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M. Sc. 2nd Semester **General Lab – 09**

STUDY THE PHOTOCELL AND VERIFY INVERSE SQUARE LAW. HENCE DETERMINE PLANCK'S CONSTANT.

APPARATUS REQUIRED

1. Experimental set up for measurement of Planck's constant
2. Filters of different colors (Red, Green, Blue, Yellow)

THEORY

Most of the metals under influence of radiation, emit electrons. This phenomenon is termed as photoelectric emission. The detailed study of it has shown:

1. That the emission process depends strongly on frequency of radiation.
2. For each metal there exists a critical frequency such that light of lower frequency is unable to liberate electrons, while light of higher frequency always does.
3. The emission of electron occurs within a very short time interval after arrival of the radiation and number of electrons is strictly proportional to the intensity of this radiation.

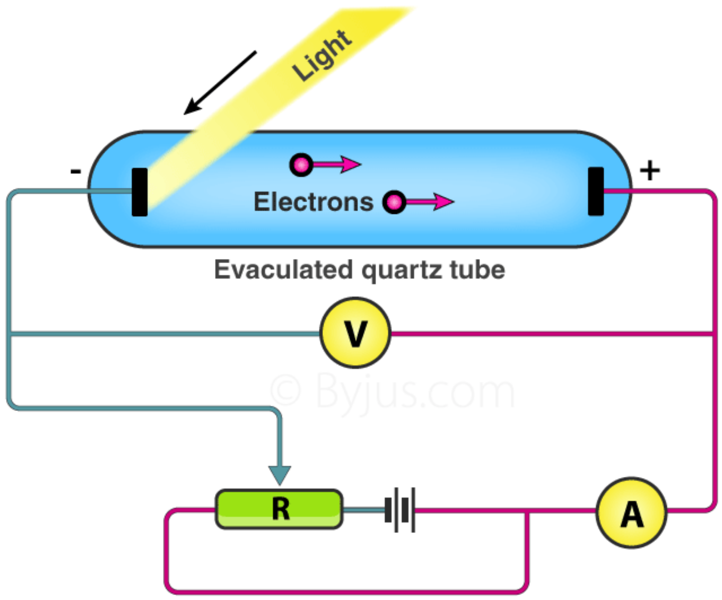

Figure 1: Experimental set up Photoelectric Effect

The experimental facts given above are among the strongest evidence that the electromagnetic field is quantified and the field consists of quanta of energy $E = h\upsilon$ where υ is the frequency of the radiation and h is the Planck's constant. These quanta are called photons. Further it is assumed that electrons are bound inside the metal surface with an energy $e\phi$, where ϕ is called the work function. It then follows that if the frequency of the light is such that $h\upsilon > e\phi$, it will be possible to eject photoelectron, while if $h\upsilon < e\phi$ it would be impossible.

In the former case, the excess energy of photon appears as kinetic energy of the electron, so that:

$$h\upsilon = e\phi + \frac{1}{2}mv^2 \tag{1}$$

$$or, \frac{1}{2}mv^2 = h\upsilon - e\phi \tag{2}$$

which is the famous photoelectric equation formulated by Einstein.

If we apply a retarding potential V_s so as to stop the photo electrons completely, it is known as stopping potential V_s. At that instant:

$$\frac{1}{2}mv^2 = eV_s \tag{3}$$

From equation (2) and (3),

$$eV_s = h\upsilon - e\phi \tag{4}$$

$$\therefore V_s = \frac{h}{e}\upsilon - \phi \tag{5}$$

So, when we plot a graph V_s as a function of υ, the slope of the straight-line yields $\frac{h}{e}$ and the intercept of extrapolated point at $\upsilon = 0$ gives work function ϕ.

To verify inverse square law of radiation using a photoelectric cell.

