Experiment

Determining Planck's Constant

Instructions

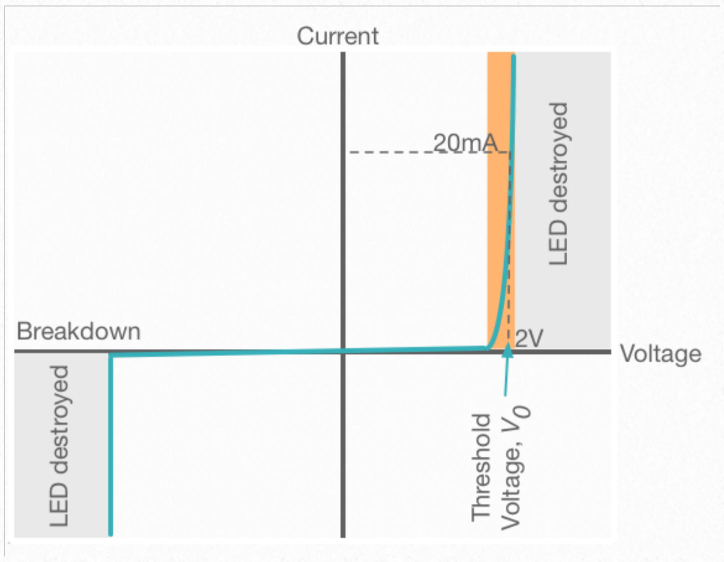
1. Read the document
2. Complete the experiment, filling in the relevant data.
3. Draw an appropriate graph and form an appropriate conclusion and evaluation.

Aim

To investigate the relationship between the Threshold Voltage of an LED and the wavelength of light emitted from the LED. To use this relationship to determine h experimentally and compare it to the best current value for Planck's constant of $6.63x10^{-34}Js$.

Theory

An LED is a light-emitting diode, which only emits light if it is forward-biased and connected correctly into the circuit. At the point at which they start emitting light (threshold voltage, V_0), they give out their maximum wavelength, λ . They typically only need between 1-3V to operate and use very small currents (~20mA).



At the threshold voltage, V_0, LEDs emit photons of energy:

$$E = hf = \frac{hc}{\lambda}$$

Electrical energy is transferred from each electron in an LED as it falls from the n to the p region, which results in a photon being emitted of the same energy, assuming the LED is 100% efficient. The amount of energy lost by the electron at V_0, can be determined by:

Energy = Charge of Electron x Threshold Voltage

$$E = eV_0$$

Where the charge of an electron is $1.6x10^{-19}C$. Thus:

$$eV_0 = \frac{hc}{\lambda}$$

and plotting a graph of V_0 against $\frac{1}{\lambda}$ of will allow Planck's constant, h , to be derived from the gradient.

Experiment Continued

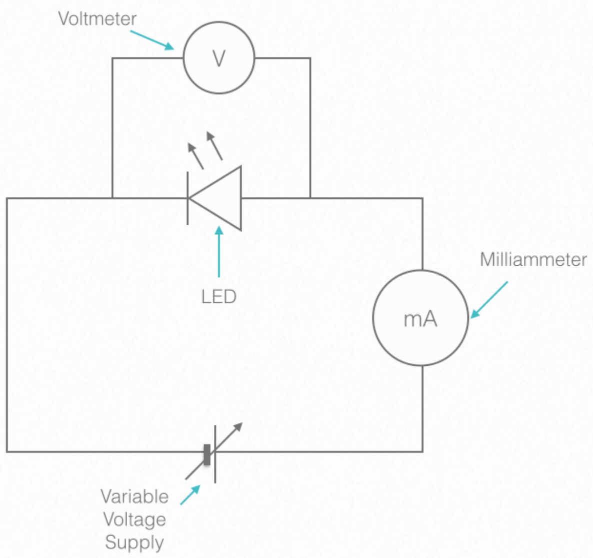
Variables

Variable	Description
Independent	**Wavelength, λ (m), of light emitted from the LED**. Controlled by changing the color of the LED.
Dependent	**Threshold voltage, V_0 (V), of each colored LED**. Measured using a voltmeter connected in parallel.
Control	**Same ambient light**, kept as minimal as possible. Controlled using a peering tube. **Same observer** to minimize random fluctuations in the judgement of the observer

Apparatus

Apparatus Needed	
6 Different colored LEDs with different, known wavelengths	2 Multimeters
Peering Tube	4mm Leads
Variable output power supply (or a fixed power supply and a variable resistor connected in series)	$1 k\Omega$ Resistor

Diagram



Safety
The current through the LEDs should not exceed 20mA.

Method

1. Construct the circuit above
2. Note the wavelength of light from the LED that is being investigated
3. Place the peering tube over the LED that is being investigated
4. Whilst looking through the peering tube, adjust the voltage across the LED until it is just lit. This is V_0 . It should never go above about 5V. Watch that the current through the LED does not go above about 20mA.
5. Repeat the process for LEDs of different colors and ensure each color have been repeated three times to increase reliability of results.

Experiment Continued

Data

Color	λ(nm) ± _____nm	1/λ ($\times 10^6 m^{-1}$)	Δ1/λ ($\times 10^6 m^{-1}$)	V_0 (V) ± ________V			Average V_0 (V)	ΔV_0 (V)
				V_{01}	V_{02}	V_{03}		

Graph

Plot a graph of V_0 (y-axis) against $\frac{1}{\lambda}$ (x-axis) and determine Planck's constant, h, from the gradient.

Conclusion

Prompt Questions

1. Describe the pattern or trend shown on the graph
2. Use the gradient to find the value of h.
3. Draw appropriate other lines of best fit (e.g. min/max possible gradients) to find the uncertainty in the value of h.
4. Comment upon the precision of the result by analyzing the uncertainty in the value of h.
5. Suggest some sources of random error that would generate this error in h .
6. Comment upon the reliability of the results, by analyzing the spread of points around the line of best fit.
7. Calculate the percentage difference between your experimental value and accepted value
8. Comment on the accuracy of the result based on the percentage difference.
9. Comment on any possible systemic errors in your results (you may see a y-intercept when you expect it to pass through the origin)

Evaluation

Prompt Questions

1. Comment upon the design and method of the investigation
2. Comment upon the quality of the data.
3. List the weaknesses and discuss how significant the weaknesses are.
4. Suggest an improvement for each of the weaknesses highlighted above.
5. Modification of experimental technique and data range should be addressed, if necessary.