Optical Phenomena

This laboratory experience looks at the physical principles behind rainbows and halos. The apparatus used is the Pasco Optics System. This lab is based on Pasco Introductory Optics Experiment 6.

**Equipment Needed:**
- Optics Bench
- Ray Plate and Base
- Slit Plate
- Cylindrical Lens
- Viewing Screen
- Light Source
- Component Holder
- Slit Mask
- Ray Table Component Holder

**REFRACTION AND SNELL’S LAW**

**Purpose:**
When light travels from one transparent medium to another, a change of speed is usually observed at the interface between the two media. This phenomenon may be demonstrated as a beam of light travels from air into glass. If the angle between the light beam and the glass surface is less than 90°, bending, or refraction, of the light occurs at the point where the speed changes. The amount of bending depends on the angle of entry and the index of refraction which will be measured in this experiment.

**Procedure:**
1. Set up the equipment as shown in the figure above, so a single light ray is incident on the curved surface of the Cylindrical lens. Set the Ray Table so the angle of incidence of the ray striking the flat surface of the lens (from inside the lens) is zero-degrees. Adjust the Ray Table Component Holder so the refracted ray is visible on the Viewing Screen.
2. Slowly increase the angle of incidence, $\theta_{\text{glass}}$, and observe the angle of refraction, $\theta_{\text{air}}$. As the angle becomes larger, you will notice that the angles are no longer the same. This is due to the speed of light being different in glass than it is in the air. The ratio of the speed of light in a vacuum compared to the speed of light in glass is called the Index of Refraction. The speed of light in air is nearly the same as that in a vacuum. As a result the index of refraction for air is nearly equal to 1.

3. At large angles you will also notice the white light separates into different colors. This effect is called Dispersion and is the result of the index of refraction depending on the wavelength of light. The index of refraction is larger for shorter wavelengths of light (blue).

4. The mathematical relationship between $\theta_{\text{glass}}$ and $\theta_{\text{air}}$ is given through Snell’s Law.

$$ n_{\text{glass}} = \frac{\sin\theta_{\text{air}}}{\sin\theta_{\text{glass}}} $$

5. On the table given below measure $\theta_{\text{air}}$ for different values of $\theta_{\text{glass}}$. When the colors begin to separate, use the red light to determine $\theta_{\text{air}}$. When $\theta_{\text{glass}}$ matches the Critical Angle, $\theta_{\text{air}}$ is equal to 90°. This results in a total reflection of light inside the piece of glass. For angles beyond the critical angle, the angle at which light is reflected matches the incidence angle. On the table indicate angles that result in internal reflection.

<table>
<thead>
<tr>
<th>Angle of Incidence, $\theta_{\text{glass}}$</th>
<th>Angle of Refraction, $\theta_{\text{air}}$</th>
<th>Index of Refraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>10°</td>
<td></td>
<td></td>
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<tr>
<td>20°</td>
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<tr>
<td>30°</td>
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<td>40°</td>
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<td>50°</td>
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<td>60°</td>
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<tr>
<td>70°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>80°</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average index of refraction for red light $n_{\text{red}} = \underline{\text{__________}}$

6. Chose an angle at which the separation of blue and red light is very clear. It is ok if there is a white band of light between the two. Measure the incident and refraction angles. Using Snell’s law determine the index of refraction for blue light.

$$ \theta_{\text{glass}} = \underline{\text{__________}} $$

$$ \theta_{\text{air}} = \underline{\text{__________}} $$

Index of refraction for blue light $n_{\text{blue}} = \underline{\text{__________}}$
APPLICATION TO HALOS

As illustrated below, the refraction and dispersion in an ice crystal results in a separation of light into its spectrum of colors. The average change in direction for light due to refraction is 22°. Since, blue light is refracted more than red, the inside of a halo is red while the outside is blue.

Hexagonal ice crystals can exist as thin plate and as columns or needles. The orientation and type of crystal in the sky can give a variety of different optical phenomena. The following diagram shows sun dogs, a sun pillar, and an upper tangent arc as the result of columns in the air.
DAILY OBSERVATION
Make an observation of the weather and record the data below. Then generate a METAR and a station model based on the information you gathered.

KCDR

Date _____________ Time _____________
Temperature _____________ Wind Speed _____________
Dew Point _____________ Wind Direction _____________
Pressure _____________ Altimeter Setting _____________
Sky Cover _____________ Present Weather _____________

METAR

STATION MODEL