the microammeter. Set the microammeter to zero by turning the zero adjust dial until it reads 0. This step eliminates current due to electrical "noise".

e) Turn the photocell voltage dial to the ***ON*** position and ***turn the voltage up fully***. Record the current, which could vary between 0 and -0.5 μA. This is the ***reverse current***, which arises from photon liberating electrons from the collector. The meter reads this current only when all the photoelectrons from the emitter have been stopped.

f) Now reduce the voltage until you get a reading of a few microamps. This is the photocurrent, Very gently, increase the voltage again until the current reads the reverse current; do it gently, the current will go down to zero and keep going until you JUST begin to get the reverse current. Only then can you be sure that all the photoelectrons have been stopped. Be careful, it's easy to overshoot and get too large a value for the stopping voltage.

g) Repeat the previous step three (3) more times. Record the stopping voltage for each trial and calculate the mean and the standard deviation of the mean.

h) Repeat this procedure for each of the other 3 filters.

4. Analysis

a) Plot a graph of the stopping voltage vs frequency and from the slope determine Planck's constant.

b) What does the y-intercept represent?

c) What does the x-intercept represent?