Course and Section_______ Names ____________________________

Date___________ __________________________________

# PLANCK'S CONSTANT EXPERIMENT

## Introduction

In this experiment you will measure the numerical value of Planck's constant *h* using an LED and a diffraction grating.

## Equipment

Optical bench, meter stick, LEDs with 1000Ω resistor mounted (green, yellow, red), plastic holder, diffraction grating, power supply, multimeter + 1 lead, 1 alligator cable, 2 banana cables.

## Theory

Planck's constant *h* is a fundamental constant of quantum physics. For example it used to describe the energy of a photon which is smallest unit of energy of light of a given frequency. The photon energy is

$$E = hf = h\frac{c}{\lambda}$$

where *h* is the Planck's constant, *f* and $\lambda$ are the frequency and wavelength and *c* is the speed of light in vacuum. In this experiment, you will measure Planck's constant by measuring *E* and λ. 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. Current flows through the diode when the forward voltage across the diode exceeds a threshold value $V_0$. At this voltage the energy of the emitted photon is $E = eV_0$ where *e* is the elementary electric charge.

## 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 m, and *y* = 0.5 m, what is the wavelength of the light source?

**Procedure**

In the laboratory room you will use there LEDs which emit light of different colors red, blue and green.

*Step 1.* Pick one of the LED connected to its holder and insert it the white plastic support. It does not matter which color you start with.

*Step 2.* Place the white plastic support at one end of the optical bench.

*Step 3.* Connect the LED to the power supply using the two cables. Connect the multimeter to the LED using the alligator cables. You want to use the multimeter to measure the voltage across the LED only and not the voltage across of the series combination of the LED and the resistor *R*.

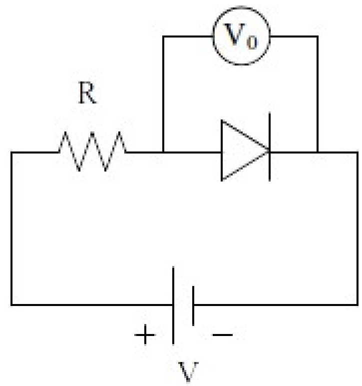


Fig. 1

*Step 4.* Gradually increase the current through the LED by increasing the supply DC 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. Use the table in the next page to collect your data.

Next you want to measure the wavelength of the light emitted by the LED. To do so you will use a diffraction grating and set up the equipment as showed below.

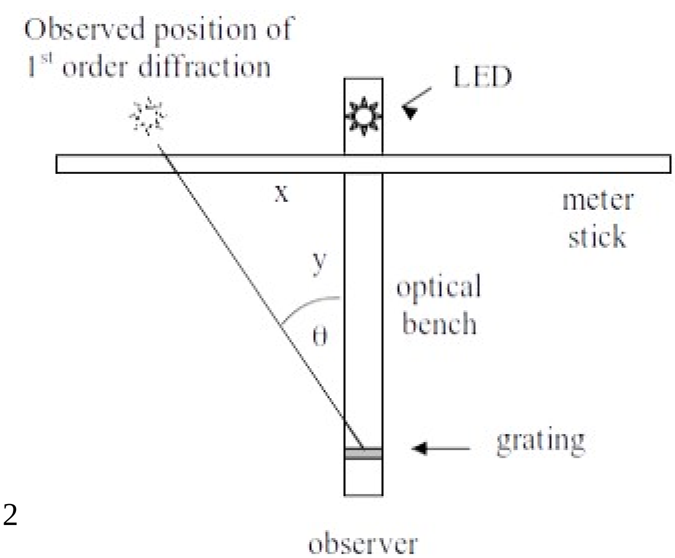


Fig. 2

*Step 5.* Place the meter stick on one end of the optical bench and perpendicular to it.

*Step 6.* Place the grating on the other end of the optics bench. Adjust the distance between the grating and meter stick *y* to about 50 cm.

*Step 7.* One lab partner is the observer and look at the LED through the grating. In addition to the central image, there is the $1^{st}$ order diffraction images to the right (or the left) of the central image. The image will look like a short line, having an angular spread because the light emitted by the LED has small distribution of wavelengths. A second lab partner moves a pencil along the meter stick to locate the position of the image. The value of $x$ is the distance between the LED (at the center of the optical bench) and this $1^{st}$ order diffraction image.

*Step 8.* Calculate the angle $\theta$ using $\tan\theta = x/y$.

**3.** What is the number of lines per mm indicated on your diffraction grating?

$N =$

**4.** The spacing between the lines $d$ is obtained as $d = 1/N$

$d =$ _______ (m)

## Analysis

To calculate the wavelength use $m\lambda = d \sin\theta$ with $m = 1$. Then repeat all the measurements using the other two colors of the LED.

**5.** Collect your data here

| LED color | $V_0$ (volt) | $x$ (m) | $y$ (m) | $\theta$ $^o$ | $\lambda$ (m) | $1/\lambda$ ($m^{-1}$) |
|---|---|---|---|---|---|---|
| Red | | | | | | |
| Yellow | | | | | | |
| Green | | | | | | |

By equating the energies of the two equations we obtain $eV_0 = h\frac{c}{\lambda}$ or $V_0 = \left(\frac{hc}{e}\right)\cdot\frac{1}{\lambda}$ .

**6.** Make a plot of $V_0$ vs $1/\lambda$, that means $V_0$ on the $y$-axis and $1/\lambda$ on the $x$-axis. Do a linear fit and find the slope

*slope* =

**7.** Calculate $h$ from the slope and knowing that $c = 3.0 \times 10^8$ m/s and $e = 1.6 \times 10^{-19}$ C

$h =$ ________ J·s

**8.** Calculate the %error with the actual value of $h = 6.626 \times 10^{-34}$ J·s

%error = ______

**TURN OFF POWER SUPPLY AND RETURN THE LEDs TO THE MAIN DESK**