Measurement of Plancks' Constant

Objectives

At the end of this activity you should be able to:

1.) Construct simple circuit on breadboard with resistor and LEDs.
2.) Measure the threshold voltage to apply in an LED to light up.
3.) Compute for the Plancks constant using several colors of LEDs.

Introduction

Planck constant *h* is a fundamental and universal constant named after Max Planck to explain blackbody radiation. Planck proposed that the energy of an emitted photon is *hf*, hence the Planck's formula $E = hf$. In 1905, Albert Einstein used the Planck's quantization of energy principle to explain the photoelectric effect where it cannot be explained by classical models. For this, Einstein received the Nobel Prize in Physics in 1921. Planck constant became the cornerstone of quantum physics.

Currently, the most accurate value for Planck's constant is 6.62607554 x 10-34 J · s. In this experiment, we will use light emitting diode (LED) to measure Planck constant. LED is a solid state device, which emits electromagnetic radiation from ultraviolet (UV) to near infrared. The commonly used LEDs such as red, yellow, orange, blue, violet and ultraviolet will be used in this experiment.

Theory

The electrical property of an atom can be represented by an energy level diagram, wherein the horizontal line in these diagrams represents the allowed energies that an electron in the atom can possess. In a semiconductor, electrons tend to occupy the lowest possible allowed and available energies. When the electrons receives extra energy from other source such as incoming photons, the electron gets excited and move to the conduction band which is not in their ground state. The electrons tend to relax back to the valence band and recombine with hole. The recombination of the electrons and hole produces emission of light. Since electrons in an atom can have only finite number of energies, hence, atoms can only emit finite number of light during the transitions.

Energy levels in a solid are closely spaced that forms energy band. Valence band is the lower group of energy levels while conduction band is the upper group of energy levels. At the conduction band, electrons are free to move and conduct electric current through the material. Current flows through the material if there are a large number of electrons in the conduction band, and the supply of energy to the electrons at the valence band is sufficient to overcome the energy gap. External source like batteries are used to supply these energies to the electrons.

LED emits electromagnetic radiation in optical and near optical frequencies when there is an applied voltage, and light is only emitted when the voltage is forward biased and above a *minimum threshold*. These conditions create an electron-hole pair in a diode, where electron-hole pairs are charge carriers and move when placed in an electrical potential. Thus, the current flows, and above the threshold value the current increases exponentially with voltage. Electron-hole pair can be created with quanta of energy and this energy is released when an electron and a hole recombine. In LED's this quanta of energy produces a photon of discreet energy $E = hf$, as proposed by Planck where h is the Planck constant and f is the frequency of emitted photon. Multiple states are excited by increasing the voltage across a diode, photons of increasing energies are emitted with increasing voltage. The light emitted by an LED is in discrete wavelengths that decrease with increasing voltage above the threshold voltage. That is, the shorter the wavelength the higher the energy. In an LED, the energy needed so that the electron and hole will recombine is given by

$$E = eV_o \tag{1}$$

where e is the electron charge $e = 1.60 \times 10^{-19}$ Coulomb and V is the minimum voltage needed. In this experiment, we can measure directly the minimum voltage V_o. Then the Planck's constant can be calculated by

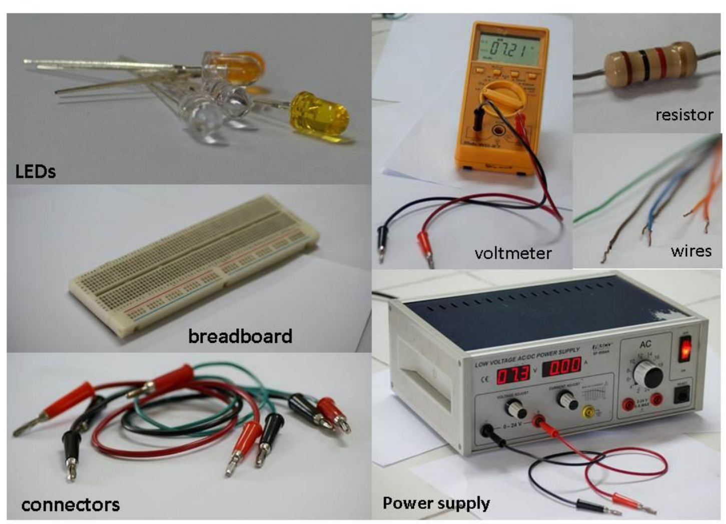
$$h = \frac{e\lambda V_o}{c} \tag{2}$$

where c is the speed of light $c = 299\ 792\ 458$ m/s and λ is the wavelength of the emitted light.

Materials

1. Different colors of LEDs
2. Power supply
3. Voltmeter
4. Resistor
5. Breadboard
6. Connectors and extra wires

Figure 1. Materials needed for measurement of Plancks Constant measurement.



Procedure

1. Construct the simple circuit of resistor, power supply, voltmeter and LED on the breadboard as shown on the diagram below. The voltmeter must be connected in parallel to the LED.

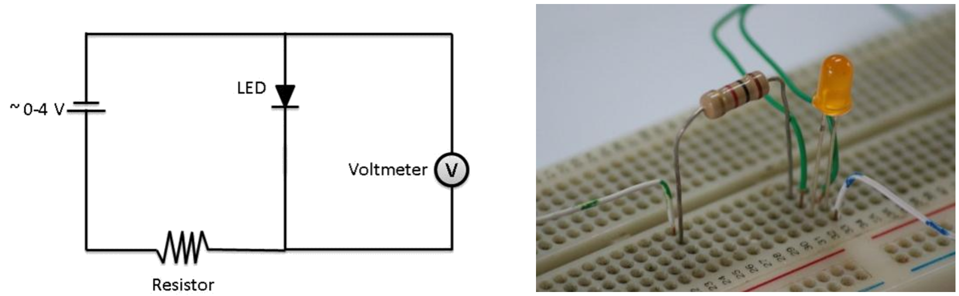


Figure 1. (a) Circuit diagram and (b) actual set-up.

2. Before connecting the power supply, make sure that the output voltage must be set to *zero.* And the knob for the output current must be in maximum so that the power supply must be in constant current mode.
3. Connect the **red** LED on the circuit.
4. Turn the voltage knob slowly until the LED emits light.
5. Take the voltage reading from the voltmeter as the minimum voltage V_o for the **red** LED on data table I.
6. Repeat procedure 3 to 5 for other LEDs such **yellow**, **yellow-orange**, **blue** and **UV**.
7. Solve for the value of the Planck's constant based on the minimum voltage given by equation 2.
8. Compare the computed Planck's constant to the more accepted value.

References

- Ducharme, Stephen *Measuring Planck's constant*, 1999
- Young, H., Freedman, R., University Physics with Modern Physics 12th Edition. Pearson Addison-Wesley Publishing Co. USA (2008)

Name	Date Submitted	Date Performed	Score
Group Members			
Instructor		Section	

Worksheet: Measurement of Planck’ s constant

Data Summary

LED	V_o	λ*	h_{exp}	error
Red				
Orange				
Yellow-orange				
Yellow				
Blue				
Ultraviolet (UV)				

λ*- the wavelength will be given from the previous experiments such as determination the wavelength of LED.

Constants

$e = 1.60 \times 10^{-19}$ Coulomb

$c = 299\ 792\ 458$ m/s

Computations