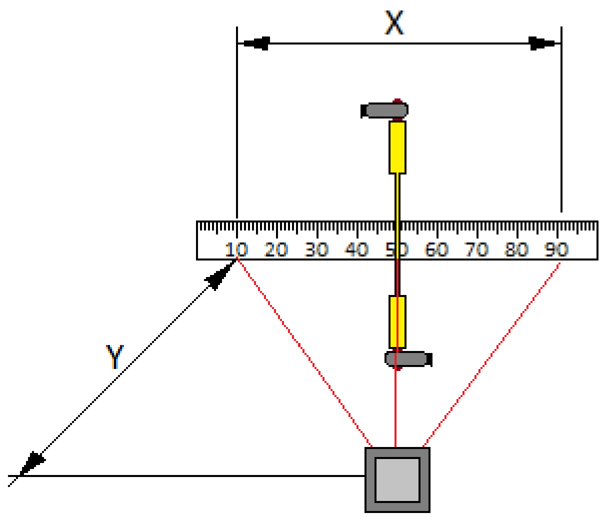
Modern Physics Lab

Determining Planck's constant with LEDs

First experiment

Purpose: Observe and measure the wavelength of different elements. This will allow us to determine the spectrum of LEDs in the second experiment.

Procedure: Mount the experiment as shown below with a discharge tube.



The discharge tube should be placed in front of the meter stick coinciding with the 50cm mark. This is not crucial, but convenient for symmetry.

The diffraction grating should be mounted on a line perpendicular to the ruler at a distance Y. Notice that the distance is from the ruler to the grating, not from the lamp.

When observing through the grating, you should be able to see the diffraction lines from the lamp.

Identify the observed spectrum and calculate the wavelengths based on the geometry of the experiment.

The equation to be used is

$$n\lambda = d\sin\theta$$

Where n is an integer (in our case we will only use $n = 1$), d is the distance between the slits in the grating (of the order of 1 micron, please check) and the angle θ is between the line of sight to the center of the meter stick and the spectral line, which you can calculate with the equation:

$$\theta = \tan^{-1}\left(\frac{X}{2Y}\right)$$

Here Y is the distance mentioned above between the meter stick and the grating and X is the distance between the spectral lines formed on the left and right of the lamp.

Table of expected spectral lines for mercury

Lambda (nm)	Intensity	Color
404.7	Medium	Violet
407.8	Medium	Violet
435.9	Strong	Violet
491.6	Weak	Blue-green
546.1	Strong	Green
577.0 - 579.0	Strong	Yellow (double)

Table for helium

Lambda (nm)	Intensity	Color
402.6	Weak	Violet
438.8	Weak	Blue-Violet
447.1	Strong	Blue
471.3	Medium	Blue
492.2	Medium	Blue-green
501.6	Strong	Green
587.6	Strong	Yellow
667.8	Medium	Red
706.5	Strong	Red

Table for hydrogen

Lambda (nm)	Intensity	Color
410.2	Weak	Violet
434.1	Weak	Violet
486.1	Medium	Blue-green
656.3	Strong	Red

Second experiment

Planck's constant using LEDs

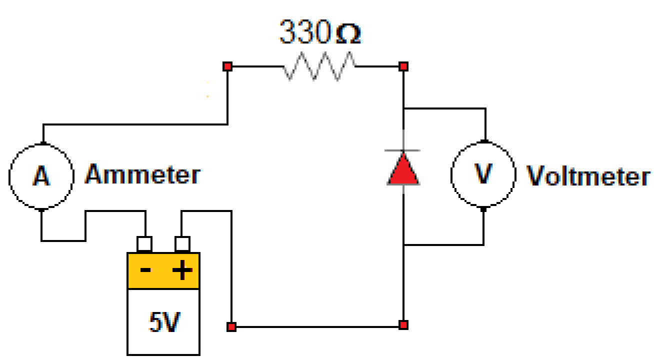
Theory: Max Planck indicated that the quantum energy of light is a constant *h* times the frequency of the wave.

$$E = hf$$

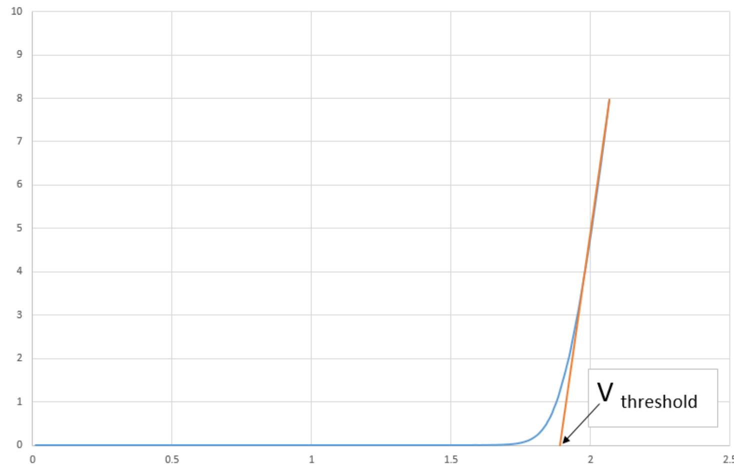
We also know that the frequency times the wavelength is the speed of light, so we can determine the wavelength using the technique of the first experiment and then calculate the frequency:

$$\lambda f = c \rightarrow f = \frac{c}{\lambda}$$

Procedure: Build a circuit with LED, resistance and voltage source to measure current and voltage on the diode for values of the source between 0 and 10V. Do not exceed 15mA in the LED to avoid shortening its life. Here is a schematic of a possible circuit:



Once you have the data do a linear regression from the curve I vs. V and find the threshold voltage (V_{th}) on the X-axis. Alternatively plot V vs. I and find the Y-intercept. Be sure to only use the linear part of the curve. Example below:



Mount the LED in place of the lamp from experiment 1. You will notice that the spectrum is not a line, it has some width, so you will have to determine the dominant wavelength of its spectrum. Do the same for other LEDs and then calculate the energy by multiplying the threshold voltage times the charge of the electron.

Based on these results you will get Planck's constant with the equation:

$$h = \frac{e\lambda V_{th}}{c}$$

Compare to the accepted value and see if the error can be explained by the uncertainties in the measurements.

Note: You can use a laser with known wavelength to confirm the precision of the first experiment.