Faculty of Physics - 1 agosto 2021
modern physics lab course

Photoelectric Effect.

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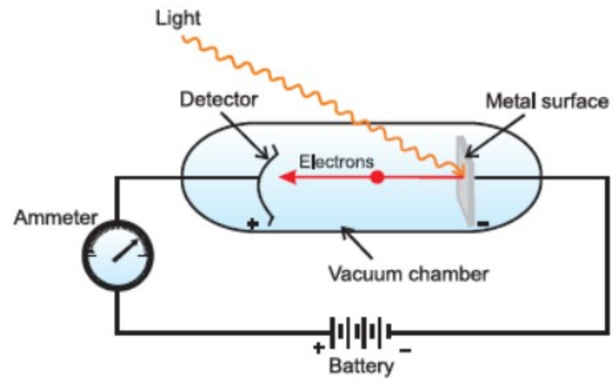
Indice

1 Objective

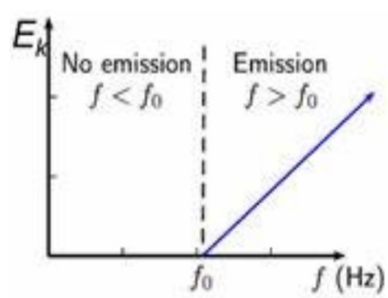
• Show validity of Einstein's explanation for the photoelectric effect.
• Measure Plank's constant ,
• Examine current versus voltage characteristic of photo-sensitive material that is shined upon with light at different intensities.
• Examine current versus voltage characteristic of photo-sensitive material that is shined upon with light at different frequencies.



2 Theoretical Introduction

The purpose of this experiment is to validate the particle model of electron behavior as Einstein's theory suggests. There are two main models that describe behavior of electrons. The first is the wave model :
According to the wave model the kinetic energy of electrons is dependant on the light intensity, we will discuss this postulate in the experiment and determine that the kinetic energy of electrons is not dependant on light intensity. We will discuss that light intensity affects the number of electrons ejected but not their kinetic energy. The wave model predicts that at any frequency, electrons will eventually eject from metal. The power(energy transferred per unit time) of a wave can be calculated to some average value dependant on its amplitude(intensity) and frequency. And this value times a certain amount of time is enough energy absorbed by the material in order to eject an electron, it is important to state that the wave model predicts that electrons are not ejected in an "instant" moment.

The second model is Einstein's model, Einstein proposed that light is made of particles called photons. Photons transfer energy in quantified amounts. The energy of a photon is $E_{photon} = hf$, when $h = 6.62 \cdot 10^{-34}[J \cdot S]$ is Plank's constant and f is the frequency. According to Einstein , each material has a work function Φ which is the minimal energy that must be given in order to eject an electron. This implies that there exists a certain frequency f_0 where electrons will be ejected from metal without kinetic energy.

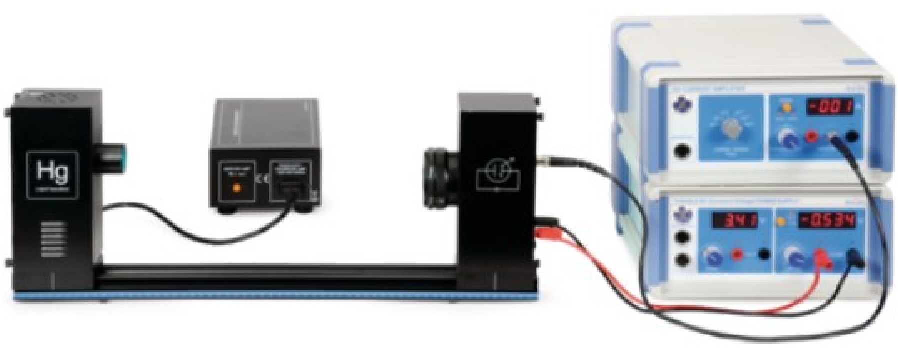


For frequencies above f_0 electrons will be ejected with a certain kinetic energy. For frequencies below f_0 there will be no ejection of electrons from the material. This approximation, in opposition to the wave model, predicts that the electrons are ejected instantaneously from the material .

