PHYS1931 Lab Report

Physics 1A SSP

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Aim

To calculate Planck's constant h by measuring the minimum voltage required in a circuit to excite photons.

1. Introduction

The core methodology of measuring Planck's constant using LEDs comes from the first method outlined in Checchetti and Fantini (2015). The first method outlined in the report relies on the relation of energy has to the voltage of a system, Planck's constant and the frequency of light.

$$E = Ve$$
$$E = hf$$
$$h = \frac{Ve}{f}$$

Therefore to calculate Planck's constant, the minimum voltage to excite photons of some frequency must be found. These voltages and frequencies are thus found by analysing LEDs and consequently Planck's constant is calculated.

1.1. *Finding the minimum voltage*

To find the minimum voltage, a characteristic voltage graph of each LED is created by plotting the voltage against the current. While not truly linear it can be largely approximated as a piece-wise function, one piece which is 0 and the other a linearly increasing function. The x intercept of this function will therefore be the minimum voltage of the LED.

1.2. *Hypothesis*

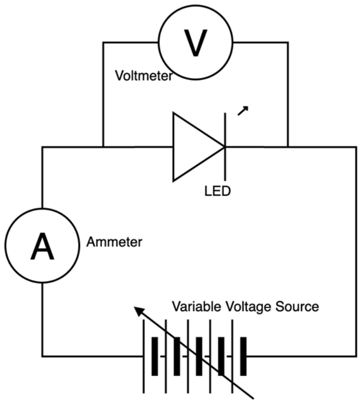
The expectation of this experiment is that Planck's constant is calculated to at least the correct magnitude and that any further precision relies on the management of sources of uncertainty within the experiment. However as this experiment relies on the model of circuits which is technically a approximate model within the bounds of modern understanding of electrodynamics, there is some limit to the preciseness that can be achieved through this method.

2. Methods and Equipment

The methodology of the experiment is comprised of two parts. Part 1 is on producing Intensity-Frequency graphs of the LEDs so that the frequency of the LED can be determined. Part 2 is on producing Current-Voltage graphs of the LEDs from where the minimum voltage is determined.

2.1. *Intensity-Wavelength Graph*

For the experiment, 5 different LEDs were used, each of which with an unknown frequency . To determine the frequency, Intensity-Wavelength graphs were created for each of the LEDs. To do this, a spectrometer connected to a computer, optic fibre cable, LED tester, LEDs and a large dark clothe was used. LEDs were slotted into the LED tester at appropriate voltages such that the intensity of the LED was moderately high then covered under a dark cloth with the other end of an optic fibre cable plugged into the spectrometer. Thus, only the light emitted by the LED was picked up by the spectrometer as all background light was blocked by the dark cloth.



One person held the open end of the optic fibre cable to the LED while another person on the computer would save the wavelength and intensity data. The end of the cable did not touch the LED housing but rather was held some small distance away from the housing to limit the intensity of the light entering the spectrometer to reduce peaking of intensity which would give invalid data as the relative intensities of the frequencies is required.

2.2. Voltage curve

To produce a Current-Voltage graph, the current and voltage had to be measured simultaneously. To do this a circuit was assembled needing cables, a benchtop multimeter, a handheld multimeter, a variable voltage source and crocodile clips. The circuit is as shown in Fig 1.

The voltmeter was a simple handheld multimeter while the ammeter was a more precise benchtop multimeter. The LED was connected to the circuit using crocodile clips which clipped onto the cathode and anode of the LED. In preliminary tests using two handheld multimeters, voltage readings where found to be quite stable, while current readings fluctuated greatly giving poor imprecise results. Thus, it was decided that the benchtop multimeter was to be used as the ammeter.

Measurements of the current were taken across increments of around 0.1 volts. Furthermore as the ammeter fluctuated greatly when the voltage would be changed before settling down, some time was given to let it stabilise before a value was recorded. Even while relatively stable the reading still fluctuated some amount and this was used to record the uncertainty.

