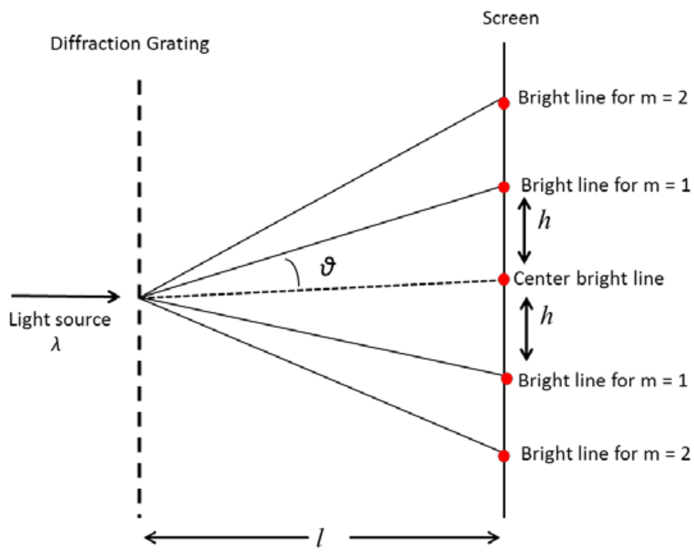
PHYS 1040 - General Physics II Lab

Diffraction Grating

In this lab you will perform an experiment to understand the interference of light waves when they pass through a diffraction grating and to determine the wavelength of the light source.

INTRODUCTION AND THEORY:

Diffraction grating is an optical component with many slits (openings). These slits are very closely spaced and hence they produce on a screen a series of sharp, bright spectral lines of a given light source. The angles at which these bright lines (also called maxima) are produced is due constructive interference of light waves. A schematic of such a pattern is as shown below.



The condition for constructive interference (or maxima) is given as-

$$\boldsymbol{d \; sin\theta = m\lambda}$$

d = spacing between the slits
λ = wavelength of the light
m = order of the pattern and *m = 1, 2, 3 etc.*
θ = angle of diffraction with respect to the horizontal incident direction.

And, $tan\theta = \frac{h}{l}$ where h = vertical distance of the bright spot from the center
l = distance between grating and the screen

<u>Monochromatic source:</u> A light source which consists of only one single wavelength (spectral line). Example: Helium-Neon laser beam which emits light in red part of the visible spectrum.

<u>Polychromatic source:</u> A light source which consist of several spectral lines of various wavelengths. Example: Mercury vapor lamp which emits violet, blue, green, yellow and red wavelengths.

CHECKPOINT 1:
Discuss the following questions with your group and write your expectations and answers.

For a diffraction grating, if *N* = number of slits/mm, then $d = \frac{1mm}{N}$

1) If *N* = 600 slit/mm, calculate *d* (in meters).

For helium-neon laser source -

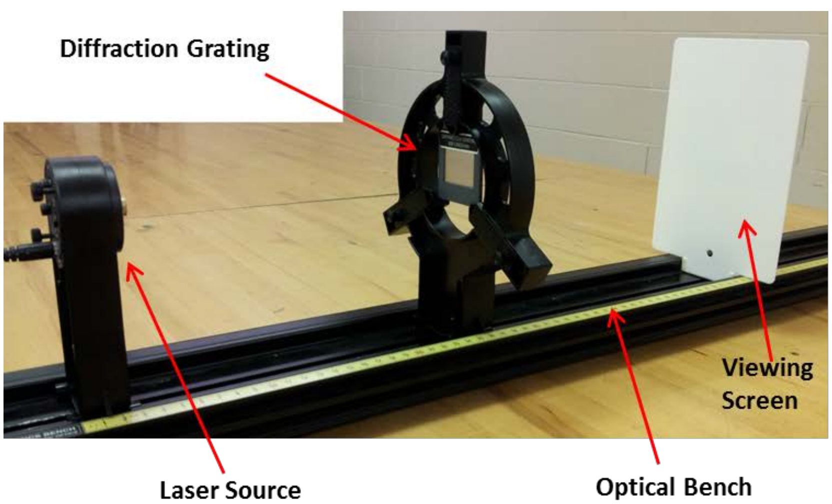
2) Explain in words the dependence of the angle θ on the order *m*.
3) Can you measure these angles without using a protractor? If so how? Explain in words.
4) In your lab notebook draw a diffraction pattern observed on a screen for the 1st and 2nd order spectra. This sketch should include all the experimental variables you plan to measure.

For mercury vapor lamp -

5) For 1st order spectral lines, explain in words the dependence of angle θ on the wavelength λ.
6) In your lab notebook draw a diffraction pattern observed on a screen for the 1st order spectra. This sketch should include all the experimental variables you plan to measure.

Show your TA your expectations before proceeding.

EQUIPMENT:
Figure 1 shown below for part-1 of the experiment with laser source:



Laser Source

Diffraction Grating

CAUTION – DO NOT LOOK INTO THE LASER SOURCE DIRECTLY!!!