3 System orientation and Equipment

Included Equipment:
1. Mercury Light Source Enclosure
2. Track, 60 cm
3. Photo diode Enclosure
4. Mercury Light Source Power Supply
5. DC Current Amplifier
6. Tunable DC (Constant Voltage) Power Supply

Optical Filters, Apertures, and Caps:
7. Filter Wheel (365, 405, 436, 546, 577 nm)
8. Aperture Dial (2 mm, 4 mm, 8 mm diameter)
9. Photo diode Enclosure Cap (not shown)
10. Mercury Light Source Enclosure Cap (not shown)



4 Experiment Course

The first part of the experiment is about measuring Plank's constant. Einstein's model provides the following equation : $K = hf - \Phi$. The kinetic energy of the electron is its charge times voltage. $eV_0 = hf - \Phi \Longrightarrow V_0 = \frac{h}{e}f - \frac{\Phi}{e}$. The first measurement is of stopping voltage V_0 as a function of frequency f. The equation is linear and provides obvious slope $m = \frac{h}{e}$, the charge of the electron is a known constant of nature $e = 1.6 \cdot 10^{-19}[c]$ such that Plank's constant is easily extracted by $h = m \cdot e$. The second parameter we can extract from this is the work function of the photo-sensitive material by linear regression that obtains $V_{(f=0)}$. The measurement is performed the following way: we shine light via Mercury light source at wavelengths of 365,405,436,546,577 [nm] and measure the stopping voltage for each wave length.

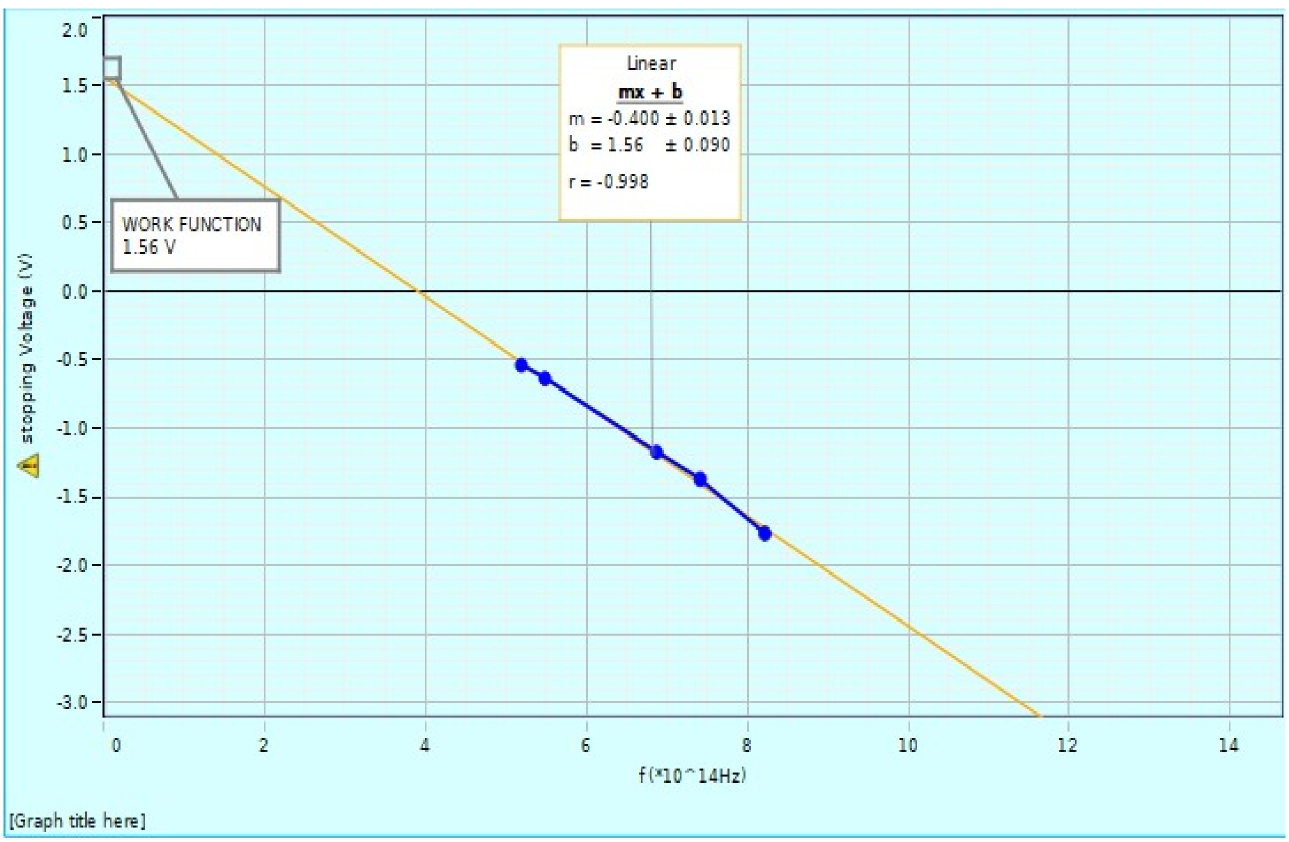
The second part of the experiment is about measuring and comparing current versus voltage characteristics of one spectral line at three different intensities. In the second part we use the Aperture dial in order to shine light at varying diameters therefore varying intensity. The wavelength used is 436_{nm}. We will discuss how the characteristics compare and contrast when we change the intensity of light. We will answer the question of whether it is the wave model or the particle model that better suits the result of the experiment.
The third part of the experiment is about comparing what happens when the light intensity is constant , but the frequency changes , we will perform the same operation, vary the voltage and measure the current in the circuit.

