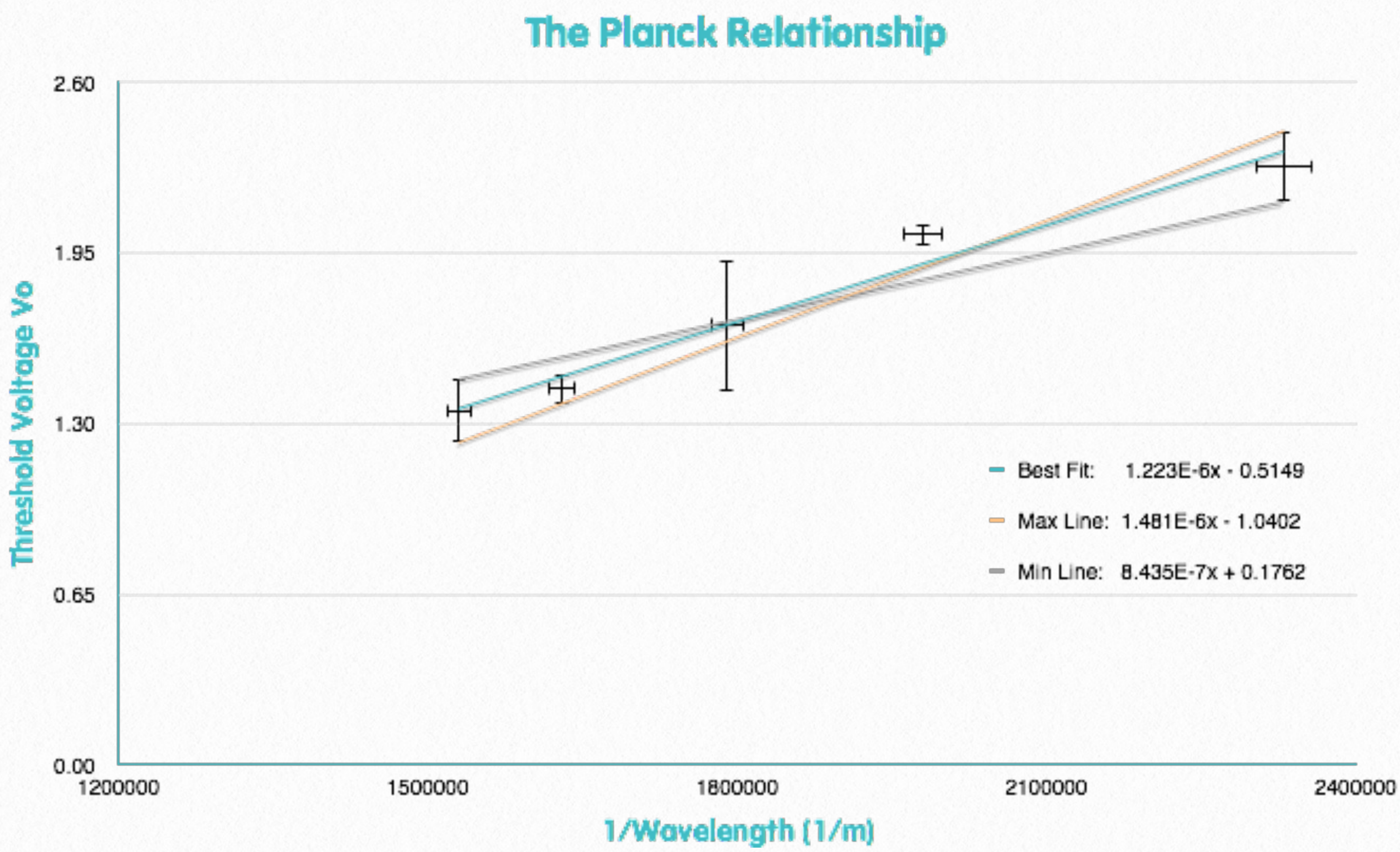
Answers

Experiment - Determining Planck's Constant

Sample Data

Color	λ(nm) ± 5nm	1/λ (x10	Δ1/λ (x10	V_0			Average V_0	ΔV
				V_{01}	V_{02}	V_{03}		
Violet	430	2.33	2.70	2.15	2.40	2.28	2.28	0.14
Green	505	1.98	1.97	1.99	2.05	2.02	2.02	0.04
Yellow	560	1.79	1.59	1.54	1.95	1.53	1.67	0.25
Orange	615	1.63	1.32	1.38	1.46	1.46	1.43	0.06
Red	655	1.53	1.17	1.22	1.40	1.42	1.35	0.12

Sample Graph



Answers - Continued

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Conclusion

The graph shows a linear, positive trend. The quantities of V_0 and $\frac{1}{\lambda}$ are not directly proportional, as expected, as the graph does not go through the origin. The line has been shifted to the right and passes through a negative y-intercept.

