Work Instruction

1.0 NAME OF THE EXPERIMENT: Studies on Photoelectric Effect.

2.0 OBJECTIVE: Determination of Planck's constant, Stopping Potential and Work Function.

4.0 PRINCIPLE: Einstein first proposed the correct explanation of photoelectric phenomenon by an extension of the quantum idea of Planck. This extension is known as Einstein's light quantum hypothesis. According to the theory of Photo electric effect, when light from an external source is incident on the cathode of a photo cell, we get a photo current recorded by the ammeter shown in the circuit diagram bellow. Here the applied voltage opposes electron emission from the cathode of the photo cell and this electric field opposes electron towards the anode of the photocell. The photo current decreases as the voltage V increases and at a particular value of this voltage, known as stopping potential (V_s), the current becomes zero. Stopping potential (V_s) increases with the frequency (v) of the incident light that causes the emission of photoelectrons from the cathode. The dependence of V_s upon v is expressed as:

$$eV_s = hv - W \quad (1)$$

where, $e \rightarrow$ electronic charge = 1.6×10^{-19} Coulomb.

$V_s \rightarrow$ Stopping Potential.

$h \rightarrow$ Planck's constant

$v \rightarrow$ frequency of incident light.

$W \rightarrow$ work function of the metal of the cathode.

There is a minimum frequency ν_0 below which no photoelectric emission occurs from a given metal. This particular frequency is known as threshold frequency. W can be defined as in term of threshold frequency as: $W = h\nu_0$ (2)

The frequency of the light can be written as: $\nu = \frac{c}{\lambda}$ (3)

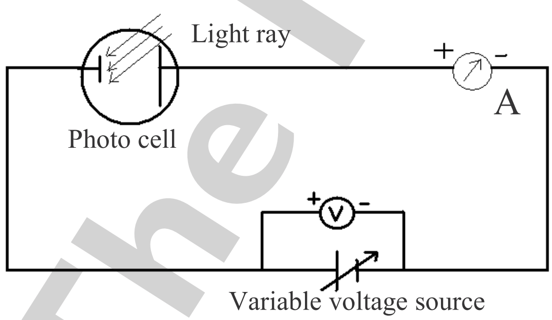
where, $c \rightarrow$ velocity of light in free space = 3×10^8 m/sec

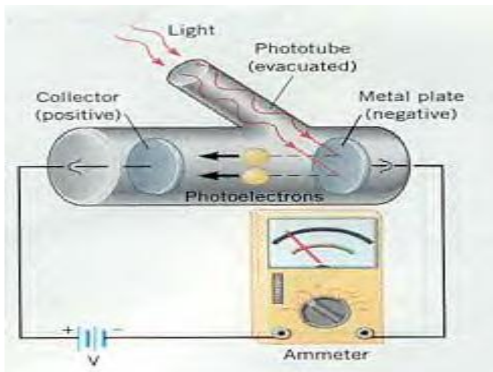
$\lambda \rightarrow$ wavelength of light (in meter)

If ν_m is the maximum velocity attained by the photo electrons, then from eqn. (1) we get

$$\frac{1}{2}mv_m^2 = eV_s = h\nu - h\nu_o \quad (4)$$

If we plot V_s versus v, we get a straight line from which we can estimate ν_0 and knowing ν_0 we determine the Planck's constant h from eqn. (4).





5.0 Apparatus required: variable voltage source, volt meter, ammeter, light Source, colour filter, photo cell, etc

6.0 PROCEDURE: (Don't write the procedure in your Lab. Copy)

- Connect the photocell with the Planck constant set up that contains variable voltage source, voltmeter (V), and miliameter (mA).

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- Switch on the set up. It will show some current in the mA. Using the zero-adjustment knob, make the current zero. Verify whether the reverse bias voltage is at zero.

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- Switch on the light source. The light is incident on the photocell. Note that the distance between the light source and photocell remains constant throughout the experiment.

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- Place the color filters in front of the source one by one.

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- When the light is incident on the photocell, the electrons emit and they are attracted by the anode. We get a current shown in the mA. Increase the reverse voltage of the variable voltage source. It reduces the current. In the Table – 1 note down the voltage and current at regular interval for each color filter until the current becomes zero. The voltage for which the current is zero is known as stopping potential.

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- Draw the graph plotting the frequency of the filter along abscissa (x-axis) and stopping potential along vertices (y-axis).

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- From the graph determine the slope, intersect on x -axis and intersect on y –axis. There from calculate the Planck's constant as indicated in the Table – 2.

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- Now repeat the procedure Tab-1 for two different colors by varying the intensity for both and record the data in Tab-3.

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- Draw a graph as V vs. I for different colors, each with different intensities to show that the stoping potential does not depend upon incident intensity.

