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WAVELENGTHS OF SUBSTANCES BY PHOTOELECTRIC EFFECT

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Abstract

The principle of photoelectric effect is used to determine the unknown wavelengths of various substances. The values of wavelengths are manipulated from the standard graph drawn for known colour filters. Stopping voltage, the minimum reverse potential needed for electrons to reach the collector in the experimental setup of photoelectric effect, is measured for colour filters and various substances. Inverse square law is verified by measuring the photocurrent for various distances between the lamp and the photocell and for various concentrations of the substances.

Keywords: *Wavelength, photoelectric effect, stopping voltage, inverse square law*

1. Introduction

Photoelectric effect is the emission of electrons from a metallic surface, when it is illuminated by a light of suitable wavelength. The emitted electrons are known as the photoelectrons and the current they constitute is called as photocurrent [1]. In 1887, Heinrich Hertz noticed a spark between the two metallic balls, when a high frequency radiation is incident on it. This is called Photoelectric effect. But this effect was explained by Albert Einstein in 1905 using Max Planck's quantum theory of light. Photoelectric effect is a very useful phenomenon and its importance can be understood from its uses. Photoelectric current is very useful in many solar light

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sensitive diodes and solar power such as solar cell. One of the major uses of photoelectric effect current is in photomultipliers.

The purpose of the present paper is to determine the unknown wavelengths of the substances by photoelectric effect and also to prove that it satisfies the inverse square law.

2. Model and Formulation

Photoelectric effect is experimented using a device shown in Figure 1. A negative electrode and a positive electrode are placed inside an evacuated glass tube. The monochromatic light of known frequency is incident on the target metal. The incoming light ejects photoelectrons from a target metal. The photoelectrons are then attracted to the collector. The result is a photoelectric current flow in the circuit which can be measured with an ammeter. When the positive voltage is increased, more photoelectrons reach the collector; hence the photoelectric current also increases. If the positive voltage becomes sufficiently large, the photoelectric current reaches a maximum constant value I_m, called saturation current.

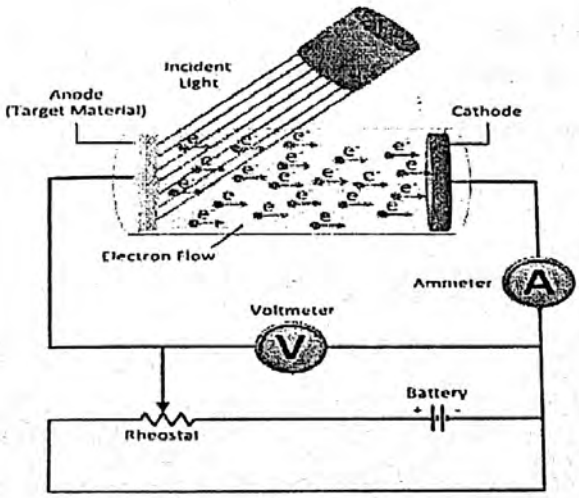

Figure 1 - Photoelectric Effect Experiment

If the positive voltage is gradually decreased, the photoelectric current will decrease slowly. Even at zero voltage, there are still some photoelectrons with sufficient energy to reach the collector and the photoelectric current flow is I_0. If the reverse voltage is small enough, the fastest electrons will still reach the collector and there will be the photoelectric current in the circuit. If the reverse voltage

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increased, a point is reached, where the photoelectric current reaches zero-no photoelectrons have sufficient kinetic energy to reach the collector. This reverse voltage is called the Stopping potential V_s. V_s is defined as the minimum reverse potential needed for electrons to reaching the collector. The figure 2 shows the variation of photocurrent as a function of voltage.