The value of h is calculated from the gradient as follows:

$$h_{av} = \frac{(1.22x10^{-6})x(1.6x10^{-19})}{(3x10^{8})} = 6.51x10^{-34}Js$$

$$h_{min} = \frac{(8.44x10^{-7})x(1.6x10^{-19})}{(3x10^{8})} = 4.40x10^{-34}Js$$

$$h_{max} = \frac{(1.48x10^{-6})x(1.6x10^{-19})}{(3x10^{8})} = 7.89x10^{-34}Js$$

$h = (6.51 \pm 2.11)x10^{-34}Js$ (to 3s.f.)

There is a random percentage error of 32.4% in the value of h. This suggests that the precision of the experimental result is poor and could be improved. There were some random errors that contributed to this result:

- Natural fluctuations in the supply voltage from the powerpack
- The judgement of the value of voltage as the voltmeter varied quickly.
- The LEDs and 4mm wires losing more energy to heat as the voltage across them was increased (i.e. for colors at the blue end of the spectrum)

There is a measurable spread of the points around the line of best fit, suggesting that the results are quite reliable. It is worth noting that at the largest voltage, the value of $\frac{1}{\lambda}$ appears to shift to the right.

The most common value of h is $6.63x10^{-34}Js$. The percentage difference between this value and the experimental value is:

$$\frac{(6.51x10^{-34}) - (6.63x10^{-34})}{(6.51x10^{-34})}x100\,\% = 1.8\,\%$$

This is a small error, suggesting that the experimental value is very accurate. However, the graph does not pass through the origin, as expected, and this is due to a systematic error of the LED heating up at larger voltages and causing a shift of the line to the right.

Answers - Continued

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Evaluation

The design of the experiment and the method produced reasonable results for an educational measurement. The data was appropriate for the scope of the experiment and produced relatively reliable results.

The weaknesses of the experiment are:

1. The stated wavelength of the LED is not necessarily a true emitted wavelength. When the voltage across the LED is greater than V_0, the emitted wavelength gets slightly smaller. This would have the effect of increasing the experimental value of h. This is a random error, depending on how far past V_0 the supply voltage is allowed until the reading is taken.

2. The relationship assumes that all energy lost by the electron is transferred to the emitted photon. This is not the case. Some of the energy is transferred into thermal energy of the LED. This will have the effect of a shift to the right of the line on the graph, causing a negative y-intercept. This is a systematic error. As the voltage gets larger (for smaller wavelengths), the thermal energy lost is greater.

3. Natural fluctuations in the power supply caused a rapid and noticeable fluctuation in the reading of the voltmeter when determining V_0. This was a random error.

4. V_0 was read when the LED was observed to have lit by the observer through a peering tube. This meant that the judgement of the observer could have caused random fluctuations in the reliability of this value. This was a random error.

5. The range of data was limited by wavelengths of visible light, as the observer had to see the light to judge whether or not the LED has turned on.

Suitable Improvements:

1. A more sensitive variable resistor should be used to vary the supply voltage to the LED. This would lessen the chance of reading V_0 as a value much greater than the turn on voltage.

2. The longer the circuit and LEDs have current flowing through them, the more thermal energy they will lose. Therefore, a switch should be installed into the circuit to allow the circuit to be broken as soon as possible after taking the V_0 readings. This is especially important for LED's at the blue end of the spectrum, which require a greater threshold voltage.

3. More repeat reading should be taken for each LED. This would lessen the value of the random error due to fluctuations in the powerpack.

4. A light sensor should be used (by connection to a datalogger) to detect the exact moment the LED is lit. This would remove the random effects of the judgement of the observer.

5. An Infrared sensor should be used with LEDs at the red end of the spectrum and for Infrared LEDs. This would allow for a greater range of data.