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# Finding Planck's Constant with Light Emitting Diodes

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**Abstract**

The experimental objective of this experiment was to determine Planck's constant, $h$, with the use of light emitting diodes, or LEDs. Several different LEDs were used in a very simple series circuit that consisting of only a tunable voltage source and the LED acting as a resistor for the purposes of the experiment. There was a significant fundamental systematic flaw in the experiment design where the results relied too much on the human eye and could not have been accounted for in the qualitative error. However, we were able to calculate Planck's constant to a relatively close approximation of $(7.03\ 2 \pm 0.03)10^{-34}$ which is 6.2% away from the agreed upon value from the scientific community [2].

# 1 Introduction

The objective of this experiment use LEDs to determine Planck's constant. The decision to use LEDs stems from the fact that these lights act as a changing resistor where it uses the potential voltage to try an excite the electrons of the atom so that they can jump energy levels and after release photons. However, once the minimum amount of voltage is reached to release light, called threshold potential, it's resistance changes exponentially, however, this is not significant for the purposes of the experiment [2]. Yet, this means that the threshold voltage corresponds to the exact moment that the LED releases light.

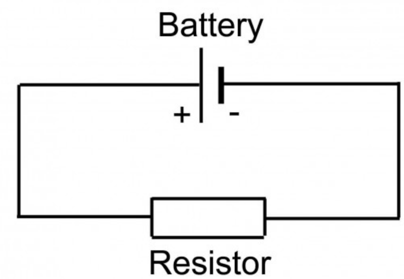
The threshold voltage is important to know as it corresponds exactly to the quantum energy that releases a photon with the color's specific wavelength. If we rearrange Planck's equation to the following form, we can easily determine Planck's constant.

$$V = \frac{hc}{e}(\frac{1}{\lambda}) \tag{1}$$

Thus, if we plot the threshold voltage ($V$) of each color versus that color's quantum wavelength ($\lambda$), then we get a slop of Planck's constant ($h$) multiplied by the speed of light ($c$) and the inverse of one electron charge ($e$). It's important to note there should not be an initial value.

# 2 Materials and Methods

The materials used to perform this experiment consisted of numerous different colored LEDs (different wavelengths) connected to a resistor. This resistor is plugged into a DC tunable power source and a PASCO interface used as a voltmeter to measure the data. The setup was simple, shown by the following diagram:




The procedure was the following: for each LED, attach the wires that are connected to the power source to the LED. Then, starting from 0V, slowly increase the voltage until the slightest bit of light may be observed. At this moment, take down the reading and its corresponding wavelength. After having completed for all LEDs, repeat two more times for each light to improve the precision of the data.

# 3 Results

| All Trials | | | | |
|---|---|---|---|---|
| Wavelength and Color (nm) | $Trial_1$ Voltage (V) | $Trial_2$ Voltage (V) | $Trial_3$ Voltage (V) | Mean and Error |
| 395 (Red) | 2.66 | 2.65 | 2.66 | 2.66 ± 0.003 |
| 460 (Blue) | 2.27 | 2.2 | 2.24 | 2.25 ± 0.02 |
| 540 (Green) | 1.87 | 1.89 | 1.88 | 1.88 ± 0.005 |
| 568 (Yellow-Green) | 1.66 | 1.66 | 1.65 | 1.66 ± 0.003 |
| 589 (Yellow) | 1.59 | 1.56 | 1.56 | 1.57 ± 0.01 |
| 605 (Yellow-Orange) | 1.5 | 1.5 | 1.49 | 1.50 ± 0.003 |
| 625 (Orange) | 1.46 | 1.43 | 1.44 | 1.44 ± 0.01 |

In Table 1, below, we show all the obtained data from all three independent trials. The error represents the error in the mean where the calculation can be found in the python code but it is quite simple.

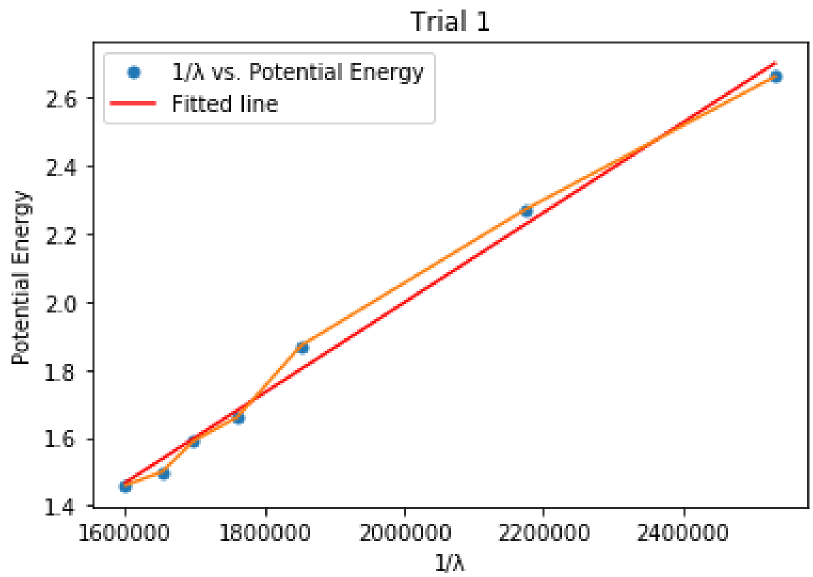



Figure 1: This graph shows the linear plot of inverse wavelength versus potential energy that follows the function of form $f(x) = 1.32x10^{-6}$. Note, the error bars are actually plotted but are too small to be seen on the graph.

