UNIVERSITY OF WOLLONGONG IN DUBAI

LAB REPORT 9

PHOTOELECTRIC EFFECT

Subject: PHYS143 (DB123) Physics for Engineers.

Group Members:

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EXPERIMENT 1

Purpose

The purpose of this experiment is to find Planck's constant by studying the photoelectric effect where electrons are emitted from a metal surface when it's exposed to light of a certain frequency. By measuring the stopping voltage of electrons emitted from a metal surface illuminated by various frequencies of light, we can calculate the relationship between stopping potential and light frequency, which will help us find Planck's constant

Hypothesis

It is expected that the stopping voltage and the frequency of incident light are directly related, meaning as frequency increases, stopping potential decreases due to higher energy of the light. It is also expected that when the wavelength increases, the stopping potential decreases. Hence the value of Planck's constant can be found precisely using the correct formulas.

Materials used

- Computer
- Photoelectric Effect Apparatus (which consisted of):
    - Ammeter
    - Voltmeter
    - Power switch
    - Current calibration
    - Voltage adjust
    - Current range switch
    - Voltage range switch

Procedure

1) Set up the experiment by aiming the light source at the wavelength.
2) Connect the power for the mercury lamp to the lamp and connect it to the computer to obtain the stoppage voltage values. (We used the PASCO application).
3) Make a table in the application which consists of the wavelength, frequency, voltage, and stopping voltage (Stopping voltage is the absolute value of the voltage).
4) Switch on the mercury lamp and let it warm up for about 20 minutes. Keep it uncovered.
5) Set the diameter of the filter at 4 mm for the first part of the experiment (the other diameters are 2 mm and 8 mm).
6) Set the wavelength of the light at the initial wavelength (365 nm).
7) Calibrate the current and set it to 0 A by adjusting the voltage.
8) Once the mercury lamp is uncovered, the value of the stopping voltage will be shown on the computer. The system takes readings every 30 seconds.
9) Within these 30 seconds, change the wavelength to the next required wavelength and set the current to 0 again by adjusting the voltage.
10) The moment another reading shows up on the computer, repeat the previous step.
11) Obtain the magnitude of the stopping voltage at this diameter for 5 different wavelengths. Repeat the experiment for the other diameters with the same wavelengths.
12) Make the tables (as shown below) make the corresponding graphs (Stopping voltage against frequency) and in the application for each of the diameters to obtain the slope which will be used to obtain the experimental Planck's constant.

Data

Table for when diameter is 4 mm

Item	1	2	3	4	5
Wavelength	365.0	404.7	435.8	546.1	577.0
Frequency	8.214	7.408	6.879	5.49	5.196
Voltage (V)	-1.874	-1.507	-1.288	-0.726	-0.677
Stopping Potential (V)	1.874	1.507	1.288	0.726	0.677