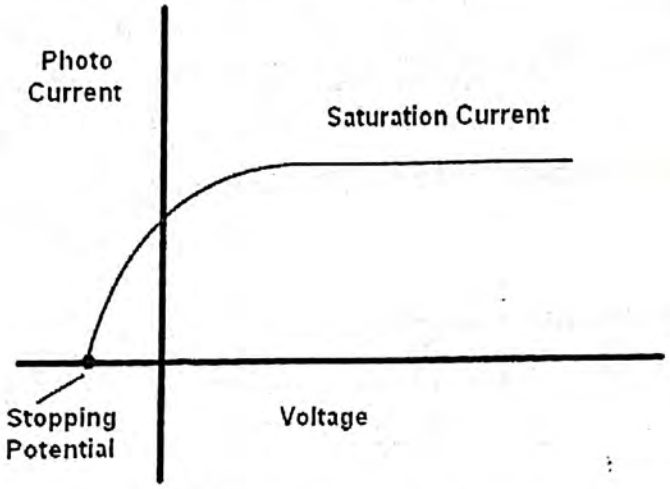

Figure 2 – Photocurrent Vs Voltage

2.1 Einstein theory of Photoelectric effect

By applying Plank's hypothesis, Einstein proposed that absorption of light of frequency υ by electrons in the metal takes place as discrete quanta of energy hυ. If hυ is the energy needed for an electron to escape from the surface of the metal, the electrons absorbing such quanta may escape with energies up to a maximum value

$$E_{max} = eV_s = h\upsilon - W_0$$

where, the work function of a metal, $W_0 = h\upsilon = hc/\lambda_0$, λ_0 is threshold wavelength [2]. According to Einstein's theory, an electron is ejected/emitted from the target metal by a collision with a single photon. In this process, all the photon energy is transferred to the electron on the surface of metal target. Since electrons are held in the metal by attractive forces, some minimum energy W_0 is required just enough to get an electron out through the surface. (i) If $h\upsilon < W_0$, then the photon will not have enough energy to eject any electron at all. (ii) If $h\upsilon \geq W_0$, then electron will be ejected and energy will be conserved. Figure 3 describes the behaviour of stopping potential with respect to frequency.

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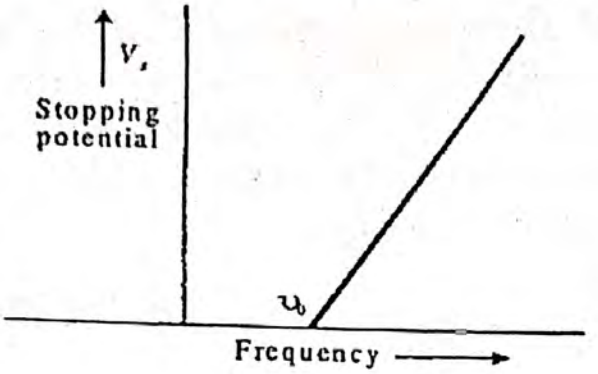

Figure 3 – Stopping Potential Vs Frequency

2.2 Inverse square law

Inverse square law states that a specified physical quantity or intensity is inversely proportional to the square of the distance from the source of that physical quantity [3]. In equation form, Intensity $\alpha \frac{1}{\text{distance}^2}$

2.3 Experimental Procedure

Experimental setup for photoelectric effect is shown in Figure 4. Colour filters have unique wavelength and hence frequency. Red, Yellow I, Yellow II, Green and Blue colour filters are used in the experiment.

Initially, the Red filter is inserted in the drawtube, the light wave is allowed on the filter and then the stopping voltage is noted. The procedure is repeated for filters of other colours. A standard graph is plotted between the known frequency of the colour filters and the measured stopping voltage.

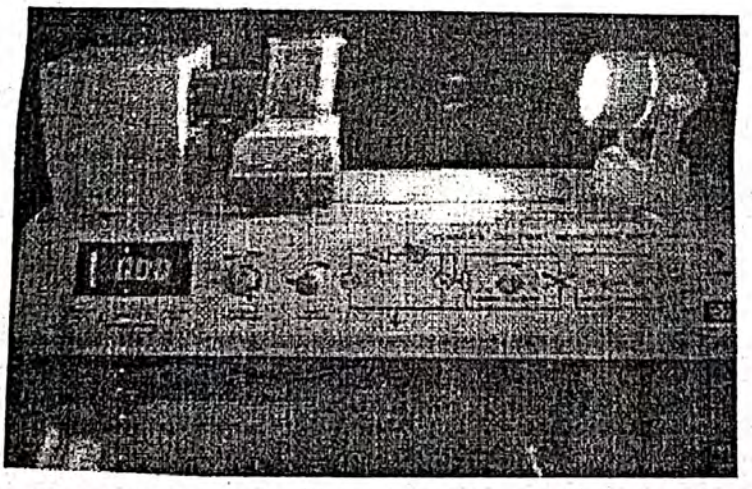

Figure 4 - Experimental setup for Photoelectric effect

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Similarly, the stopping voltage for various solutions such as Water, Oil, Copper sulphate, Nickel chloride, Potassium chromate, Potassium dichromate, Methyl orange, Ferric chloride, Ammonium chloride and Ferrous sulphate of known concentrations are measured. From the standard graph, the frequencies of the various solutions are manipulated according to their stopping voltage V_s. The wavelengths of the solutions are calculated from the corresponding frequency as $\lambda = c/\upsilon$. To prove that the photoelectric effect satisfies inverse square law; place a solution in front of the photoelectric cell. Keeping the voltage and the position of the photocell fixed, photocurrent is measured for various positions(r) of lamp from the photocell for different solutions with different concentration. A graph between $1/r^2$ and photocurrent is plotted.

