Candidate 1 evidence

Higher Physics Assignment

Aim; to determine Planck's constant using the voltage required to light different coloured LEDs

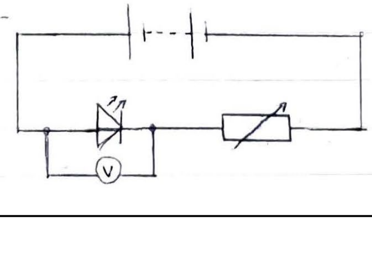
Underlying Physics:

Planck's constant is a highly important number which relates the energy of a light photon to its frequency. It is used in various aspects of physics, such as Schrödinger's Equation and de Broglie's relation for wavelength of matter waves. Planck's constant can be determined using LEDs.[1]

LEDs, when supplied with enough voltage, emit photons. When the minimum energy required to emit a photon, ~~is~~ ~~measured~~ and the wavelength of photons emitted is measured, it can be used to calculate the energy, hf, of the photon.[2] In the equation $E=hf$, h is Planck's constant. Planck had discovered as the energy of radiation increased, so did its frequency, leading to the Planck's constant equation. The equation $h=\frac{E}{f}$ proves that, given that as frequency increases energy increases, ~~...~~ h is a constant. Planck's constant can also be determined using $E=h\frac{c}{\lambda}$,[3] using the speed and wavelength of a photon, where $c = 3\times10^{8}\,ms^{-1}$

Experimental Method:

Different coloured LEDs were ~~...~~ used in a circuit, and the voltage across them was changed until they first began to emit light. This voltage was recorded for each different LED. The process was repeated ~~...~~ so that a mean could be calculated.



Data:

LED colour	λ of light (nm)	QV	frequency (Hz)	voltage required to light (V) 1	2	3	4	MEAN
violet	405	4.14×10^{-19}	7.41×10^{14}	2.60	2.59	2.58	2.59	2.59
blue	470	3.78×10^{-19}	6.38×10^{14}	2.43	2.32	2.35	2.32	2.36
green	525	3.30×10^{-19}	5.71×10^{14}	2.10	2.03	2.06	2.03	2.06
yellow	590	2.72×10^{-19}	5.08×10^{14}	1.75	1.67	1.66	1.70	1.70
orange	605	2.53×10^{-19}	4.96×10^{14}	1.60	1.61	1.55	1.54	1.58
red	640	2.32×10^{-19}	4.69×10^{14}	1.46	1.45	1.44	1.43	1.45

mean voltage calculation:

$$\frac{2.60+2.59+2.58+2.59}{4} = 2.59\,V$$

$$\frac{2.43+2.32+2.35+2.32}{4} = 2.355 = 2.36\,V$$

QV calculation:

$QV = 1.6 \times 10^{-19} \times 2.59$

$= 4.144 \times 10^{-19} = 4.14 \times 10^{-19}$

$QV = 1.6 \times 10^{-19} \times 2.36$

$= 3.776 \times 10^{-19} = 3.78 \times 10^{-19}$

frequency calculation:

$f = \frac{v}{\lambda}$

$= \frac{3 \times 10^8}{405 \times 10^{-9}}$

$= 7.407407\ldots \times 10^{14}$

$= 7.41 \times 10^{14}$ Hz

$f = \frac{v}{\lambda}$

$= \frac{3 \times 10^8}{470 \times 10^{-9}}$

$= 6.382978\ldots \times 10^{14}$

$= 6.38 \times 10^{14}$ Hz

Uncertainties

Scale Reading Uncertainty on voltmeter: ±0.01 V

Random uncertainties:

violet: 0.005

blue: 0.03

green: 0.018

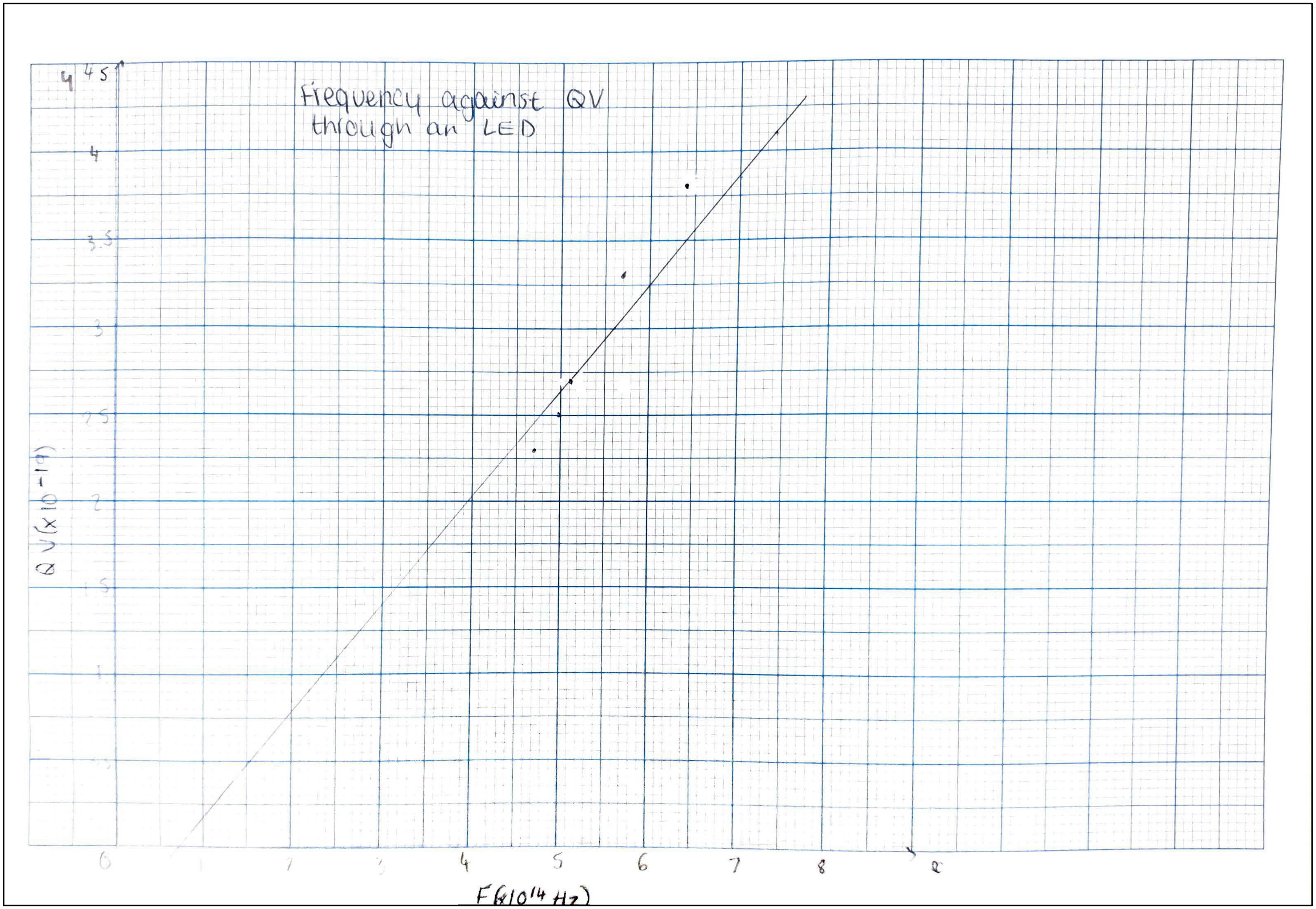
yellow: 0.02

orange: 0.018

red: 0.008

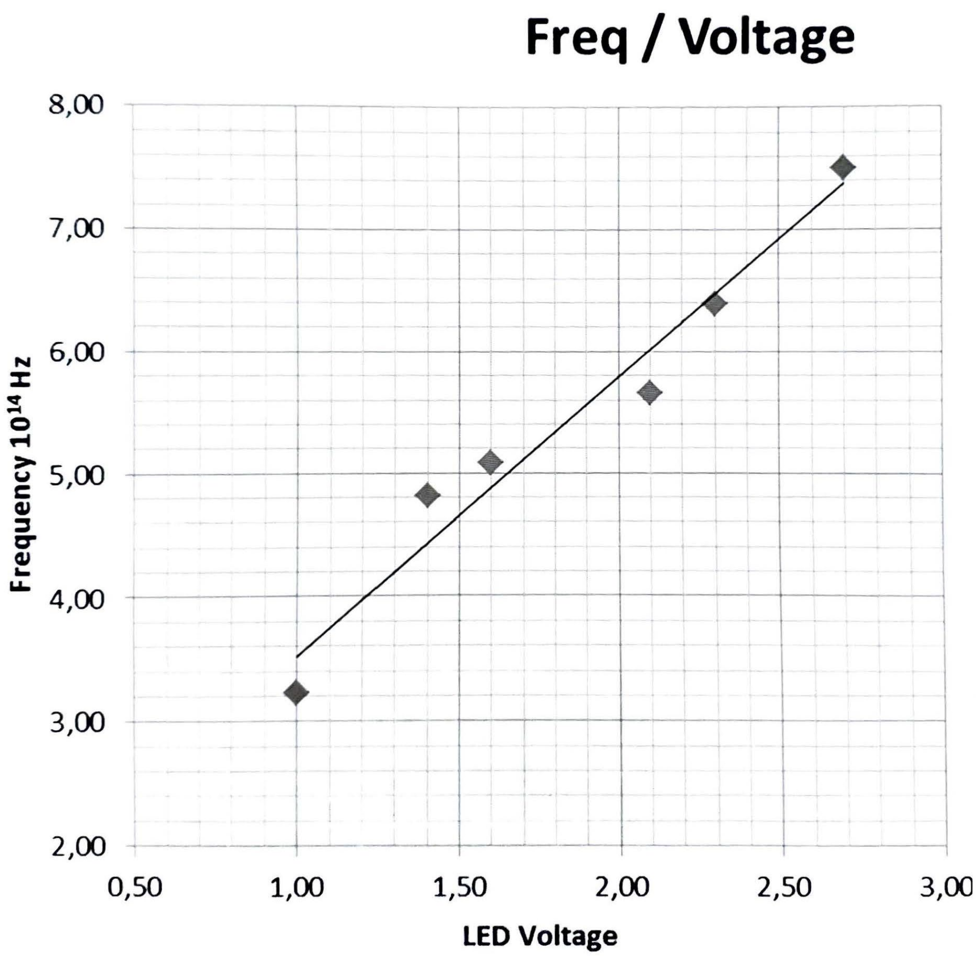
random uncertainty calculation:

$$\frac{2.60 - 2.58}{4} = 0.005$$


Frequency against QV
through an LED
Q V (x 10 −19)
F (x10^14 Hz)
0
1
2
3
4
5
6
7
8
1.5
2
2.5
3
3.5
4
4.5

Data

LED Type	λ (nm)	Freq. (10^{14}Hz)	Voltage (V)
Infrared	930	3.22581	1.0
Red	624	4.80769	1.4
Yellow	590	5.08475	1.6
Green	530	5.66038	2.1
Blue	470	6.38298	2.3
UV	400	7.50000	2.7



http://physicsopenlab.org/2015/12/08/planck-constant-measurement/

Second source
(graph)[4]

Analysis:
source 1 calculation

$m = \frac{y_2 - y_1}{x_2 - x_1}$ Points: (6, 3.25)
(7, 3.35)

$= \frac{3.35\times10^{-19} - 3.25\times10^{-19}}{7\times10^{14} - 6\times10^{14}}$

$= 6\times10^{-34}$ Js

Source 2 calculation[4]

$m = \frac{y_2 - y_1}{x_2 - x_1}$ Points (2, 5.8)
(2.2, 6.2)

$= 2\times10^{14}$

$h = \frac{V}{f} \times Q$

$= \frac{1}{m} \times Q$

$= 8\times10^{-34}$ Js

Conclusion:
Planck's constant can be roughly determined by use of LEDs. Given the voltage required to emit photons from various LEDs, Planck's Constant can either be worked out using $h = \frac{QV}{f}$ or by finding the gradient of a graph of QV against f.

Evaluation:
Source 1 was more accurate for determining Planck's constant than source 2. This may relate to the amount of repeats done. Source 1 may be more accurate because more repeats have been made, and a more accurate average taken to be used in calculations.
However, source 1 does not give the same value for Planck's constant as the official value, 6.63×10^{-34}, and the line of best fit on the graph does not go through the origin. This is due to systematic uncertainties. A systematic

Uncertainty in this experiment could be an error in the equipment used - the voltmeter's reading, or some of the components of the circuit may have been inaccurate, thus causing the readings taken to be inaccurate.
~~Another cause of less accurate results could be human error. The experiment~~
The results could also be less accurate because the experiment was user sensitive. Human error could mean that the ~~F~~ switch on voltage of the LED was determined inaccurately - ~~and that the~~ meaning it was not as precise as it could be were technology used to detect when the LED first began to emit light. The ~~experimen~~ results could be more accurate if the experiment was carried out in a darkened room, so that the first emission of light from the LED could be better determined.

~~References:~~

Source	Reference
(1) website	https://web.phys.ksu.edu/vqm/tutorials/planck/
(2) website	https://electron6.phys.utk.edu/phys250/Laboratories/Light%20emitting%20diodes.htm
(3) textbook	Brightred study guide CfE higher physics ISBN: 978-1-906736-67-5 Page 106
(4) website	http://physicsopenlab.org/2015/12/08/planck-constant-measurement/

~~Further Underlying Physics~~

Further Underlying Physics

Planck's constant gives the relationship between the energy of radiation and its frequency / wavelength. The energy of ~~tgh~~ radiation can be ~~ase~~ calculated given the frequency and ~~wavelength in the relationship~~ Planck's value. This value has uses in areas of quantum physics, and also in the photoelectric effect, where $E_0 = hf_0$; In this relationship, Planck's constant is used to work out the minimum energy of a photon.[3]

LEDs are semiconductors, and when the voltage across them is varied, the radiation put out also changes.[2]

References

Source	Reference
(1) website	https://web.phys.ksu.edu/vqm/tutorials/planck/
(2) website	https://electron6.phys.utk.edu/phys250/Laboratories/Light%20emitting%20diodes.htm
(3) textbook	Brightred study guide CfE higher physics ISBN: 978-1-906736-67-5 Page 106
(4) website	http://physicsopenlab.org/2015/12/08/planck-constant-measurement/