PHY 124 Lab 9 - Atomic Spectra

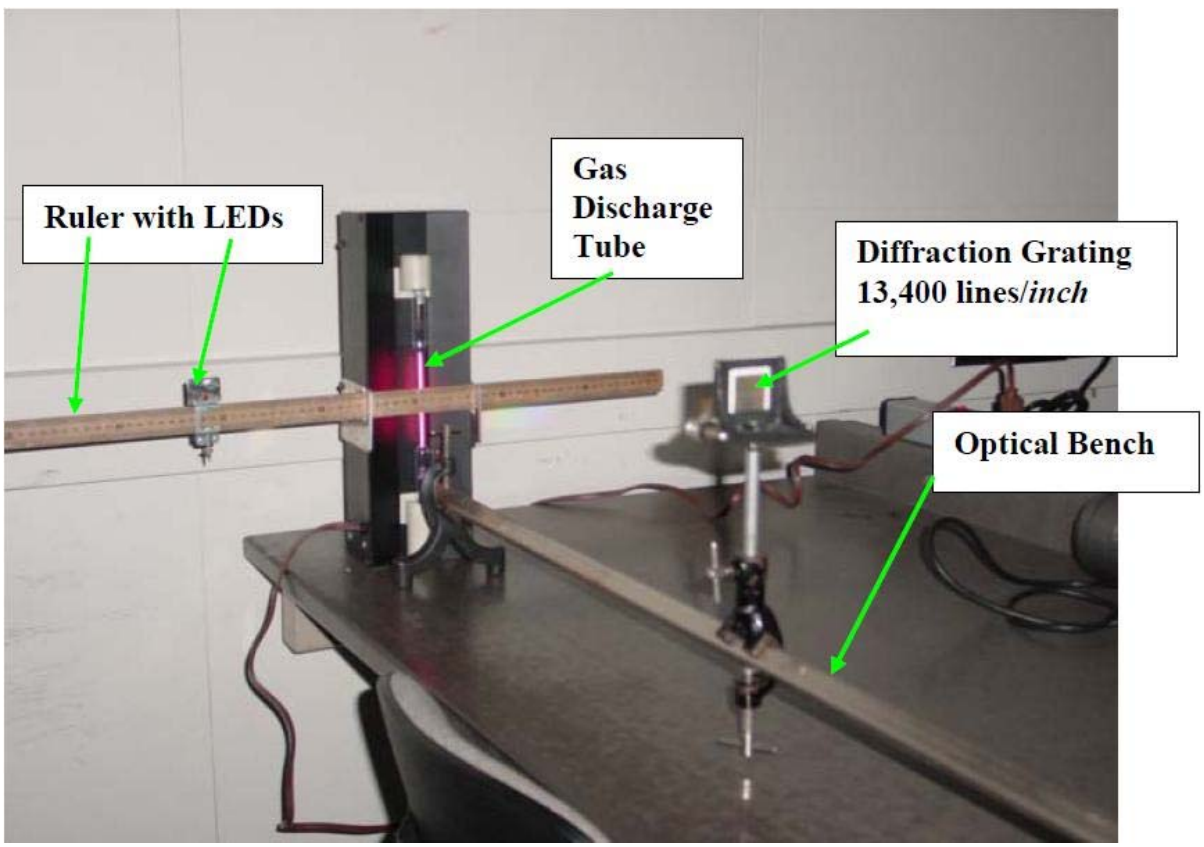
The purpose of this laboratory is to study energy levels of the Hydrogen atom by observing the spectrum of emitted light when Hydrogen atoms make transitions to lower lying energy levels. You use a diffraction grating to measure the wavelengths.

Important! You need to print out the 2 page worksheet you find by clicking on this link and bring it with you to your lab session. [http://www.ic.sunysb.edu/Class/phy122ps/labs/dokuwiki/pdfs/124lab9worksheet.pdf]

If you need the .pdf version of these instructions you can get them here [http://www.ic.sunysb.edu/Class/phy122ps/labs/dokuwiki/pdfs/phy124lab9.pdf].

