

**Physics Laboratory - Report #2**

Experiment: 48

**Determination of the Planck constant using electroluminescent diodes**

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**Introduction**

Light-emitting diodes (LEDs) convert electrical energy into light energy. They emit radiation (photons) of visible wavelengths when they are “forward biased” (i.e. when the voltage between the p side and the n-side is above the “turn-on” voltage). This is caused by electrons from the “n” region in the LED giving up light as they fall into holes in the “p” region.

**APPARATUS**

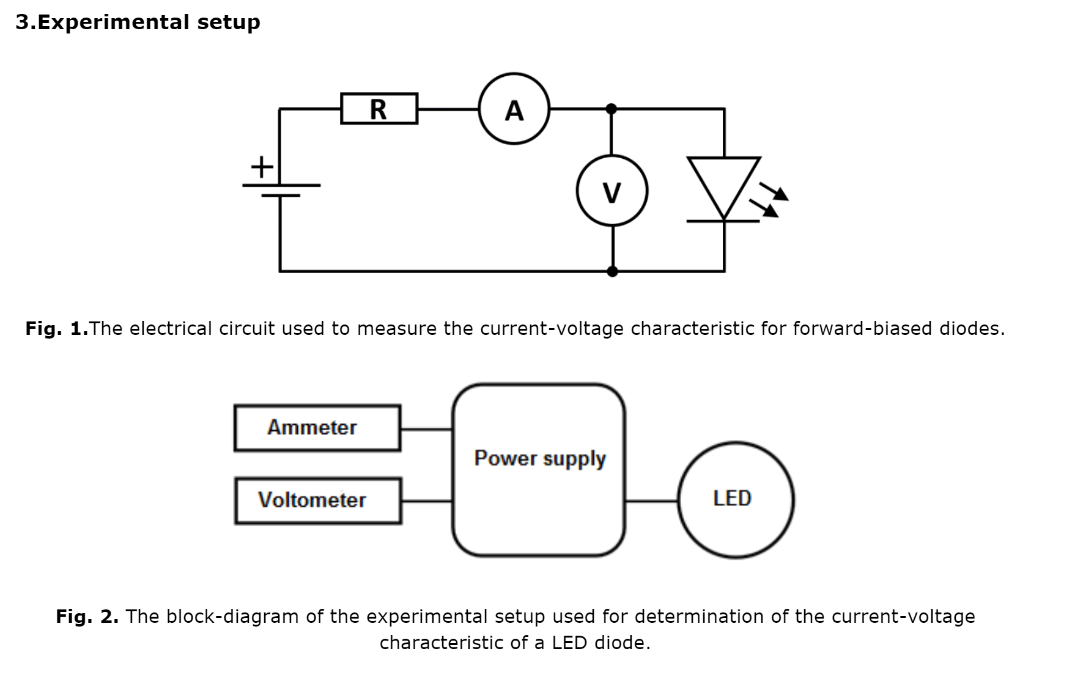
● Tunable power supply

• Electroluminescent diode

• Digital multimeters

• Monochromator

• Photoresistor

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**Determining of the Planck constant from the I-V characteristic of LED**

When we connect the LED to an external voltage in the forward bias direction, the height of potential barrier across the p-n junction is reduced (see Fig. 8a). At a particular voltage the height of the potential barrier becomes very low and the LED starts glowing, i.e. in the forward biased condition electrons crossing the junction recombine with the holes moving in the opposite direction and the excess energy is emitted as photons. The light energy emitted during forward biasing of LED is given by the equation:



The relationship between the light energy emitted from LED and the applied voltage is the following:



where e = 1.602 × 10−19 C is the magnitude of the electron charge, Ub – a voltage referring to the potential barrier of a diode, determined from the I-V curve (cf. Fig. 8b).

The experimental determination of Planck’s constant is then easily obtained by measuring the wavelength of the emitted radiation from an LED and applied voltage over the LED concurrently, by combining the equations to get h:



Rearranging Eq. 4 we get:

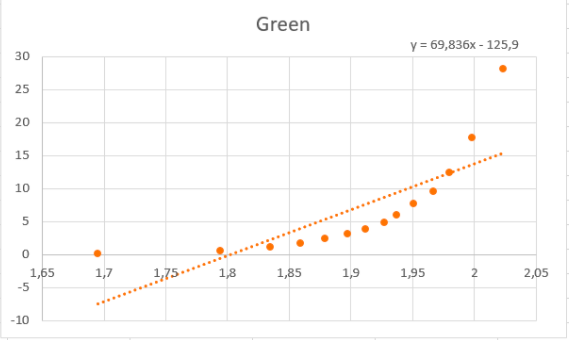


**REFERENCE**

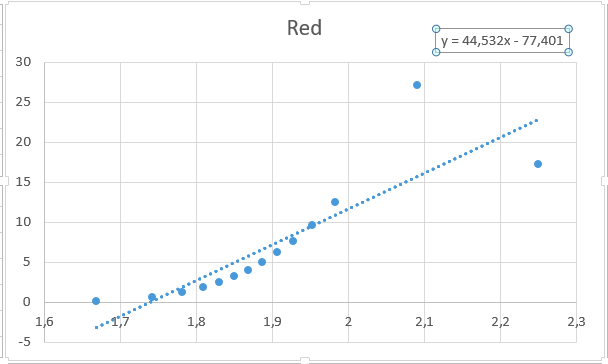
Laboratorium Podstaw Fizyki, Politechnika Wroclawska, “http://lpf.wppt.pwr.edu.pl/opisy.php”

**Measurements**

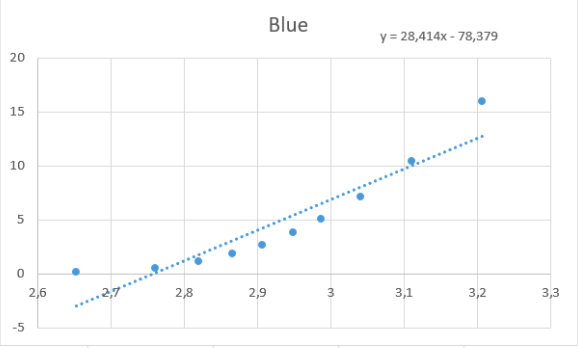
Twenty potential-current instances are measured for 4 different colors of LEDs. For each color, wavelengths are measured. Resulting data sets are plotted and analyzed.



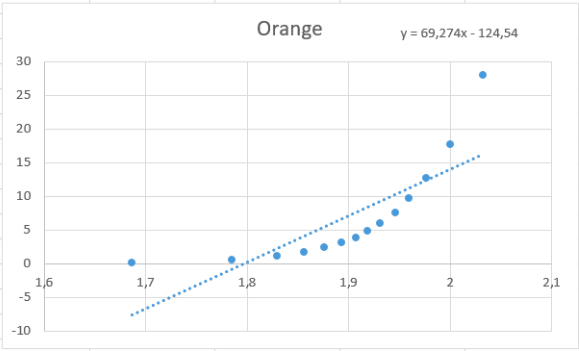
|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Green | U[V] | I[mA] | λ[nm] |  | ( | | h | | (h) | |
| Resolution | 0,001 | 0,1 | 1 | 1,91 | 0,55 | | 4.31e-34 | | 1.05e-24 | |
| 1 | 0.022 | 0 | 560 |  | |  | |  | |
| 2 | 0.48 | 0 |  |
| 3 | 0.727 | 0 |  |
| 4 | 0.976 | 0 |  |
| 5 | 1.224 | 0 |  |
| 6 | 1.475 | 0 |  |
| 7 | 1.695 | 0.04 |  |
| 8 | 1.794 | 0.48 |  |
| 9 | 1.835 | 1.07 |  |
| 10 | 1.859 | 1.66 |  |
| 11 | 1.879 | 2.37 |  |
| 12 | 1.897 | 3.07 |  |
| 13 | 1.912 | 3.84 |  |
| 14 | 1.927 | 4.88 |  |
| 15 | 1.937 | 5.97 |  |
| 16 | 1.951 | 7.63 |  |
| 17 | 1.967 | 9.59 |  |
| 18 | 1.98 | 12.43 |  |
| 19 | 1.998 | 17.67 |  |
| 20 | 2.023 | 28.09 |  |



|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Red | U[V] | I[mA] | λ [nm] |  | ( | | h | | (h) |
| Resolution | 0,001 | 0,1 | 1 | 3,56 | 0,37 | | 3.45e-34 | | 5.85e-35 |
| 1 | 0.021 | 0 | 616 |  | |  | |  |
| 2 | 0.483 | 0 |  |
| 3 | 0.726 | 0 |  |
| 4 | 0.97 | 0 |  |
| 5 | 1.22 | 0 |  |
| 6 | 1.467 | 0 |  |
| 7 | 1.668 | 0.12 |  |
| 8 | 1.742 | 0.58 |  |
| 9 | 1.782 | 1.2 |  |
| 10 | 1.809 | 1.82 |  |
| 11 | 1.83 | 2.47 |  |
| 12 | 1.85 | 3.21 |  |
| 13 | 1.868 | 3.99 |  |
| 14 | 1.887 | 4.96 |  |
| 15 | 1.906 | 6.16 |  |
| 16 | 1.927 | 7.61 |  |
| 17 | 1.953 | 9.61 |  |
| 18 | 1.983 | 12.46 |  |
| 19 | 2.25 | 17.26 |  |
| 20 | 2.09 | 27.04 |  |