To find the initial voltage from where to measure, the voltage was tuned until the ammeter gave a reading in the magnitudes of several hundred microamps. The increments of voltages were taken capping at 15 increments so as not to potentially damage the LEDs. This method was performed for each of the LEDs.

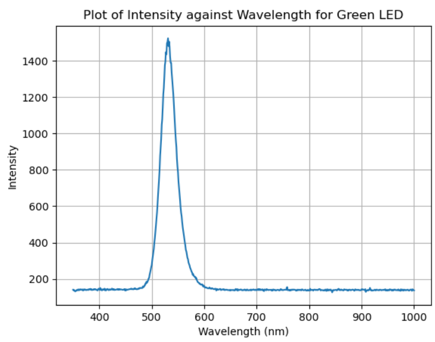
2.3. Data Analysis

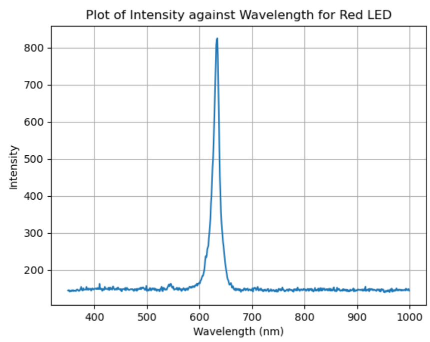
For the data analysis the main two tools that were used were Excel and Python. In Excel, the gradients and intercepts of the linear functions were found using LINEST. Python was used to determine how the piecewise functions should be created and to analyse the intensity-wavelength data.

3. Results

3.1. Frequency Data

The data for the frequencies of light released for each LED are graphed below and the table contains the mean frequency of light calculated along with its uncertainty for each of the LED's. Note that the graphs labelled high and low voltage are those of the Lime LED which had a different graph if it was measured at a high or low voltage.