5 Results

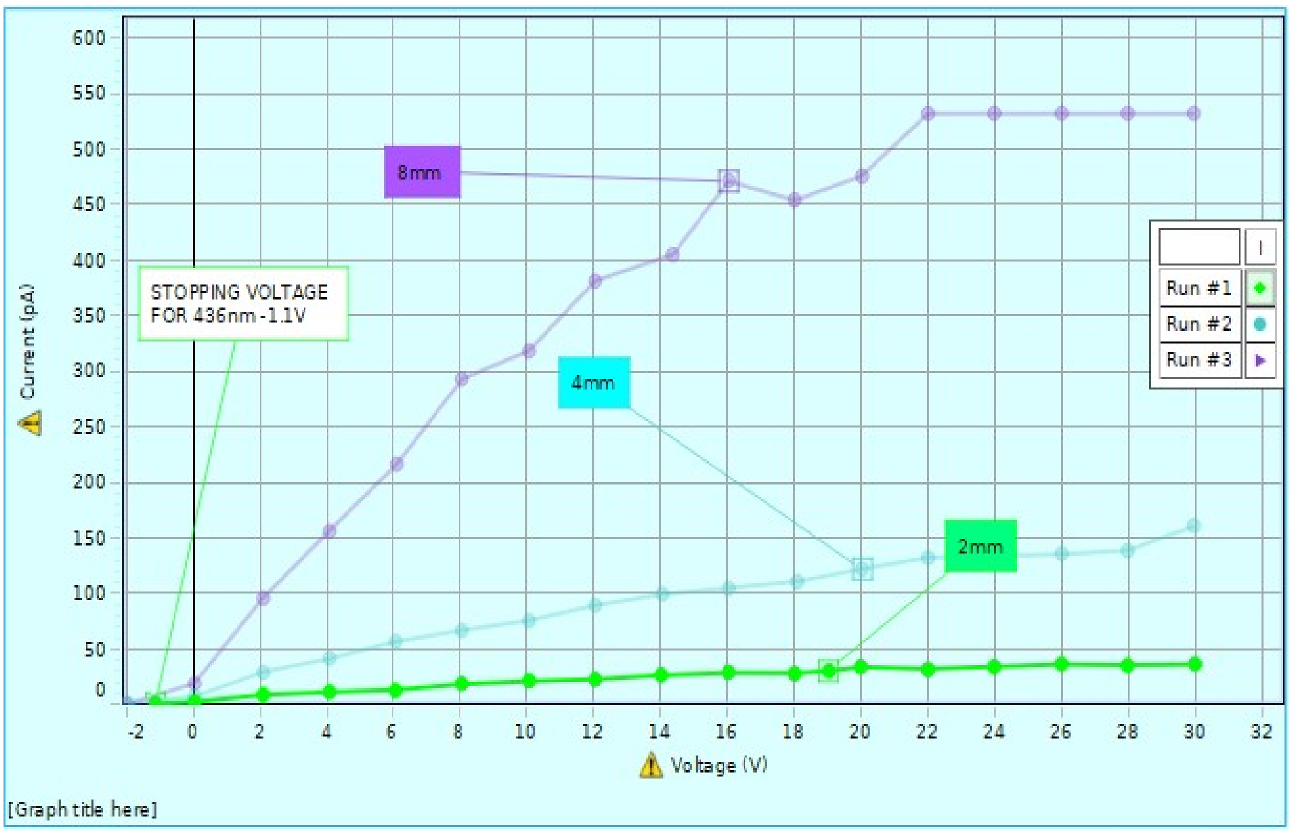
A linear function was expected. Calculating h from the slope:

$$m \cdot e \cdot 10^{-14} = 6.4 \cdot 10^{-34}$$

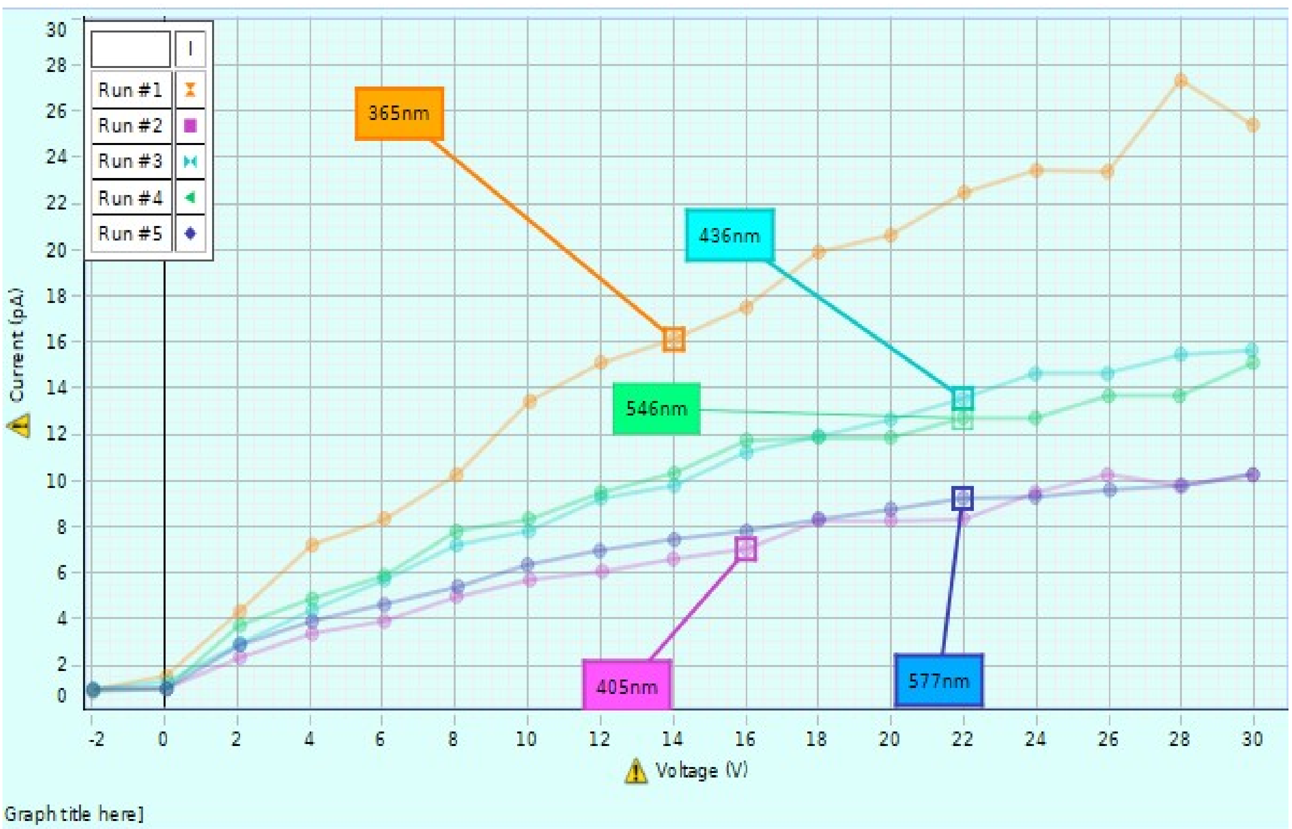
with a percent difference $\frac{6.4-6.62}{6.62} \cdot 100\% = 3.323\%$ The work function is found easily to be $\Phi = 1.56[V]$, so we know the minimal energy required to eject an electron is $1.56[eV]$.