Table for when diameter is 2 mm

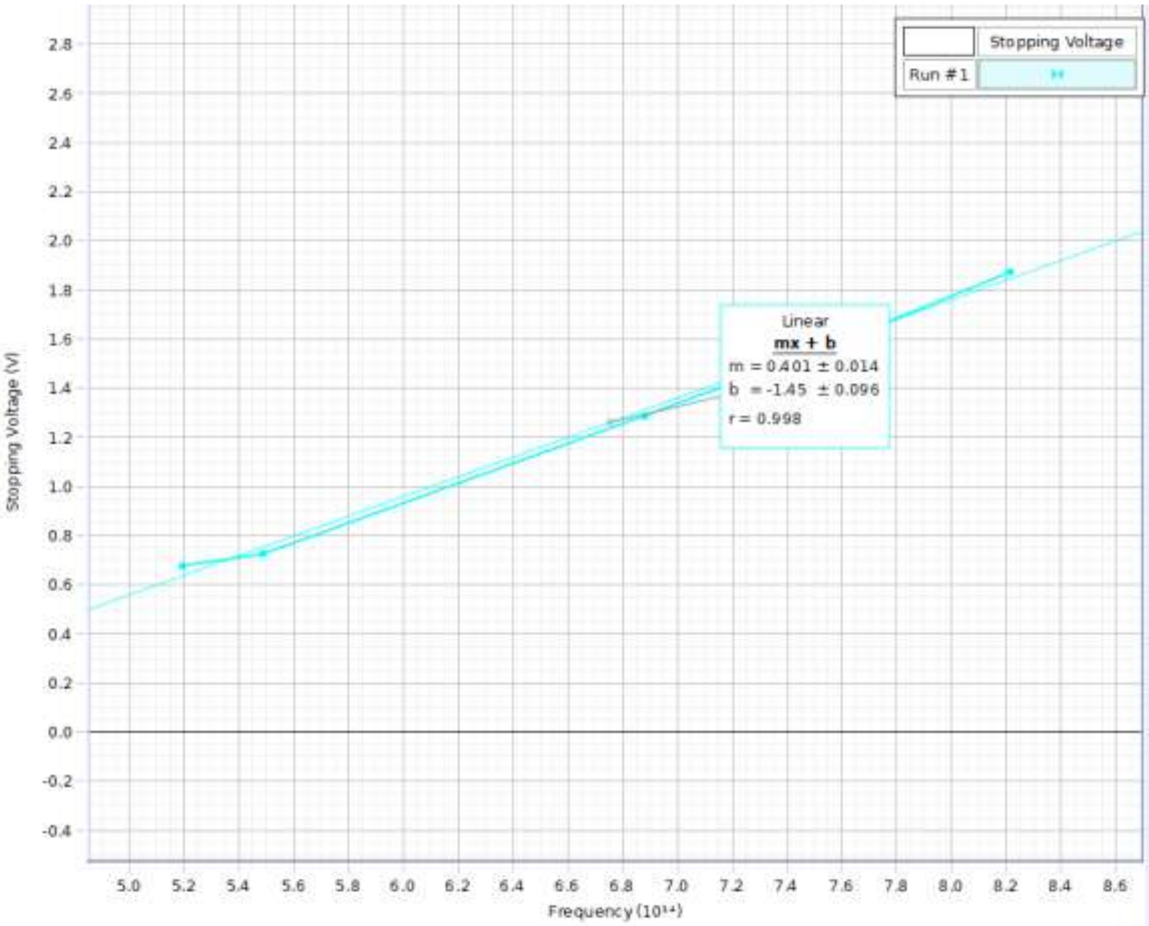
Item	1	2	3	4	5
Wavelength	365.0	404.7	435.8	546.1	577.0
Frequency	8.214	7.408	6.879	5.49	5.196
Voltage	-1.800	-1.483	-1.288	-0.75	-0.628
Stopping Potential (V)	1.800	1.483	1.288	0.75	0.628

Table for when diameter 8 mm

Item	1	2	3	4	5
Wavelength	365.0	404.7	435.8	546.1	577.0
Frequency	8.214	7.408	6.879	5.49	5.196
Voltage	-1.874	-1.507	-1.336	-0.750	-0.628
Stopping Potential (V)	1.874	1.507	1.336	0.750	0.628

