

**MANUAL FOR
STUDYING
PHOTOELECTRIC
EFFECT USING A
PHOTOTUBE**

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AIM

Study of Photoelectric Effect by studying:

- i) Photocurrent versus intensity and wavelength of light;
- ii) Maximum energy of photoelectrons versus frequency of light
- iii) Planck's Constant determination

APPARATUS REQUIRED

Photoelectric Setup
Vacuum Phototube
Light source
Different colour filters

THEORY

In the photoelectric effect, light strikes a material, causing electrons to be emitted. The classical wave model predicted that as the intensity of incident light was increased, the amplitude and thus the energy of the wave will also increase. This will then cause more energetic photoelectrons to be emitted. The new quantum theory, however, predicted that higher frequency light would produce higher energy photoelectrons, independent of intensity, while increased intensity would only increase the number of electrons emitted (or the photoelectric current). In the early 1900's several investigators found that the kinetic energy of the photoelectrons was dependent on the wavelength, or frequency, and independent of intensity, while the magnitude of the photoelectric current, or number of electrons was dependent on the intensity as predicted by the quantum model. Einstein applied Planck's theory and explained the photoelectric effect in terms of the quantum model using his famous equation, for which he received the Nobel Prize in 1921:

$$E = hv = K_{E_{\max}} + W_0 \quad (1)$$

Where, ' $K_{E_{\max}}$ ' is the maximum kinetic energy of the emitted photoelectrons
' W_0 ' is the energy needed to remove them from the surface of the material (the work function) 'E' is the energy supplied by the quantum of light known as photons

FORMULA USED

$$h = \frac{e(V_2 - V_1) \lambda_1 \lambda_2}{c(\lambda_1 - \lambda_2)} \quad (2)$$

where,

- e = Electronic charge (1.602×10^{-19} C)
- V_2 = Stopping potential corresponding to wave length 2
- V_1 = Stopping potential corresponding to wave length 1
- λ_1 = Wavelength 1 of coloured filter
- λ_2 = Wavelength 2 of coloured filter
- c = Velocity of light (3×10^8 m/s)

We know, $K_{E_{\max}} = hv - \phi$

$$\text{Also, } K_{E_{\max}} = eVs \quad (3)$$

B. FOR INTENSITY vs. PHOTOCURRENT READINGS

1. Switch on the apparatus and the light bulb such that the light is allowed to fall on the photocell.
2. Keeping the filter holder fixed at 0cm, adjust the distance between phototube and light source by sliding the phototube.
3. Take down the readings for the position of the phototube using the scale and pointer provided and also the corresponding photocurrent values from the microammeter.
4. Change the filters to get different wavelengths and repeat steps 2 and 3.
5. Plot the graph between intensity [which is proportional to $1/(\text{distance})^2$] and photocurrent.
6. Intensity measurement can also be done directly using a Lux meter (this is optional and is provided on request).

OBSERVATION TABLE

Wave length of Orange filter, $\lambda_1 = 6110 \times 10^{-10} \pm 2\%$ meter
 Wave length of Yellow filter, $\lambda_2 = 5800 \times 10^{-10} \pm 2\%$ meter
 Wave length of Blue filter, $\lambda_3 = 5240 \times 10^{-10} \pm 2\%$ meter
 Charge of electron, $e = 1.6 \times 10^{-19}$ coulombs
 Velocity of light, $c = 3 \times 10^8$ m/sec

TABLE 1: WAVELENGTH vs. PHOTOCURRENT

Sl. No.	Filters	Wavelength ($\times 10^{-10}$ m)	Current Readings (μ A)	Stopping Potential V_s (V)	Planck's constant 'h' ($\times 10^{-34}$ Js)
1.	Orange	6110	0.74	-0.230	6.706 (For Orange and Yellow)
2.	Yellow	5800	1.48	-0.340	6.657 (For Yellow and Blue)
3.	Blue	5240	2.28	-0.570	6.673 (For Orange and Blue)