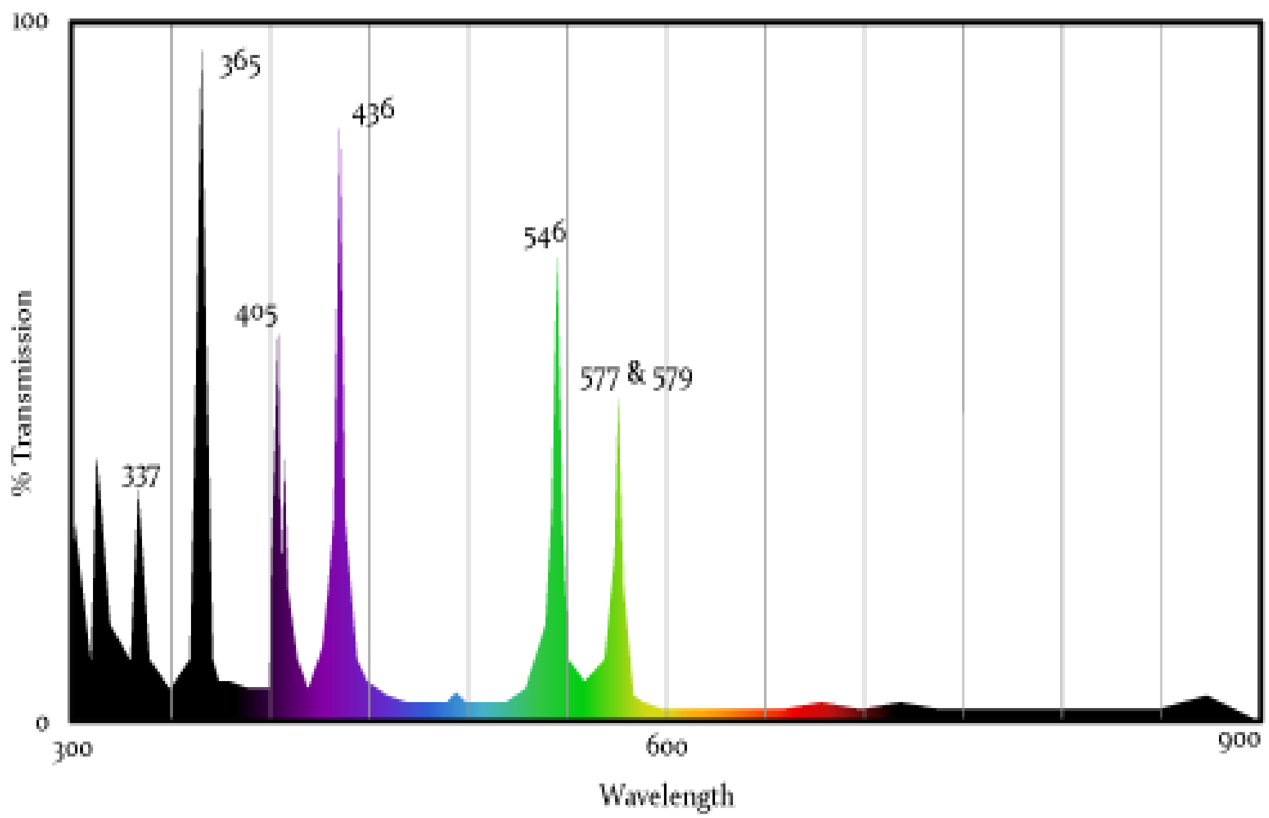
he correct stopping voltage is the stopping voltage seen on the 1st measurement(green) -1.1v it is the measured stopping voltage for $\lambda = 436_{nm}$ as seen on previous graph, it seems that the stopping voltage changed for the 4mm and 8mm apertures but it is not a function of light intensity , we blame noise for this minor change. The bigger the aperture $\longrightarrow$ more photons hit the metal $\longrightarrow$ more electrons ejected $\longrightarrow$ higher current for given voltage. We note that there is a saturation of current at $V_{sat} = 22[V]$, the current saturates because the anode is already able to pull all the ejected electrons at V_{sat} , this shows us that the current is not completely dependant on the kinetic energy of the electrons. Current is obviously dependant on light intensity which has a direct connection to number of photons.



The measurements start from -2[V] , this does not mean that -2[V] is the stopping voltage for any of the frequencies. The measurement shows that there is no direct connection between wavelength(one over frequency) to the current. We see this in the intersection of the blue(436nm) and green(546nm) lines, at 18V voltage the currents intersect and behave in an opposite manner on different sides of the point . The same case with blue(577nm) and purple(405nm) . These results are explained by the following graph showing the spectrum of mercury :



The emission spectrum of a mercury arc lamp is shown above, the y axis shows transmission of light which is related to light intensity. Wave lengths with higher transmission value represent a higher number of photons emitted with same wavelength. The spectrum shows that the 365nm wavelength(orange) has the highest transmission coefficient , the 436nm and 546nm data does not completely correlate with the spectrum. The 577nm and 405nm data does correlate with the spectrum.



6 Conclusion

The experiment shows the validity of Einstein's explanation for the photoelectric effect. Plank's constant was measured with a difference of 3.323% of the accepted theoretical value . The work function of the photo-sensitive material was found to be 1.56[V]. An obvious connection between light intensity and current in was found via changing the aperture of the emitted light and also by looking at the emission spectrum of mercury. It was found that the wavelength(energy) of a photon has no direct connection with the current in the circuit, in opposition to the wave model of the photon that demands this.