If L is the luminous intensity of an electric lamp and E is the illuminiscence (intensity of illumination) at point r from it, then according to inverse square law.

$$E \propto \frac{L}{r^2} \tag{6}$$

If this light is allowed to fall on the cathode of a photo-electric cell, then the photo-electric current (I) would be proportional to E.

$$I \propto E \tag{7}$$

From equation (6) and (7) graph between $\frac{1}{r^2}$ and I is a straight line, which verify the inverse square law of radiation.

OBSERVATION

Table 1: For the determination of Planck's constant (h).

SN	**Filters**	υ **(Hz)** $\times 10^{14}$	**Stopping Voltage (V_s in Volts) at d = 30 cm**
1.	Red (635 nm)	4.72	0.28
2.	Yellow I (570 nm)	5.26	0.49
3.	Yellow II (540 nm)	5.56	0.64
4.	Green (500 nm)	6.00	0.82
5.	Blue (460 nm)	6.50	0.99

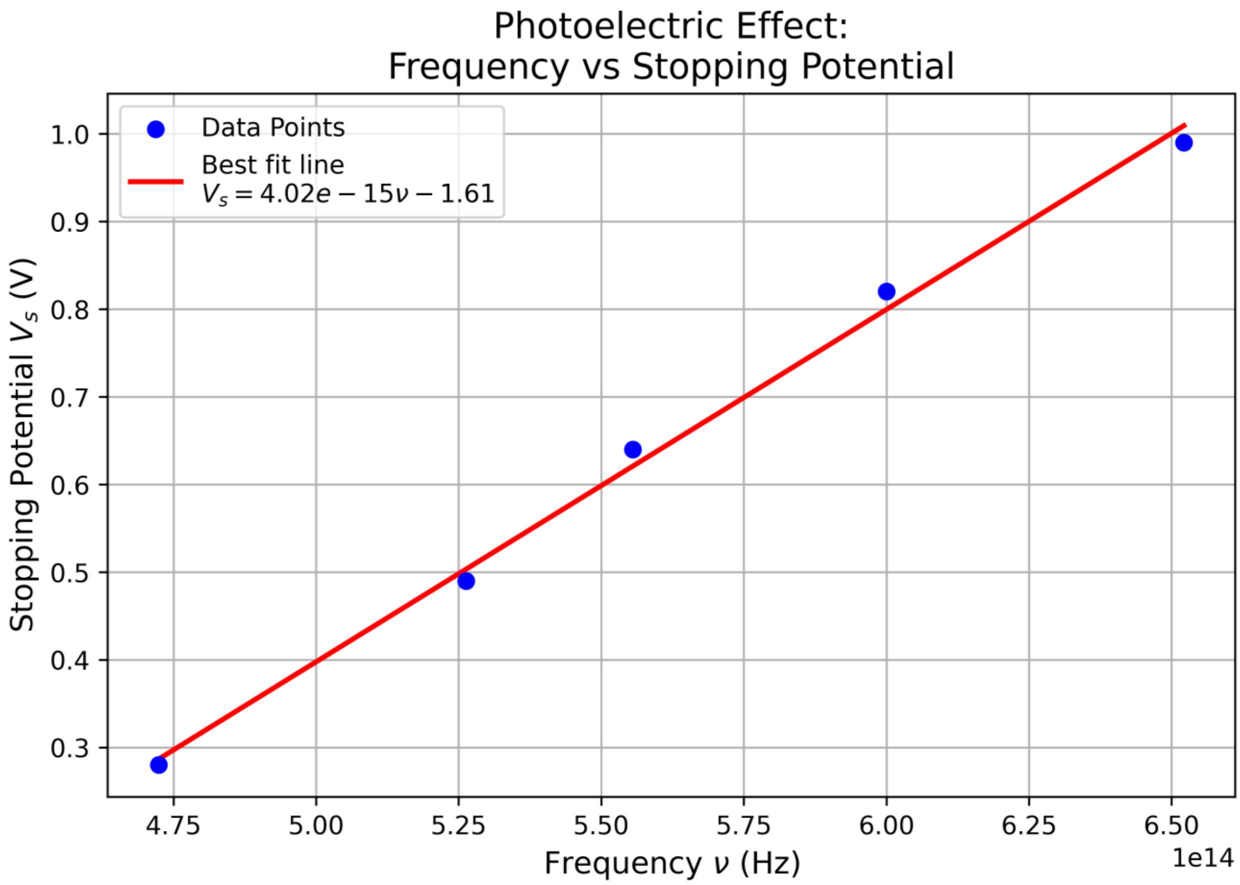

Figure 2: Frequency vs stopping potential and best fit line.