|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Blue | U[V] | I[mA] | λ [nm] |  | ( | h | (h) |
| Resolution | 0,001 | 0,1 | 1 | 1,61 | 0,40 | 4,03e-34 | 2.03e-35 |
| 1 | 0.0234 | 0 | 447 |  |  |  |
| 2 | 0.491 | 0 |  |
| 3 | 0.729 | 0 |  |
| 4 | 0.971 | 0 |  |
| 5 | 1.226 | 0 |  |
| 6 | 1.489 | 0 |  |
| 7 | 1.724 | 0 |  |
| 8 | 1.972 | 0 |  |
| 9 | 2.207 | 0 |  |
| 10 | 2.46 | 0 |  |
| 11 | 2.653 | 0.12 |  |
| 12 | 2.761 | 0.54 |  |
| 13 | 2.82 | 1.14 |  |
| 14 | 2.866 | 1.85 |  |
| 15 | 2.906 | 2.67 |  |
| 16 | 2.949 | 3.83 |  |
| 17 | 2.987 | 5.04 |  |
| 18 | 3.041 | 7.12 |  |
| 19 | 3.111 | 10.46 |  |
| 20 | 3.206 | 15.96 |  |



|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Orange | U[V] | I[mA] | λ [nm] |  | ( | h | | (h) |
| Resolution | 0,001 | 0,1 | 1 | 1,92 | 0,21 | 4.34e-34 | | 3.36e-35 |
| 1 | 0.023 | 0 | 574 |  |  | |  |
| 2 | 0.476 | 0 |  |
| 3 | 0.733 | 0 |  |
| 4 | 0.996 | 0 |  |
| 5 | 1.224 | 0 |  |
| 6 | 1.472 | 0 |  |
| 7 | 1.687 | 0.07 |  |
| 8 | 1.785 | 0.51 |  |
| 9 | 1.83 | 1.1 |  |
| 10 | 1.856 | 1.68 |  |
| 11 | 1.876 | 2.35 |  |
| 12 | 1.893 | 3.11 |  |
| 13 | 1.907 | 3.88 |  |
| 14 | 1.919 | 4.87 |  |
| 15 | 1.931 | 5.95 |  |
| 16 | 1.946 | 7.6 |  |
| 17 | 1.96 | 9.67 |  |
| 18 | 1.977 | 12.65 |  |
| 19 | 2 | 17.73 |  |
| 20 | 2.033 | 27.95 |  |

**Calculations:**

**Deriving Planck’s Constant**

Planck’s Constant is calculated for each data set by the equation:

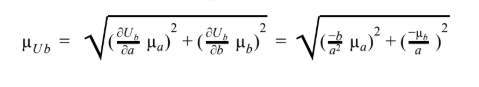
where potential barrier is calculated by:

Variables from *y=ax+b* line fit. (U vs I)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Green | Red | Blue | Orange |
| a | 69.83622174 | 44.53210712 | 20.32014952 | 69.27397902 |
| b | -125.901761 | -77.40105596 | -54.23981351 | -124.5405601 |
|  | 16.21 | 7.53 | 4.056 | 14.95 |
|  | 30.90 | 14.3 | 11.74 | 28.43 |

**Uncertanities**

Uncertanity of potential barrier calculated by:



Uncertanity of Planck’s Constant calculated by:

**CONCLUSION**

Planck’s constant was determined by measuring the energy emitted by a selected number of light emitting diodes. A spectrometer was used to measure the wavelength of the light emitted by each LED. A measure of voltage drop across each light emitting diode was used to Planck’s constant by relating it to the energy absorbed/emitted by the diodes through calculating it from the wavelength and voltage. It was found to be approximately similar to the theoretical value whereby it was concluded that the proposed method can be used to determine the wavelength of light emitted by unknown LED.

**RESULTS AND DISCUSSION**

The purpose of this study was to determine Planck’s constant using the energy needed to excite free electrons in a light emitting diode. In this work, an electric current was used to excite electrons and the corresponding energy was measured using a voltmeter as it was emitted.