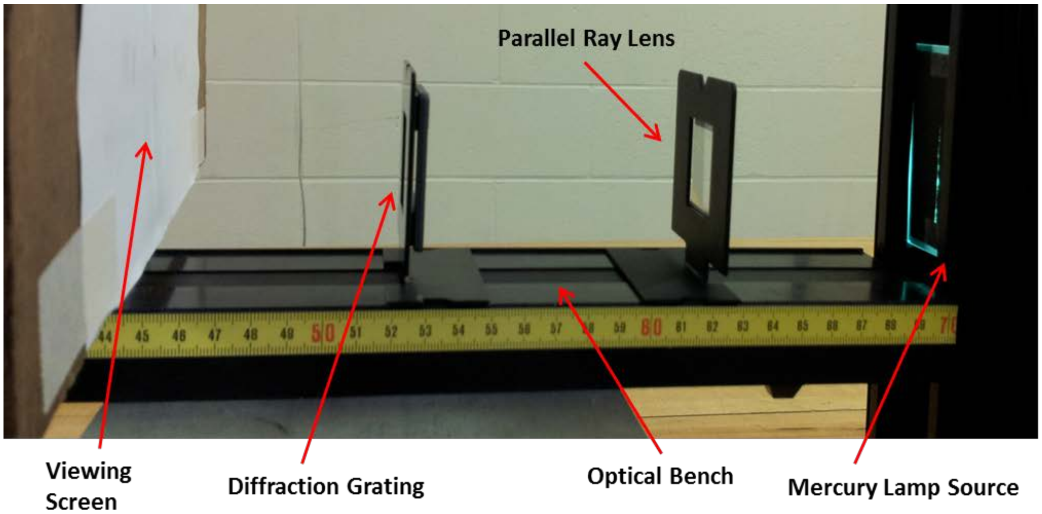
Laser Source: Serves as a monochromatic source which emits red color light.

Diffraction Grating: An optical component with many closely spaced slits (mounted on a holder).

Viewing Screen: Constructive interference pattern with bright spots can be observed.

Optical Bench: Provides the platform to mount the laser, diffracting grating and viewing screen. The distance between the grating and the viewing screen can be adjusted to obtain 1st and higher orders of the bright spots.

Figure 2 shown below for part-2 of the experiment with mercury vapor lamp:



Parallel Ray Lens

Diffraction Grating

Mercury Lamp Source: Serves as a source which emits violet, blue, green, yellow and red spectral lines.

Viewing Screen: Constructive interference pattern with bright lines can be observed.

Optical Bench: Provides the platform to mount the diffracting grating, parallel ray lens and viewing screen.

Parallel Ray Lens: A plano-convex lens which is used to focus the light from the mercury lamp to obtain a sharp and focused beam.

Note:
- The curved side of this lens should be towards the lamp.
- First, you have to line up the lamp, lens and the viewing screen without the grating to obtain a focused beam. You need to adjust the distance between the lens and screen to achieve this.

Diffraction Grating: An optical component with many closely spaced slits (mounted on a stand).

Note:
- Mount this on the optical bench only after you have obtained a focused beam from the lamp.

The distance between the grating and the viewing screen can be adjusted to obtain 1st and higher orders of the bright spectral lines.

EXPERIMENT

Part 1 – Conduct the experiment to determine the wavelength of the helium-neon laser.

Plan your experiment:

You need to create a data table in your lab notebook, deciding on number of columns to be included in the table. Record all the data you take, even though some data may not be within the expected value. This is an experiment and hence uncertainty is associated with any measurement.

CAUTION **– DO NOT LOOK INTO THE LASER SOURCE DIRECTLY!!!**
– TURN ON THE LASER BEAM ONLY WHILE TAKING DATA…
– MAKE SURE YOU TURN OFF THE BEAM…

Analyze your data performed in part 1 of the experiment:

- Does the angle of diffraction depend on the order?
- Calculate the wavelength (in nm) of the helium-neon laser.
- How well does your calculated value for λ agree with accepted value? Determine the percentage difference.

CHECK POINT 2:
Show your TA your experimental data and calculated wavelength of the laser beam from the part-1 of the experiment.

Part 2 – Conduct the experiment to determine the wavelengths of 1st order spectral lines of mercury vapor lamp.

Plan your experiment:
You need to create a data table in your lab notebook, deciding on number of columns to be included in the table. Record all the data you take, even though some data may not be within the expected value. This is an experiment and hence uncertainty is associated with any measurement.

Analyze your data performed in part 2 of the experiment:

- Does the angle of diffraction depend on the wavelength of the line?
- Calculate the wavelength (in nm) for each of the observed spectral line and provide a reasoned estimate of the uncertainty in your result.
- How well does your calculated values for λ agree with accepted values? Determine the percentage difference for each spectral line. Do any differences lie within your uncertainties?
- Suppose you change the orientation of the screen from vertical position to horizontal position, what can you conclude observing the path of the different spectral lines you see now?

CHECK POINT 3:
Show your TA your experimental data and calculated wavelengths for the mercury spectral lines from the part-2 of the experiment.

Part 3 – Spectrum from flashlight bulb:

If light from a flashlight strikes the diffraction grating –

- How does the diffraction pattern look?
- Make an observation for this case using a flashlight (e.g. on your cellphone camera) – you may need to remove other sources of light first.
- In your lab notebook draw a diffraction pattern for the 1st and 2nd order spectra for this case.

CHECK POINT 4:

- Show your TA your observations of the diffraction pattern for a flash light bulb from the part-3 of the experiment.

- Show your TA all the experimental data, analysis and observations for all parts of the experiment.
- Explain to the TA whether the measured data support your expectations.
- Do not leave the laboratory until you have collected all data that you need to write the report.

LAB REPORT – due one week after the lab.

The procedure you followed should be clearly written and all the data, analysis and diagrams of your observations should be included. Make sure you address the questions posed at the beginning of this handout, your expectations before conducting the experiment and use to your experimental data to support your conclusions. Your conclusion should indicate whether or not you were able to confirm your expectations. Finally describe 3 practical applications of diffraction.