3. Results and Discussion

The stopping voltages measured for various colour filters are given in Table 1.

Table 1 - Stopping voltages for various colour filters

Filters	Frequency (υ) 10^{14} x sec^{-1}	Stopping Voltage (V_s) Volt
Red	4.72	-0.37
Yellow I	5.13	-0.60
Yellow II	5.56	-0.74
Green	6.00	-0.94
Blue	6.50	-1.18

Figure 5 shows the standard graph between the frequency and stopping voltage for different colour filters.

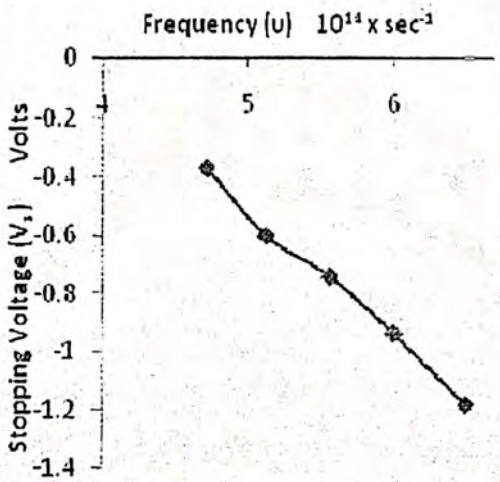

Figure 5 - Stopping voltage for various colour filters

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As the frequency increases, the stopping (reverse) voltage increases, indicates that more minimum reverse potential is needed for electrons to re the collector. The unknown wavelengths of the different solutions, determined the standard graph, are given in Table 2.

Figures 6 and 7 show the variation of photocurrent as a function of d between the photocell and light lamp for various solutions. The photoc increases with the decrease of the distance between the photocell and light When the photocurrent is plotted against $1/r^2$, there is a straight line for all sol which proves the inverse square law.

Table 2 - Wavelength of the various solutions determined by PEE

S.No.	Substances	Stopping voltage (V_s) Volt	Frequency (υ) 10^{14} x sec^{-1}	Wavelen Å
1.	Copper sulphate	-0.99	6.2	4838
2.	Nickel chloride	-0.77	5.6	5357
3.	Potassium chromate	-0.56	5.1	5882
4.	Potassium dichromate	-0.48	4.7	6382
5.	Methyl orange	-0.42	4.6	6521
6.	Ferric chloride	-0.54	4.9	6122
7.	Sodium chloride	-0.93	6.1	4918
8.	Ammonium chloride	-0.93	6.1	4918
9.	Water	-0.91	6	5000
10.	Oil	-0.89	5.9	5084
11.	Ferrous sulphate	-0.72	5.5	5454