# 4 Discussion

Before mentioning the actual final results of this experiment, it is extremely important to realize that there is a huge systematic error in the experiment. It stems from the fact that it was practically impossible to adequately find the threshold voltage as it is the human eye is too imprecise to actually see the very low emission of light that LEDs emit at its threshold point. But, multiplying the the average slope of the three trials, and multiplying that slope by $c^-1$ and $c$, we obtained a result where Planck's constant is (7.03 2$\pm$ 0.03)x$10^{-34}$ where the accepted value is 6.626x$10^{-34}$ [1]. This is visibly quite far off from the accepted value, 6.2% to be more specific. However, it would be very hard to get rid of this error entirely though eliminating all other light sources would be a starting point. However, the experiment in whole was a success as we obtained a value relatively close to the the actual value and we did it creating our own method and circuit.

# 5 Conclusions

In conclusion, despite having a slightly off experimental Planck's constant, the experiment can still be considered a success. This is because the tools used were not exceptionally sophisticated, yet the procedure worked. If systematic errors due to imperfection can be eliminated, the result would have undoubtedly been closer to the accepted value. In the end, this has demonstrated that not much is needed to perform a theoretically high-level physics experiment.

# References

[1] Aaron Zo *LED Current Limiting Resistors*, SparkFun.(2010). 3

[2] James Trefil *Website Determination of Planck's Constant*, Amrita (2002). 1

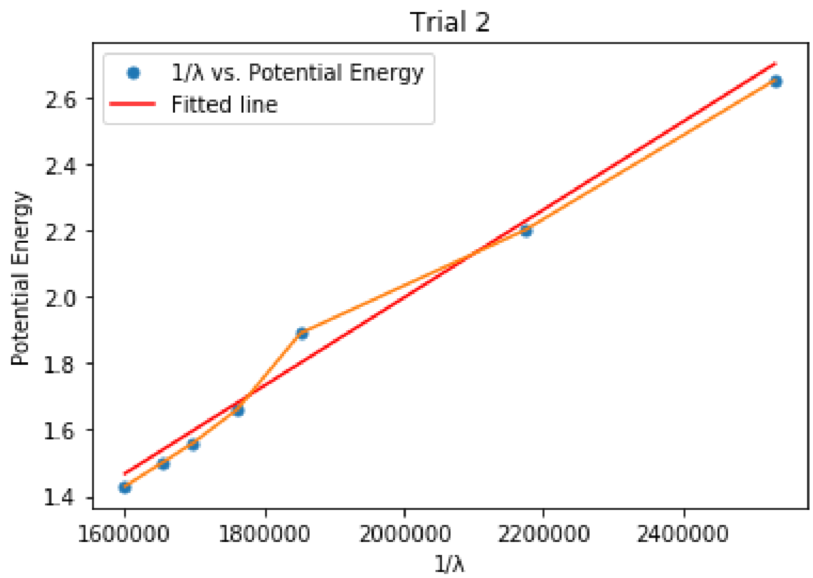
# A Sample Calculations

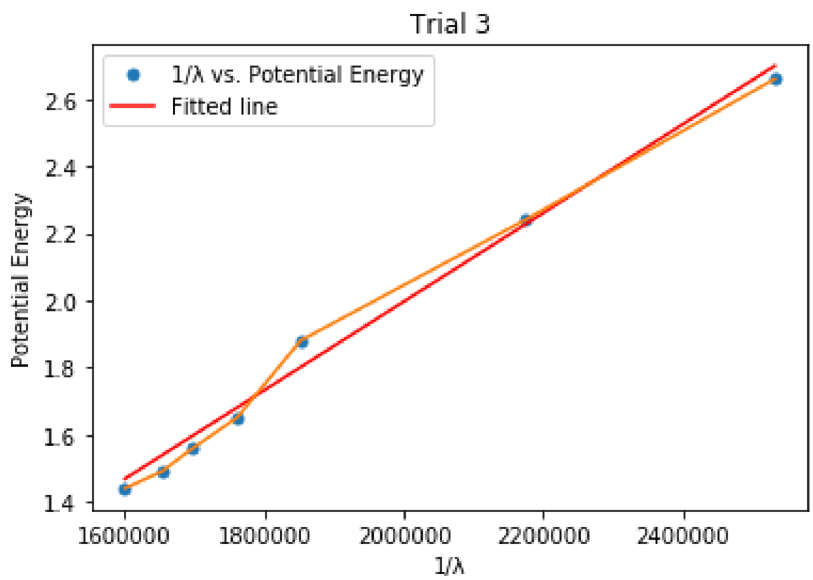
Please see attached Python code to see all relevant sample calculations including; linear least square fit, calculation of $h$ and all errors.

# B Author Contribution

T.Elbaz participated in the Python coding and the writing of all sections of the experiment and report.
W.Sugiarta participated in the Python coding and the writing of all sections of the experiment and report.

# C Data


Trial 2
1/λ vs. Potential Energy
Fitted line
Potential Energy
1/λ
1600000
1800000
2000000
2200000
2400000
1.4
1.6
1.8
2.0
2.2
2.4
2.6


Trial 3
1/λ vs. Potential Energy
Fitted line
Potential Energy
1/λ
1600000
1800000
2000000
2200000
2400000
1.4
1.6
1.8
2.0
2.2
2.4
2.6