Equipment

- Optical Bench
- Diffraction Grating
- Ruler with light emitting diodes mounted
- Gas Discharge Tube with Hydrogen Gas (our light source)
- Small ruler to measure the distance "y" in Fig 2. accurately (at the end)



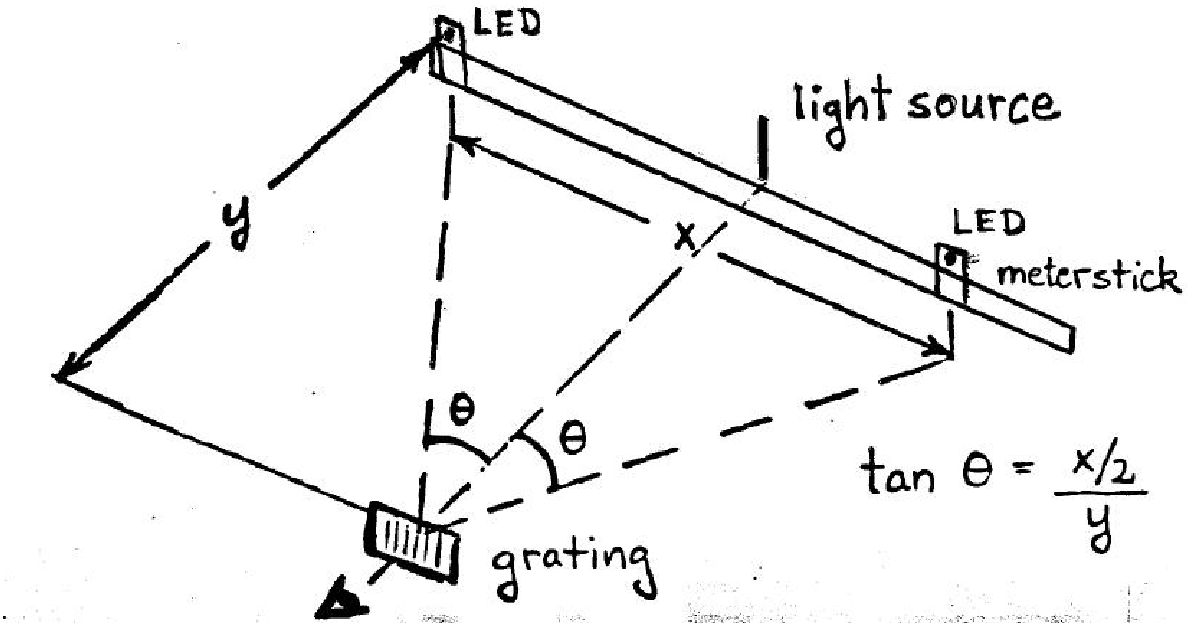
Introduction

A plate with very many closely-spaced slits is called a diffraction grating (see Ch21 sheet 28' and 29). If the slit spacing is d, then the wavelength(s) $\lambda$of light diffracted by the grating can be determined from the equation in Ch21 sheet 28';

$$d \sin\theta = m\lambda$$
(9.1)

We use a diffraction grating (13,400 lines per inch) to measure several wavelengths of the discharge spectrum of hydrogen, which are emitted with intensities such that they can easily been seen for this experiment. The whole apparatus is called a spectroscope. It consists of the light source, the grating, an optical bench and a meter stick. Two adjustable light-emitting diodes (LEDs) are mounted on the meter stick. The LEDs will be used to locate the position of the "spectral lines", which are the interference maxima for specific wavelengths and hence specific colors, under study. In the previous experiment you were using a monochromatic light source, so all the diffracted maxima and minima of different orders were the same color

The geometry of the setup to measure the angles pointing to a specific part of the spectrum is illustrated in the figure below.



The angle θ can be calculated from the distance x between interference maxima of the same order m and same wavelength λ (color), and the distance y between the grating and the ruler with the LEDs,

$$\tan\theta = \frac{x}{2y}$$
(9.2)

Be careful when using this formula! You must remember that you are measuring the distance x, but Eq. (9.2) requires you to use the distance (x/2). This is because the distance to the maxima is always taken with respect to the central maximum, which is this case is the light source itself.

Use Eq. (9.2) to determine θ for each spectral line, and then use Eq. (9.1) to find the wavelengths λ .

Part I: Qualitative Study of the Diffraction Grating

The purpose of this part is to observe the interference orders m which are visible with the diffraction grating

The room has to be dark. Your TA will turn off the lights when all groups are ready to take data.

