# Spectroscope and index of refraction

## 1 Object

To experimentally determine the index of refraction as a function of wavelength for two media and to become familiar with the spectroscope.

## 2 Apparatus

Spectroscope, mercury vapor light source, glass prism, water filled plastic prism, small lamp.

## 3 Theory

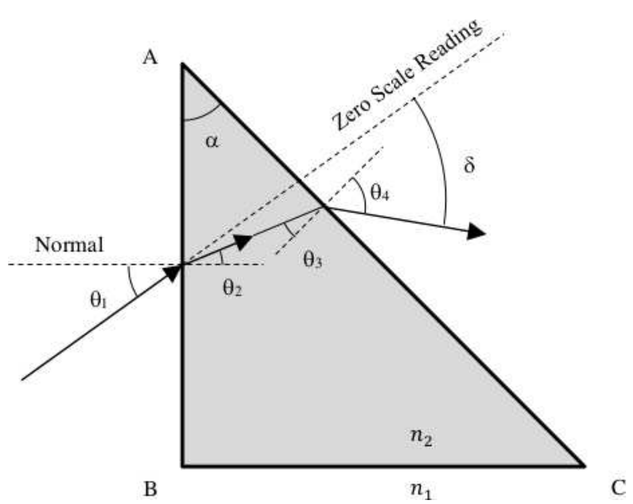


Figure 1: A ray of light incident from the left onto a prism of apex angle $\alpha$. The angle $\delta$ is the deviation of the ray from its incident direction, and should be minimized.

As white light (light composed of all wavelengths, or colors) passes through a prism, it is bent at each interface due to the difference in index of refraction across each interface. This is shown in figure 1. Recall that index of refraction, $n$, is defined as the speed of light in free space divided by the speed of light in the medium: $n = c/v$. Since white light is made up of many wavelengths, each color is bent a different amount at each interface due to the fact that the index of refraction is wavelength dependent. So, the prism breaks the light up into the full spectrum of colors. If light with only certain wavelengths is used, each wavelength is bent to a different angle. Refraction (bending) of light at such an interface is described by Snell's law:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \tag{1}$$

where $\theta_1$ is the incident angle measured with respect to the normal to the interface and $\theta_2$ is the refracted angle again measured with respect to the normal. Assuming the material the prism is made of is of index of refraction larger than air, light will bend toward the normal upon entering the prism, and will bend away from the normal upon exiting. Using Snell's law and some basic geometry, it can be shown that the index of refraction of the material, $n_2$, can be determined by knowing the apex angle $\alpha$ of the prism and the minimum possible angle of total deflection of the light as it passes through the prism, called $\delta_{min}$. The equation is:

$$\boxed{n_2 = n_1 \frac{\sin\left(\frac{\delta_{min}+\alpha}{2}\right)}{\sin\left(\frac{\alpha}{2}\right)}} \tag{2}$$

For our experiment medium 1 is air, and so we use the value $n_1 = 1.00$. Known values of wavelength which you will need are in the following tables.

| Mercury Vapor Light | |
|---|---|
| color | wavelength ($nm$) |
| Yellow | 578.0 |
| Green | 546.1 |
| Blue | 435.8 |
| Violet | 404.7 |

| Hydrogen Light | |
|---|---|
| color | wavelength ($nm$) |
| Red | 656.3 |
| Green-ish | 486.1 |
| Blue/purple | 434.0 |
| Violet | 410.2 |

## 4 Procedure

1. Place the Mercury vapor tube in the light source power supply, plug in the supply, and turn it on. The light from the tube should have a bluish tint. Do NOT touch the tube or connectors while the supply is on – a high voltage is present.

2. With no prism on the spectroscope table, place the light at the end with the slit. After adjusting the slit width to allow a suitable amount of light through, focus so you can see the cross hairs and line them up on the slit. Record this reading as your "zero" scale reading.

3. Place the prism on the table of the spectroscope such that the light must pass through it before reaching the eyepiece. The Mercury light should be split into yellow, green, blue, and dark violet. You may not be able to see the dark violet. Start with the yellow band in the eyepiece, and while looking through the eyepiece slowly rotate the prism and watch what happens to the yellow band. If it deflects to larger angles, stop and rotate the other sense so

that the deflection goes to smaller angles. Continue to rotate the prism until the yellow band is deflected through the minimum possible total angle. Line up the cross hairs on the yellow band and read and record this angle.

4. Repeat the last step for the other colors. For each, make sure you have the minimum angle by rotating the prism before you record the angle.

5. Now switch to the Hydrogen tube and repeat for the colors of its spectrum. Be aware that you may not be able to see the dark violet.

6. Determine and record the apex angle ($\alpha$) for your prism.

7. Replace the glass prism with the water prism and repeat all steps.

## 5 Calculations

1. Using your data calculate the minimum total angle of deflection and the index of refraction for each color of each prism. You will then have many index values for each prism.

2. Make a graph of index of refraction as a function of $\lambda$ for the glass prism, and a second graph for the water filled prism.

## 6 Questions

1. Based on your results, determine what the index of refraction is in both water and glass for light of wavelength $629.0\,nm$.

2. Which color of light is bent more by the prism for a given orientation, red or violet? Explain why.

3. Does the plastic that the water prism is made of affect your results for the index of refraction? That is, are your index values too high, too low, or not affected? Explain.

Some useful wavelengths for the challenge

| Neon Light | | |
|---|---|---|
| wavelength ($nm$) | color | strength |
| 534.1 | green | strong? |
| 585.2 | yellow | strong? |
| 597.5 | yell/oran | strong? |
| 616.3 | orangey | |
| 640.2 | orange/redish | |

| Argon Light | | |
|---|---|---|
| wavelength ($nm$) | color | strength |
| 451.0 | blue/violet | strong |
| 470.2 | blue | strong |

| Krypton Light | | |
|---|---|---|
| wavelength ($nm$) | color | strength |
| 587.1 | yellow | strong? |
| 557.2 | Green | strong? |

| He Light | | |
|---|---|---|
| wavelength ($nm$) | color | strength |
| 706.5 | red | weak |
| 667.8 | red | med |
| 587.6 | yellow | strong |
| 504.8 | green | weak |
| 501.6 | green | strong |
| 492.2 | cyan | med |
| 471.3 | blue | med |
| 447.2 | blue/viol | strong |