6.0 Tabulation:

TABLE-1

To find the stopping potential:

No Of Obs.	Red filter Frequency of filter: Red =		Yellow filter Frequency of filter: yellow =		Green filter Frequency of filter: green=		Blue filter Frequency of filter: blue=		Orange filter Frequency of filter: Orange=	
	Voltage (mV)	Current (mA)	Voltage (mV)	Current (mA)	Voltage (mV)	Voltage (mV)	Voltage (mV)	Current (mA)	Voltage (mV)	Current (mA)
1										
2										
3										
4										
5										
6										

TABLE-2

Determination of Plank's constant (h) and Work function (W)

Value of intersect on x-axis Threshold frequency ν_o (Hz)	Value of the slope h/e (J-s/coulomb)	Value of h $= e \times$ slope (J-s)	Intersect on y-axis $\frac{h\nu_o}{e}$ (V)	Value of h $= \frac{e}{\nu_o} \times$ intersect (J-s)	Mean value of the h (J-s)	Value of the Work function (W) (eV)

TABLE-3

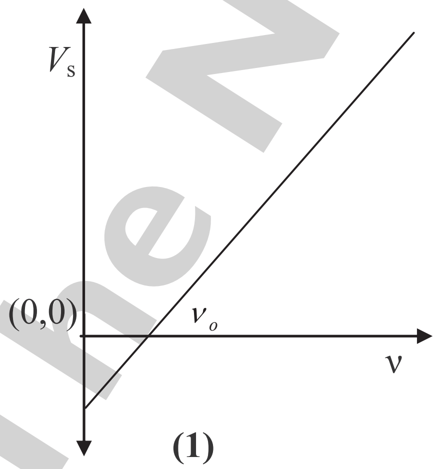
To find the intensity and frequency variation of stopping potential:

No Of Obs.	Red filter Frequency of filter: Red =				Blue filter Frequency of filter: yellow =			
	High Intensity		Low intensity		High Intensity		Low intensity	
	Voltage (mV)	Current (mA)	Voltage (mV)	Current (mA)	Voltage (mV)	Current (mA)	Voltage (mV)	Current (mA)
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

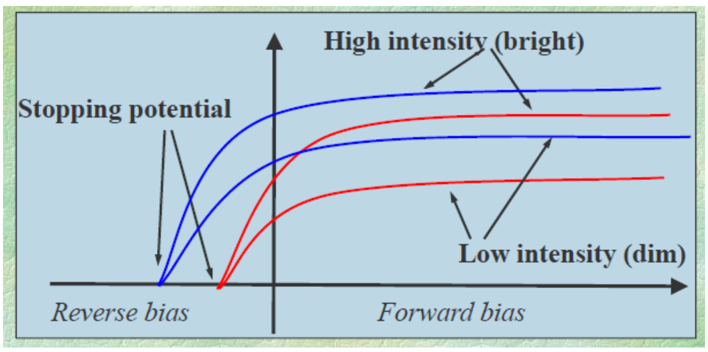
Graph: 1. We have the working formula as $eV_s = h(\nu - \nu_o)$ Or, $V_s = \frac{h\nu}{e} - \frac{h\nu_o}{e}$

Now a graph will be plotted between stopping potential (V_s) (along y-axis) vs. ν (along x–axis)

2. A graph will be plotted between potential (V) (along x-axis) vs. current I (along y–axis) form Tab-3



(1)



(2)

7.0 Error calculation:

We have the formula for the Determination of Plank's constant as $eV_s = h(\nu - \nu_o)$

$$\text{or, } h = \frac{eV_s}{\nu - \nu_o}$$

Where, e = electronic charge,
Vs = stopping potential.
ν = frequency of the filter,
ν_0 = Threshold frequency.

Taking ln in both sides we get, $\ln h = \ln e + \ln V_s - \ln(\nu - \nu_0)$

Differentiating we get for maximum proportional error,

$$\frac{\delta h}{h} = \frac{\delta V_s}{V_s}$$

(Rest of the term will be zero as e and υ are constants and differentiation of these terms will vanish)

δV_s = error in measuring V_s

= smallest division of the voltmeter. (Because probability of making error is in one side)

Hence, the percentage error is $\left(\frac{\partial h}{h} \text{ x } 100\right)$ %

8.0 Discussion:

You have to write all the difficulties you faced during the experiment and their remedies. Also you have to mention some way out that one should adopt during the practical to have a better result.

Reference

1) Physics _ Halliday and Resnick
2) Modern Physics – Kenneth Krane
3) Introduction to Modern Physics – Richtmayer, Kennard and Cooper
4) Modern Physics - Beiser

9.0 Applications:

The Photoelectric effect has numerous applications, for example night vision devices take advantage of the effect. Photons entering the device strike a plate which causes electrons to be emitted, these pass through a disk consisting of millions of channels, the current through these are amplified and directed towards a fluorescent screen which glows when electrons hit it. Image converters, image intensifiers, television camera tubes, and image storage tubes also take advantage of the point-by-point emission of the photocathode. In these devices an optical image incident on a semitransparent photocathode is used to transform the light image into an "electron image." The electrons released by each element of the photoemitter are focused by an electron-optical device onto a fluorescent screen, reconverting it in the process again into an optical image.

Popular three applications are-1. Night Vision Device 2. Smoke Detector 3. Solar panels