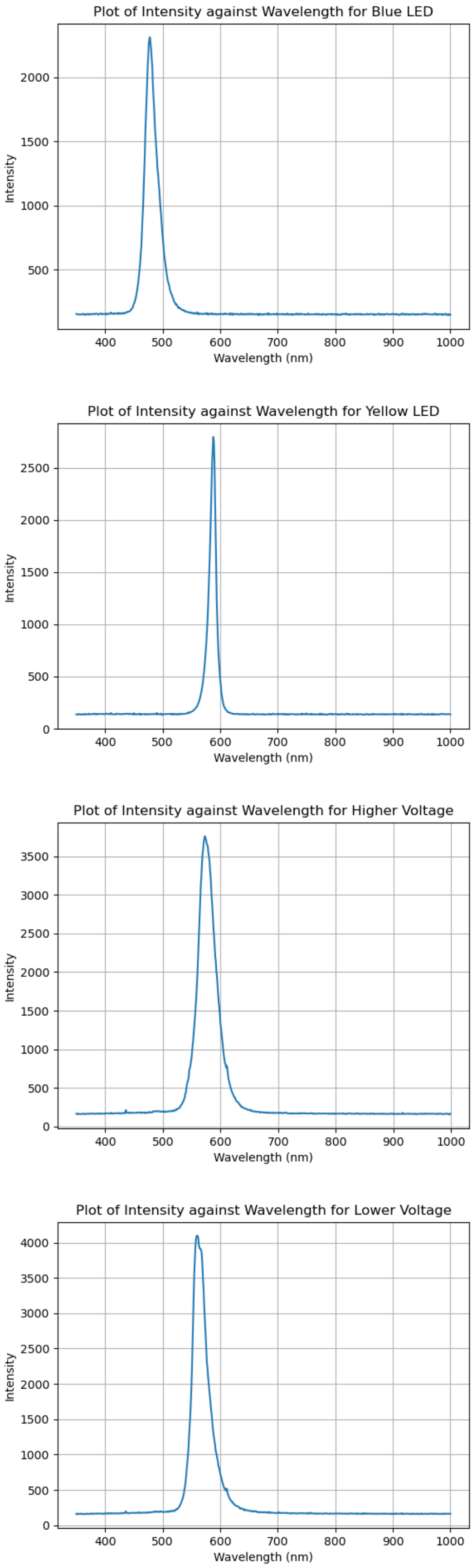
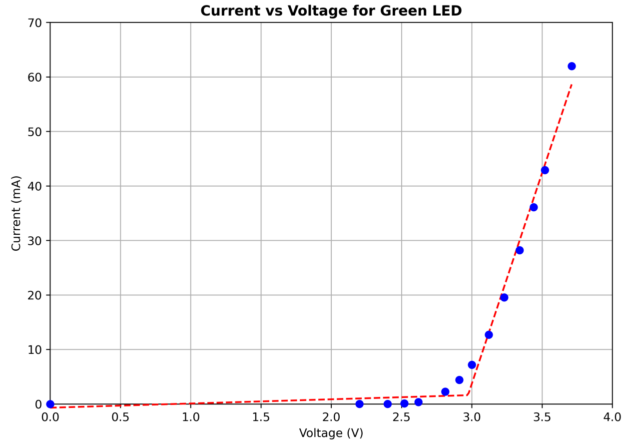
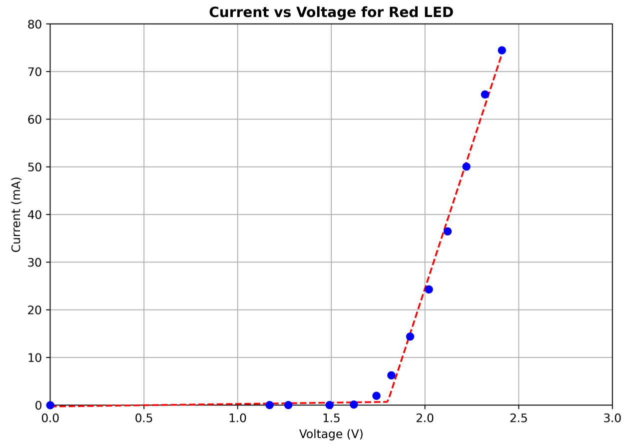


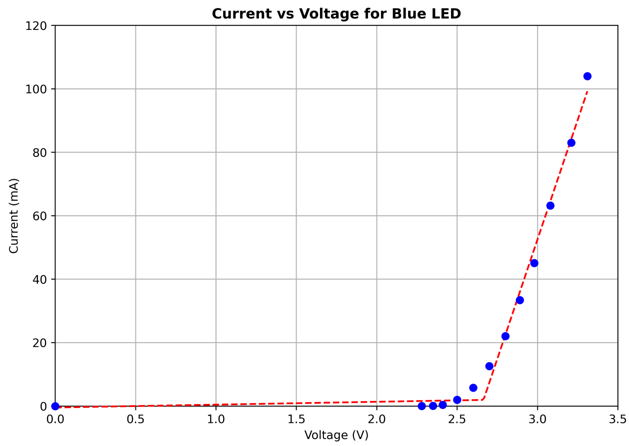
Figure 1: Wavelength Intensity Graphs of the LEDs

