Experiment 8

Index of Refraction

Preparation

Prepare for this experiment by reviewing old material and by reading about index of refraction, Snell's Law, prisms, continuous and discrete spectra.

Principles

When light passes at an angle from one medium to another it undergoes **refraction**. The **angle of incidence, Θ_1,** and the **angle of refraction, Θ_2**, are measured relative to the **normal** (a line perpendicular to the surface). If the indices of the two media are n_1 and n_2, respectively, Snell's Law states that:

$$n_1 \sin \Theta_i = n_2 \sin \Theta_r$$

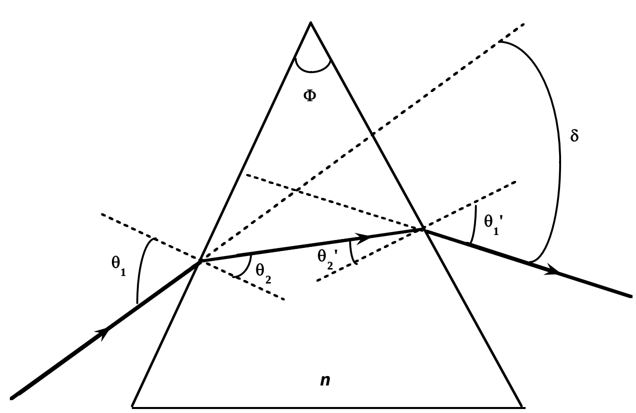
The **index of refraction, *n***, is the **ratio** of the **speed of light in vacuum to the speed of light in the medium:**

$$n = \frac{c}{v}$$

The index of refraction depends on the medium and on the **wavelength**, λ, of the light. Because of this a prism can be used to spread a beam of light and produce a **spectrum**.

A prism has an **apex angle, ϕ**. As light passes through the prism it will be deviated from its original path by an angle, Θ. If you change the angle of incidence Θ will change. At a particular angle of incidence the angle of deviation will be a minimum (Θ_{min}) for light of a particular wavelength. When this angle is known, the index of refraction for that wavelength can be found using the equation:

$$n(\lambda) = \frac{\sin \frac{1}{2}(\Theta_{min} + \phi)}{\sin \frac{1}{2}\phi}$$



In this experiment a prism spectrometer will be used to examine discrete spectra. Continuous spectra are produced when a source is heated. When the source is white hot, all visible wavelengths can be seen. Discrete spectra result from transitions of electrons in atoms and molecules. Since each element produces a unique set of spectral lines, this characteristic can be used to identify various substances. Spectral lines of gasses are easily produced by passing an electric current through the gas.

A spectrometer is an instrument used for analyzing spectra. The light source is placed close to a narrow slit. The light then passes through a collimating lens. The lens is placed so that the slit is at its focal point; this means that the rays leaving the collimating lens are parallel. These rays then pass through a prism which is placed in a holder in the center of the apparatus. A moveable telescope is used to bring the deviated rays to a focus so that they can be observed. The spectrometer is marked so that the angular deviation of the spectral lines can be measured.

Equipment

1 spectrometer
1 light shield
1 spectrum tube power supply
1 lab jack
1 helium spectrum tube
1 60° glass prism
desk lamp

Procedure

This experiment must be performed in the dark. It is important that each spectrometer be shielded from stray light sources. Measure angles to the nearest .1°.

1. Place the slit at 180°. Place the incandescent light against the slit. Adjust the cross-hairs on the telescope until they are in focus.

2. Adjust the spectrometer until you have a clear image of the slit. It may be necessary to move the slit toward or away from the collimating lens or to move the lens on the telescope.

3. Set the telescope at 0.0°. If the image of the slit does not appear at 0.0°, move the slit to one side or the other until it appears in the crosshairs. Tighten the clamp that holds the slit in place.

4. Place the helium tube in the spectrum tube power supply, plug it in and turn it on. Do not touch the tube while the power supply is on. If the tube makes a buzzing sound you do not have a good connection between the spectrum tube and the power supply terminals; ask your instructor for help.

5. Put the power supply on the lab jack and position it so that the narrow part of the spectrum tube is as close to the slit as possible. Look through the telescope to make sure the slit is illuminated. If it is not, gently move the spectrometer from side to side until the slit shows up clearly.

6. Place the prism in the holder and gently tighten the screws on the holder. **Do not tighten the screws on the holder very much; this will chip the edges of the prism, which is quite expensive.** The prism should be positioned so that one smooth face is nearest to the telescope and apex points toward the collimating lens. The spectrum will appear on the same side of the spectrometer as the frosted side of the prism. Look at the prism from the side and raise or lower the holder in order to get the maximum illumination. Find the spectrum with the unaided eye and then with the telescope.

7. Set the cross-hairs on the first red line. If the line is very faint, gently move the entire spectrometer back and forth to line the slit up with the light source. It may be necessary to refocus the telescope. Observe the line through the telescope while you slowly rotate the prism in its holder. When you rotate the prism you are changing the angle of incidence. Therefore Θ, the angle of deviation will also change. The line will move back and forth as you rotate the prism. Find the minimum angle of deviation for that line, that is, the smallest angle from 0° that it reaches. This is Θ_{min} for that wavelength. Set the crosshairs on the line and measure and record Θ_{min}.

8. Repeat the above procedure for every spectral line that you can find.

9. Turn everything off. Unplug everything and put it away. Be sure the spectrum tube has cooled before you remove it from the power supply.

Analysis

1. The apex angle, ϕ, of the prism is 60°.

2. Use $n(\lambda) = \dfrac{\sin\frac{1}{2}(\Theta_{min} + \phi)}{\sin\frac{1}{2}\phi}$ to find the index of refraction for each wavelength that you observed. Fudge a bit and calculate the indices of refraction to three decimal places. This isn't quite proper, but the results will show the effect better and make your graph look better. Show at least one sample calculation.

3. Make a graph of the index of refraction as a function of wavelength. The points will not fall on a straight line. Draw the smooth curve that best fits your results.