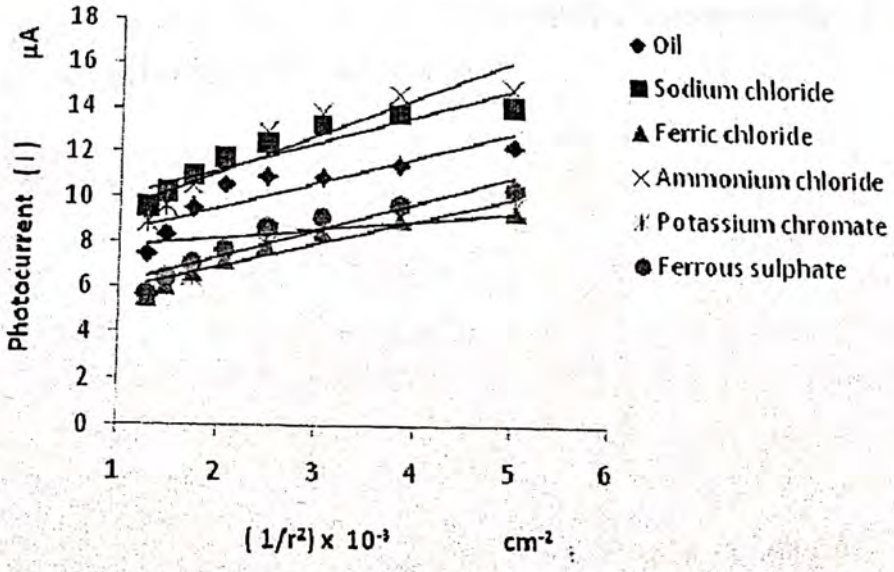

Figure 6 - Variation of photocurrent as a function of distance for different so

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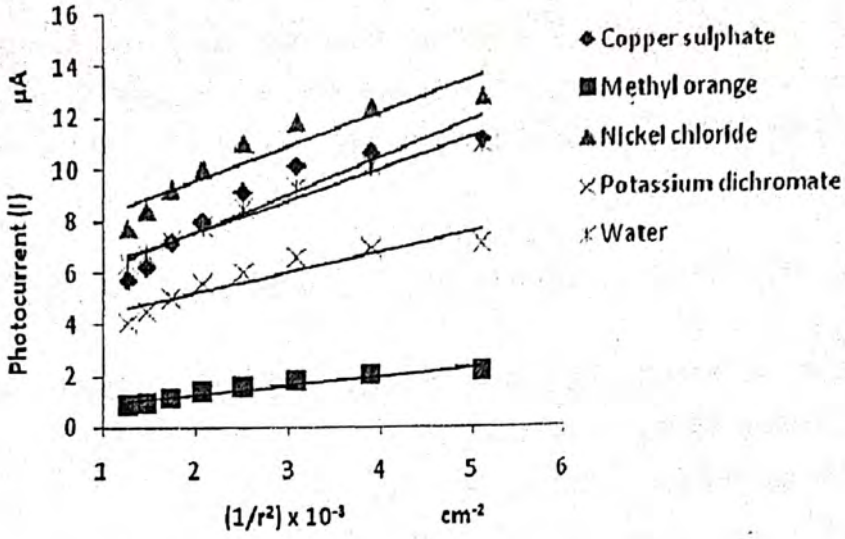

Figure 7 - Variation of photocurrent as a function of distance for different solutions

The concentrations of potassium dichromate and copper sulphate are varied and the photocurrent is measured for various distances between the photocell and light lamp. Inverse square law is again proved for various concentrations of potassium dichromate as shown in Figure 8. As the concentration decreases, the mobility of ions will increase, which results in the increase of photocurrent.

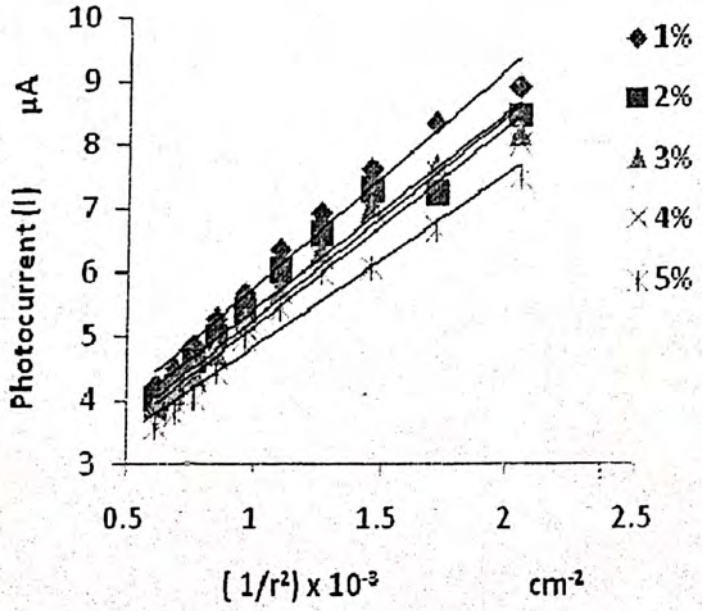

Figure 8 - Photocurrent Vs $1/r^2$ for various concentrations of Potassium dichromate

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4. Conclusion

The unknown wavelengths of various substances are determined by the photoelectric effect. The inverse square law i.e the photocurrent is inversely proportional to r^2, is verified for various solutions with different concentrations.

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