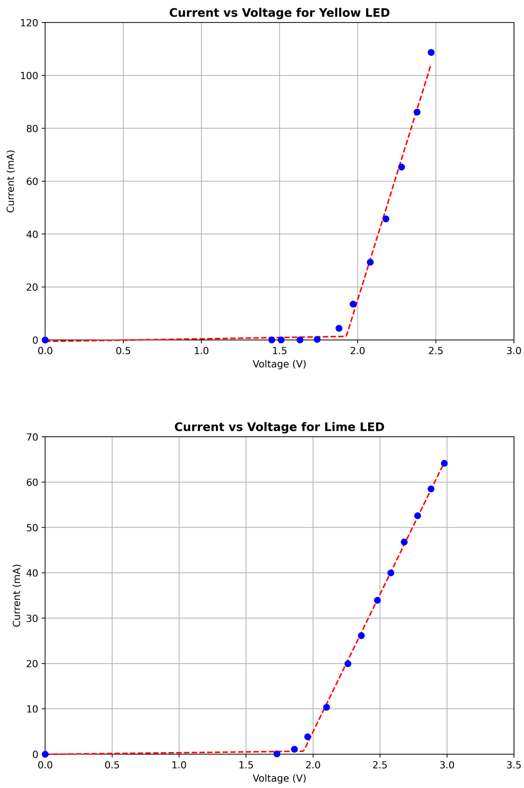
3.2. IV Graphs

The IV graph for each of the LED's with the respective piece-wise functions on top is shown below.









IV graphs of the LEDs

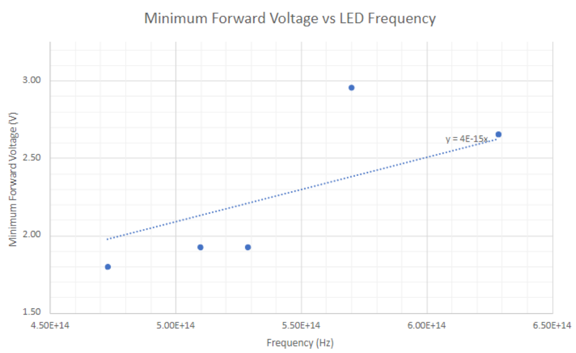
The table shows the minimum voltage and frequency for each of the LEDs with the uncertainty.

LED Colour	Frequency (Hz)	Uncertainty (Hz)	Min Forward Voltage (V)	Uncertainty (V)
Red	4.72858766562E+14	1E+03	1.80	0.09
Yellow	5.09851119048E+14	2E+03	1.9	0.1
Lime	5.28734493827E+14	8E+03	1.92	0.04
Green	5.69947638783E+14	2E+03	3.0	0.2
Blue	6.2849571908E+14	3E+03	2.7	0.2

Figure 2: Table of data for each LED

3.3. Plotting voltage to frequency

The graph below plots minimum voltage to frequency



The final value of Planck's constant calculated is: $(6.7 \pm 0.5) \times 10^{-34}$ J·Hz

4. Interpretation

While a value of Planck's constant with the same magnitude to one significant figure was determined in line with the hypothesis, the error of value was still substantially high and better consideration in minimising error could have been done.H However, it can be seen that the final result is indeed valid and thus the assumptions made in order to determine Planck's constant are reasonable.

One major source of error and a major inconsistency within the results is the minimum voltage of the green LED which was higher than that of the blue LED even though the blue LED emitted higher frequency light, likely due to inefficiencies in the green LED requiring higher energies.

Furthermore, the distribution of frequencies released by the LEDs also changed across voltages to a largely small extent so was not taken into account for. The exception is the lime LED which had a large difference and so was accounted for.

One major assumption made was in the linearity of the LED curve which in actuality, follows a much more complex equation and likely introduced significant error within the system.

As well, because data from the ammeter was not continuously recorded the fluctuations could not be properly analysed thus lowering the precision of the measurement, although it was still quite precise.

5. Conclusion

While the experiment confirmed the validity in attempting to calculate Planck's constant using an LED and found an accurate value, significant sources of error could have been minimised allowing for an even more precise value.

Appendix A. References

[1] Andrea Checchetti, and Alessandro Fantini, "Experimental Determination of Planck's

constant using Light Emitting Diodes (LEDs) and Photoelectric Effect.” World Journal of Chemical Education, vol. 3, no. 4 (2015): 87-92. doi:10.12691/wjce-3-4-2.

[2] Planck, Max (1901), ”Ueber das Gesetz der Energieverteilung im Normalspectrum”