PLANCK’S CONSTANT EXPERIMENT

Short description:
Planck’s constant is a fundamental physical constant used to describe the energy of a photon. The existence of a smallest unit of light energy is one of the foundations of quantum mechanics. The photon energy is given by

\[ E = hf = h \frac{c}{\lambda}, \]

where \( h \) is Planck’s constant and \( f \) and \( \lambda \) are the frequency and wavelength of the photon.

In this laboratory experiment, you will measure Planck’s constant by measuring \( E \) and \( \lambda \).

The source of the photons is a light emitting diode (LED). A diode is an electronic device that allows current to preferentially flow in one direction. A semiconducting diode consists of two types of semiconductors (p-type and n-type) sandwiched together. The electronic energy levels consist of a valence band and a conduction band with an energy gap. Current flows through the diode when the forward voltage across the diode exceeds a threshold value, \( V_0 \). At this voltage, electrons in the conduction band make transitions to the valence band in the p-n junction. In a light emitting diode, this energy difference is converted to a photon with energy \( E = eV_0 \).

Equipment:

- Optical bench and meter stick
- LEDs with 1000Ω resistor mounted (green, yellow, red)
- Grating
- White plastic holders for optical bench
- Multimeter, Pasco power supply, 2 alligator cables, 2 banana cable.

Preliminary questions:

1. The turn-on voltage for a light emitting diode is 2.1 volts. What is the wavelength of the light? What is its color?

2. Refer to Fig. 2 in the laboratory procedures. If the diffraction grating has 1000 lines per mm, \( x = 0.3 \text{ m} \), and \( y = 0.5 \text{ m} \), what is the wavelength of the light source?
Procedure:

In the laboratory room, there are a collection of LEDs which emit light at various colors. Pick three different colors types by using the LED tester to view the emitted light. For each LED measure the threshold voltage and the emission wavelength.

1. Measurement of threshold voltage:

Use the circuit below and to measure the threshold voltage of the LEDs with the hand multimeter. Insert the LED in the white plastic holder set in the optical bench. Connect the red/black outputs of the plastic support to the Pasco DC power supply. Connect the mutimeter to measure the DC voltage across the LED. Gradually increase the current through the LED by increasing the supply voltage until light emission barely becomes visible. The voltage measure with the multimeter at this point is $V_0$. If the LED does not light up, then reverse the cable connections at the power supply.

![Figure 1. Circuit for measuring LED threshold voltage.](attachment:figure1.png)

2. Measurement of wavelength:

The wavelength of the light from the LED will be measured with a diffraction grating using the setup below.

![Figure 2. Setup for measuring wavelength of light from LED.](attachment:figure2.png)
Place the meter stick on one end of the optical bench and perpendicular to it. Place the grating on its support and position it on the opposite end of the optical bench. Adjust the distance between the grating and meter stick (y) to about 50 cm.

One lab partner will look at the LED through the grating. In addition to the central image, there should be the 1st order diffraction images to the right (or the left) of the central image. The diffraction images will have some angular spread since the light emitted by the LED has some distribution of wavelengths. A second lab partner will stand behind the meter stick and move a pencil along the meter stick to determine the position (x) of the center (same color of the LED) of the first order diffraction image as described by the observer.

Calculate $\theta$ using \( \tan \theta = \frac{x}{y} \). Now using the d-spacing of the diffraction grating, calculate $\lambda$ using \( m\lambda = d \sin \theta \). (You will have two different measurements of $\lambda$ for each LED, one from each of the diffraction images.)

Repeat for the other two LEDs.

**Grating:** Number of lines per mm = ________, \( d = \) ________ m

<table>
<thead>
<tr>
<th>Color</th>
<th>( V_0 ) (volt)</th>
<th>( x ) (m)</th>
<th>( y ) (m)</th>
<th>( \theta ) (deg)</th>
<th>( \lambda ) (nm)</th>
<th>( h ) (J·s)</th>
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Average value of $h = \__________$ J·s

**Questions**

1. How does your average value of \( h \) compare with the expected value \( h = 6.63 \times 10^{-34} \) J·s?

   Percentage error: \( \left( \frac{|h - h_{\text{exp}}|}{h_{\text{exp}}} \right) \times 100 = \__________ \)

2. What are some of the major sources of error in your measurements?