Graph

Graph for when diameter is 4 mm



$KE = hf - \phi$

$KE = eV_{stopp}$

$eV_{stopp} = hf - \phi$

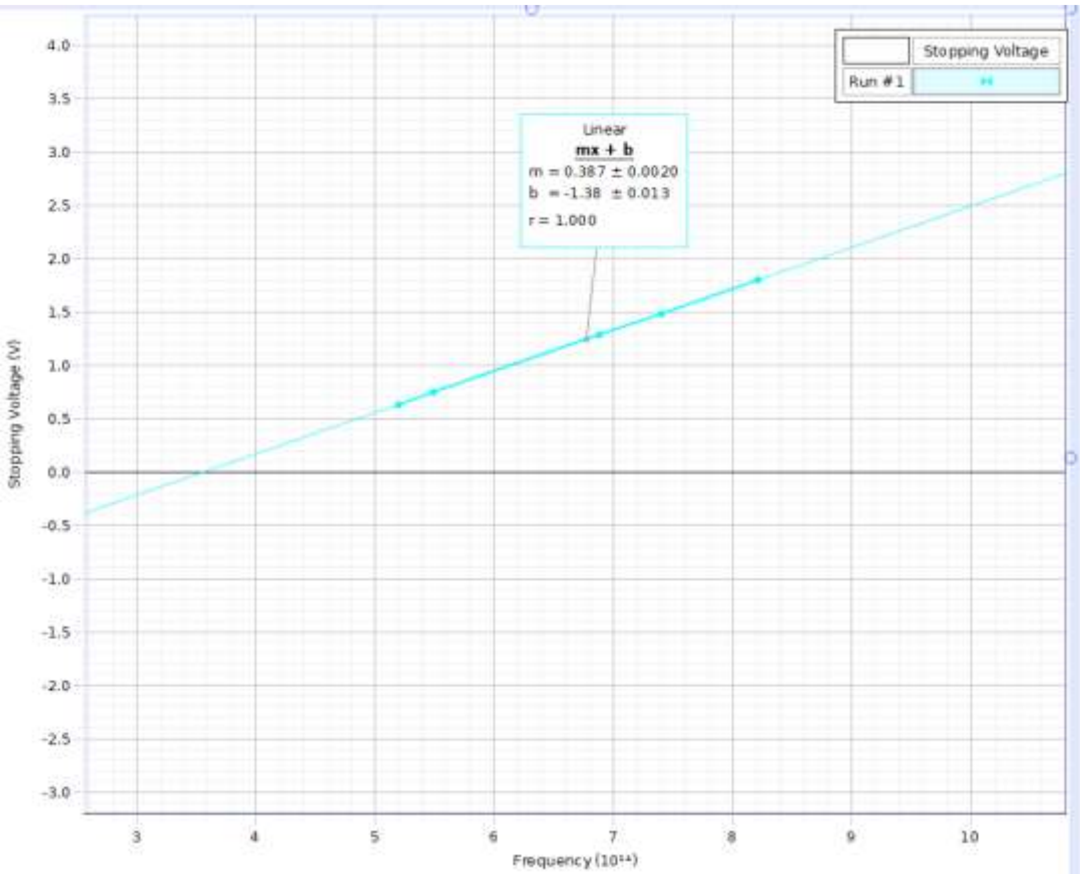
$f = c/\lambda$

$eV_{stopp} = hc/\lambda - \phi$

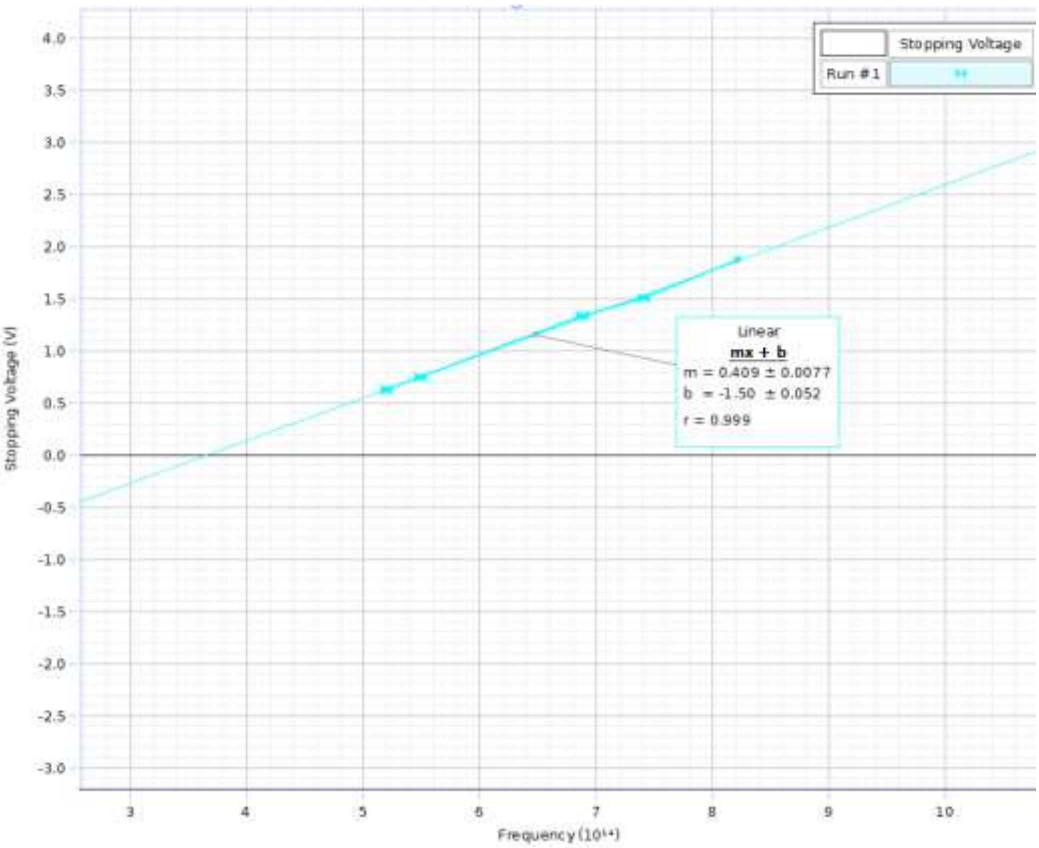
$V_{stopp} = (hc/\lambda)/e - \phi/e$

or $V_{stopp} = hf/e - \phi/e$

<u>Graph for when diameter is 2 mm</u>



<u>Graph for when diameter is 8 mm</u>



Calculations

When diameter = 4 mm

Slope = $0.401*10^{-14}$

h = e*slope

h = $(1.6 \cdot 10^{-19}) * (0.401*10^{-14})$

h = $6.416*10^{-34}$ J s

Percentage error = $\left| \frac{h - h0}{h0} \right| * 100$

= 3.17%

When diameter = 2 mm

Slope = $0.387*10^{-14}$

h = e*slope

h = $(1.6 \cdot 10^{-19}) * (0.387*10^{-14})$

h = $6.192*10^{-34}$ J s

Percentage error = $\left| \frac{h - h0}{h0} \right| * 100$

= 6.55%

When diameter = 8 mm

Slope = $0.409*10^{-14}$

h = e*slope

h = $(1.6 \cdot 10^{-19}) * (0.409*10^{-14})$

h = $6.544*10^{-34}$ J s

Percentage error = $\left| \frac{h - h0}{h0} \right| * 100$

= 1.24%

Observations

For all the tables and for all the diameters, we can also see that as wavelength increases the stopping potential decreases. We also observed that for different diameters, the values of the stoppage voltage do not differ from each a lot. In all the experiments, we obtained the value of h similar to the h_0.

Analysis questions

1) How does your calculated value of h compare to the accepted value?

   The values are close to each other; hence we can say it was a successful experiment.

2) What do you think may account for the difference between your calculated value of h and the accepted value?

   - Small current readings which aren't visible on the apparatus may affect the h value i.e. current may not be exactly 0.
   - Nearby devices can affect the readings.
   - The computer did not take exact values and rounded of the voltage to obtain the stopping voltage.

3) How can you find the value of the work function from the graph of stopping potential versus frequency?

   - work function = - y intercept/e

4) How does your calculated value of h for each different aperture compare to the accepted value, $h_0 = 6.626*10^{-34}$?

   - All the calculated h values from the 2 mm, 4mm, and 8 mm diameter experiments are similar to the accepted value. The percentage error is minimal.

5) How does light intensity affect the stopping potential?