Turn the LEDs and the hydrogen spectrum tube on. The gas discharge tubes lose effectiveness the longer they are turned on, so when you don't observe the spectral lines please turn the tube power off! The same holds for the LED power.

Set the distance between Hydrogen tube and diffraction grating to ~ 45 cm. Make sure the tube is centered on the optical bench and the grating is perpendicular to the bench. Look through the grating at the tube. On both sides of the tube you see, apart from a continuum spectrum (This will appear as a rainbow that has a much lower intensity than the maxima.), several sharp colored spectral lines – a purple, a blue-green and a red line (disregard the line in the green-yellow region in case it occurs, it is due to contamination of the hydrogen gas). You can move your head slightly such that you see lines further away from the center. You should see at least 2 full orders (the "m" in equation (9.1)). Make sure you see the m = 2 order red line (the second bright red line) still on the ruler.

Choose either the left or right side, ask your lab partner to position the LED light on the maxima line for each color. This can be done quickly and does not have to be accurate since the recorded positions will only be used to make an approximate sketch. Record the positions of the lines with colors and order, and the position of the gas tube on your worksheet.

Make a sketch of all lines along the horizontal meter stick with their approximate distances from the tube and label their colors and their orders m. Explain the sequence of colors and orders in terms of equation (9.1).

Part II: Quantitative Study of the Hydrogen Spectral Lines

The theoretical equation given below is called the Balmer formula:

$$\frac{1}{\lambda_n} = R_H\left[\frac{1}{2^2} - \frac{1}{n^2}\right] \text{ n=3,4,5,..}$$
(9.3)

R_H is a quantity called the Rydberg constant, $R_H = 1.097 \times 10^7 m^{-1}$

We are going to measure the Rydberg constant by plotting $\frac{1}{\lambda}$vs $\frac{1}{2^2} - \frac{1}{n^2}$. We will determine $\frac{1}{\lambda}$from the positions of the spectral lines.

In your lab prep exercise you will calculate the value of d; the answer is required for the analysis of the data. The number of grooves per inch of the diffraction grating is 13,400. Calculate the slit distance in meters from it. This will give the value of d. Be careful with units! Not only do you have to convert from inches to meters, but you also must notice that the units of grooves per inch is one over length.

Move the diffraction grating to ~ 60 cm from the tube. This is the distance "y" in the Fig.2 above which defines the geometry of your set up. Record y accurately and estimate its error.

Place your observing eye very close to the grating and keep it centered on it. You should be able to see the full first order spectrum on both sides by only turning your eyes without moving your head. Have your partner place the LEDs at the positions where the maxima appear on both the left and right sides of the discharge tube. Record the position of the first order lines for all three colors, left and right of the tube, now with more accuracy than you did in Part I. Make sure the LED is placed such that the maxima line in question passes through the center of the LED. Note that the errors are substantial, probably about 3-4 mm is appropriate.

Enter your readings and errors in the table on your worksheet.

Calculate the difference (left position – right position) and its error according to equation (E.6) in Error and Uncertainty.

Calculate the angle θ from equation (9.2) above and the wavelength λ from θ using equation (9.1) and the known value of d.

To find the error in λ.

Propagate the error in x and y into the error of (x/2y) according to equation (E.7) in Error and Uncertainty. For the error in λ assume that it has the same relative error as (x/2y).

Now convert λ into 1/λ.

The relative errors of λ and 1/λ are the same (and are the same as the relative error in x/2y). So to find the absolute error in 1/λ you need to take the relative error in x/2y and multiply it by 1/λ.

Enter your values for 1/λ and it's error in to the table below and click submit.

n=3 1/λ=		m^{-1}	Δ(1/λ)=		m^{-1}
n=4 1/λ=		m^{-1}	Δ(1/λ)=		m^{-1}
n=5 1/λ=		m^{-1}	Δ(1/λ)=		m^{-1}

submit

The computer plots $\frac{1}{\lambda}$vs $\frac{1}{2^2} - \frac{1}{n^2}$.

From the slope of your plot, find an experimental value for R_H. Compare your value for R_H and its error to the textbook value quoted above, are they consistent?

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