Table 2: For verification of inverse square law

SN	Distance in cm (r)	$\frac{1}{r^2} \times 10^3$ (cm^{-2})	Current (μA)			
			Blue	Green	Yellow	Red
1.	16	3.906	5.13	4.49	2.98	1.16
2.	18	3.086	4.45	3.91	2.54	0.99
3.	20	2.500	3.54	3.11	2.03	0.76
4.	22	2.066	2.86	2.44	1.61	0.61
5.	24	1.736	2.40	2.10	1.36	0.51
6.	26	1.479	2.10	1.81	1.19	0.44
7.	28	1.276	1.87	1.60	1.04	0.39
8.	30	1.111	1.67	1.42	0.94	0.35
9.	32	0.977	1.50	1.29	0.85	0.31
10.	34	0.865	1.38	1.17	0.78	0.29
11.	36	0.772	1.28	1.07	0.73	0.26
12.	38	0.693	1.19	1.03	0.68	0.24
13.	40	0.625	1.11	0.96	0.63	0.23

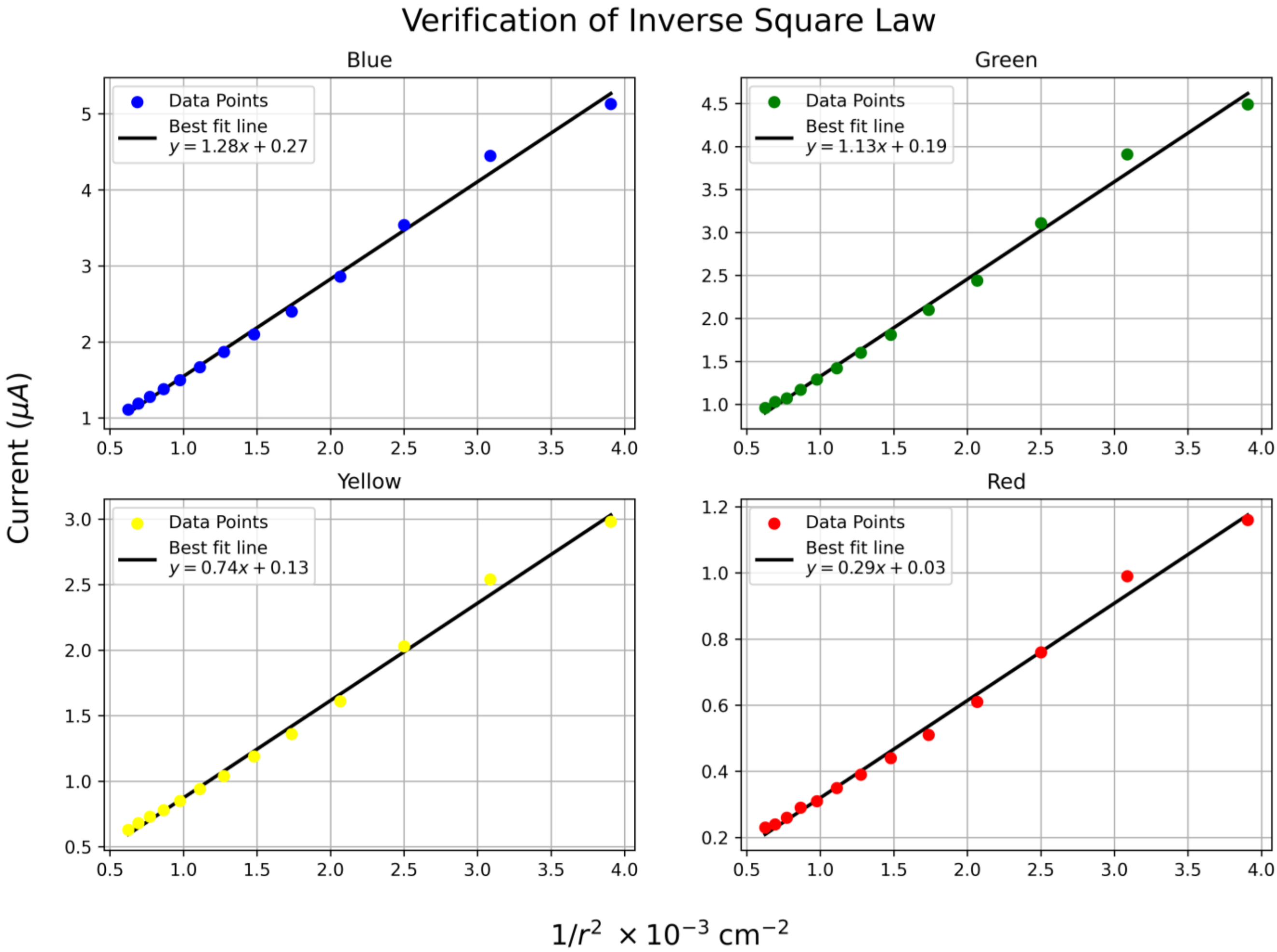

Figure 3: Inverse square of distance vs current and best fir graph.

CALCULATION

From figure 1,

Slope of best fit line = $4.02 \times 10^{-15}\ Vs$

From equation (5),

Slope = $\frac{h}{e}$

$\therefore h = e \cdot m = 1.6 \times 10^{-19} \times 4.02 \times 10^{-15} = 6.43 \times 10^{-34}\ Js$

ERROR ANALYSIS

Comparing $V_s = \frac{h}{e}\upsilon - \phi$ with $y = mx + c$

$y = V_s$ and $x = \upsilon$

Table 3: Error analysis for Planck's constant (h).

SN	$x \times 10^{14}$	y	$\hat{y} = mx + c$	$(x - \bar{x})^2 \times 10^{28}$	$d_i^2 = (y - \hat{y})^2$
1.	4.72	0.28	1.90	0.7885	2.6161
2.	5.26	0.49	2.11	0.1211	2.6391
3.	5.56	0.64	2.24	0.0023	2.5444