   - The light intensity does not affect the stopping potential directly. When intensity increases, number of photons increases but it does affect the work function of the metal.

Conclusion

The purpose of this experiment is to determine Planck's constant by conducting an experiment regarding the photoelectric effect. The hypothesis states that the stopping voltage and frequency of the incident light are directly related. The materials used in the experiment include a computer and a photoelectric effect apparatus, which consists of an ammeter, voltmeter, power switch, current calibration, voltage adjust, current range switch, and voltage range switch. The experiment involves setting up the apparatus and connecting it to the computer to obtain stoppage voltage values. The mercury lamp is turned on and allowed to warm up, after which the diameter is set, and the frequency is adjusted. The current is calibrated and set to 0, and the stopping voltage is recorded every 30 seconds for five different wavelengths at each diameter. Graphs are made for each diameter, and the slope is used to calculate the experimental value of Planck's constant.

There are a few potential factors that could introduce errors into this experiment. These include:

1. Imprecise readings of the current and stopping voltage due to limitations in the measuring equipment.
2. The temperature and lighting of the experiment room can affect the operation of the instruments and the photoelectric effect.
3. The response time of the instruments used to record data may not be quick enough to detect changes in the stopping voltage with the necessary accuracy.
4. It is also crucial to take great care during the measurement process to minimize any potential human errors (human reaction time).
5. Improper calibration of the current.

We learnt that as light intensity increases, number of photons also increases but the work function of the metal remains the same.

In conclusion, the photoelectric effect was used to determine Planck's constant in the experiment, and the results confirmed the hypothesis that the stopping voltage and incident light frequency are directly correlated. Despite the possibility of errors that may have impacted the accuracy of the results, the experiment ultimately yielded precise findings that verified the validity of Planck's constant. When redoing the experiment, we can try to calibrate the current more precisely by using a meter which shows more decimal places.