TABLE 2: INTENSITY vs. PHOTOCURRENT

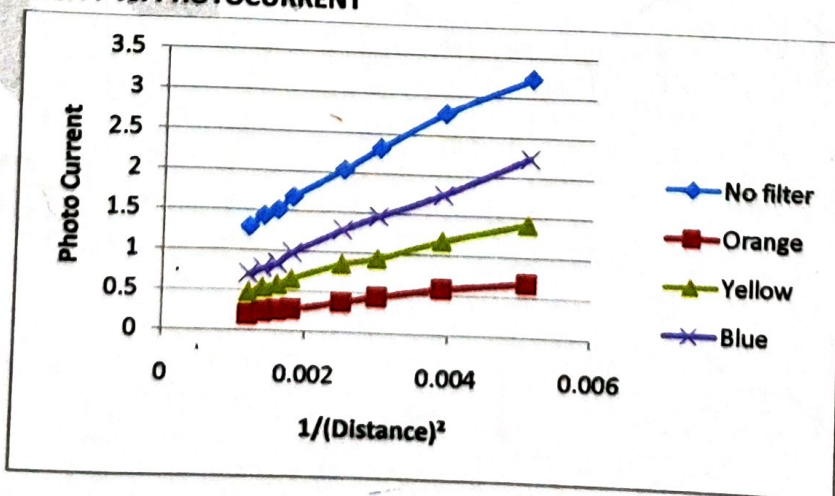
Distance between '0' of scale and bulb filament = 8cm
 Keep bulb voltage at maximum and current at 250 mA

Sl.No.	Position of Filter Holder, X (cm)	Position of Phototube, Y (cm)	Position of phototube from filament, $r=(Y+8)$ (cm)	$1/r^2$ (in cm^{-2})	Photocurrent (μA)			
					Without filter	Orange	Yellow	Blue
1.	0	6	14	0.0051				
2.	0	8	16	0.0039	3.24	0.68	1.42	2.24
3.	0	10	18	0.003	2.78	0.58	1.18	1.76
4.	0	12	20	0.0025	2.32	0.46	0.94	1.46
5.	0	15	23	0.0018	2.04	0.38	0.86	1.28
6.	0	17	25	0.0016	1.68	0.28	0.66	0.98
7.	0	18	26	0.0014	1.52	0.26	0.58	0.84
8.	0	20	28	0.0012	1.44	0.24	0.54	0.78
					1.30	0.20	0.48	0.70

TABLE 3: INTENSITY vs. PHOTOCURRENT USING LUX METER

Sl.No.	Position of Filter Holder, X (cm)	Position of Phototube, Y (cm)	Position of phototube from filament, $r=(Y+8)$ (cm)	Intensity (Lux)			
				No Filter	Orange	Green	Blue
1.	0	6	14				
2.	0	8	16	3720	1500	590	390
3.	0	10	18	2820	1260	510	320
4.	0	12	20	2180	910	390	250
5.	0	15	23	1920	810	320	220
6.	0	17	25	1520	670	280	180
				1330	540	220	140

GRAPH FOR INTENSITY vs. PHOTOCURRENT



CALCULATIONS

1. TO FIND PLANCK'S CONSTANT:

For Orange and Yellow Filters (Sl. No.1 & 2) from Table 1:

Using Eq. 2 we have,

$$h = \frac{e(V_2 - V_1) \lambda_1 \lambda_2}{c(\lambda_1 - \lambda_2)}$$

$$\text{or, } h = [1.6 \times 10^{-19} \times (0.340 - 0.230) \times 6110 \times 10^{-10} \times 5800 \times 10^{-10}] / [3 \times 10^8 \times (6110 \times 10^{-10} - 5800 \times 10^{-10})] \text{ Js}$$
$$= 6237.088 \times 10^{-36} / 930 \times 10^{-2} \text{ Js}$$

Therefore, $h = 6.706 \times 10^{-34} \text{ Js}$

[Similarly do all calculations for data as shown in Table 1]

2. TO FIND MAXIMUM KINETIC ENERGY:

From eq. (3) we have, $KE_{\text{max}} = e|Vs|$

For Orange Filter (6110Å), $KE_{\text{max}} = 1.6 \times 10^{-19} \times 0.230 = 0.23 \text{ eV}$

For Yellow Filter (5750Å), $KE_{\text{max}} = 1.6 \times 10^{-19} \times 0.340 = 0.34 \text{ eV}$

For Blue Filter (5240Å), $KE_{\text{max}} = 1.6 \times 10^{-19} \times 0.570 = 0.57 \text{ eV}$

RESULT

We have obtained excellent results for Planck's Constant which are very near to the standard value of Planck's constant which is 6.626×10^{-34} , for different coloured filters.

Also, the maximum kinetic energy of the photoelectrons increases with frequency as seen in the calculations above.

Thus, we conclude that the experiment using Photoelectric Effect with the help of Photocell has been successfully conducted.

ACCESSORIES

SL. NO.	ITEMS	QUANTITY
1	Planck's Constant Setup	01
2	Black Box containing Photocell and Filter Holder	01
3	Light Source	01
4	Coloured Filters	03
5	Patch Cords (2mm-4mm)	02
7	Manual	01