4.	6	0.82	2.41	0.1537	2.5345
5.	6.5	0.99	2.61	0.7957	2.6341
				D=$\sum(x-\bar{x})^2$ =1.8613	**$\sum d_i^2 =$ 12.9682**

Mean $\bar{x} = 5.61 \times 10^{14}$

$$\therefore \Delta m = \sqrt{\left(\frac{\sum d_i^2}{n-2}\right) \times \frac{1}{D}} = \sqrt{\frac{12.9682}{5-2} \times \frac{1}{1.8613 \times 10^{28}}} = 1.52 \times 10^{-14}$$

So,

$\Delta h = \Delta m \times e = 1.52 \times 10^{-14} \times 1.6 \times 10^{-19} = 0.24 \times 10^{-34}\, Js$

$\therefore h = (6.43 \pm 0.24) \times 10^{-34}\, Js$

RESULT

Hence, the value of Planck's constant is determined to be $(6.43 \pm 0.24) \times 10^{-34}\, Js$.

CONCLUSION

The experiment to study the photocell and verify the inverse square law demonstrates the relationship between the intensity of light and the distance from the source. The results confirm that the intensity of light decreases proportionally to the square of the distance, validating the inverse square law.

By analyzing the photoelectric effect using the photocell, the threshold frequency for the material was determined, and Planck's constant was calculated. The experimentally obtained value of Planck's constant is $(6.43 \pm 0.24) \times 10^{-34}\, Js$.

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