February 4, 2010
Due February 14, 2010

Lab Exercise #1

INDEX OF REFRACTION MEASUREMENTS

Materials Requirements: Ruler, protractor, calculator, container, water, sugar, scale, laser.
Team Requirements: the class is divided into 3 teams (~ 5 students max per team).

Objectives:

- To determine the specific relationship between the angle of incidence and the angle of reflection
- To quantify the refraction of light through different media
- To analyze the measured data: calculate the mean, error and deviation

Description of Concepts:

When light waves pass through a substance, they can be partially absorbed, bounced (reflected), or bent (refracted) as a result of entering the medium. The law of reflection states that the angle of incidence is equal to the angle of reflection. When "refraction" occurs the degree of bending depends on both the composition of the medium and the wavelength of the incoming light. The refraction (bending) of the beam occurs because the light slows down in the material, so the **index of refraction** is found to be the ratio of the speed of light in a vacuum to the speed of light in a material,

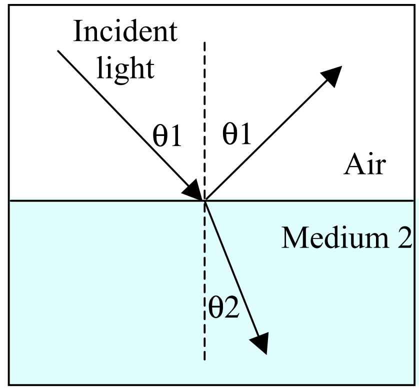
$$\mathbf{n = c/v}$$

When visible light passes through a prism (eg, rainbows from the rain droplets), the incident beam is separated into different colors. This occurs as a result of differences in the degree of bending that occurs for the various wavelengths of light. Each wavelength of light travels at different speed $\boldsymbol{\nu}$.

The relationship between the angle of incidence (incoming light) and the angle of refraction (degree of bending) through the medium / lens is given by the equation:

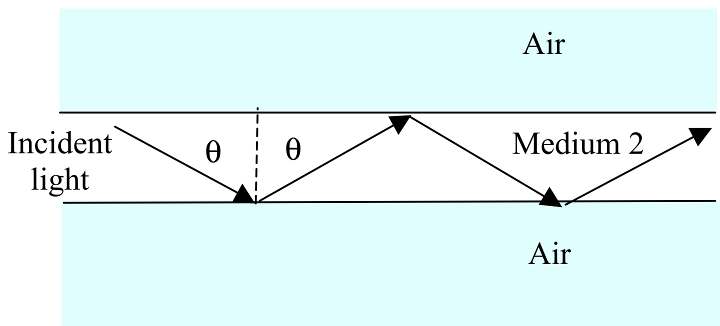
$$\mathbf{n_1 \sin \theta_1 = n_2 \sin \theta_2}$$

where: $\mathbf{n_1}$ is the index of refraction for air
$\mathbf{n_2}$ is the index of refraction for the second medium
$\boldsymbol{\theta_1}$ is the angle of the incoming beam (compared to "normal" or 90° to surface)
$\boldsymbol{\theta_2}$ is the angle of then refracted beam (compared to "normal")
This relation is also known as **Snell's Law**.



If $\mathbf{n_1} < \mathbf{n_2}$, $\boldsymbol{\theta_1} > \boldsymbol{\theta_2}$ ➔ denser medium bends the light ray more!

When $\boldsymbol{\theta_2} = \mathbf{sin^{-1}\ (n_1 / n_2)}$, incident angle $\boldsymbol{\theta_1}$ becomes 90^o, then $\boldsymbol{\theta_2}$ is called the **critical angle**. If light is launched in the denser medium ($\mathbf{n_2} > \mathbf{n_1}$) at an angle $\boldsymbol{\theta} > \boldsymbol{\theta_{critical}}$, effectively all of the incident light will be "bouncing" back and forth within the medium. This is the fundamental principle of how light is guided in an optical fiber.



Exercise 1.

Graph **sin** $\boldsymbol{\theta_1}$ as a function of **sin** $\boldsymbol{\theta_2}$. The slope of the straight line is the index of refraction. Tabulate the calculated index of refraction from each student in the team. Compare your results for **n** with known indexes of refraction (the tables are available at the Lab or on the Internet. Indicate the source of information you used.) Calculate the mean, error, and deviation among the data.

$$\text{Arithmetic mean} = \frac{\Sigma \text{ data points}}{\text{number of data points (n)}}$$

$$\text{Percent Error} = \frac{|\text{ Error }|}{\text{Theoretical value}} \bullet 100$$

$$\text{Deviation} = \frac{\text{Deviation}}{\text{Theoretical value}} \bullet 100$$

What is the accuracy of your measurement methodology?
What is the precision of your methodology?
What are the sources of variation in accuracy and precision?

Exercise 2.

Adding sugar to water will change the index of refraction. Repeat exercise 1 with 2 different concentrations of sugar. Compare your index of refraction to literature (indicate the source you used).
What is the polarizability of one sugar molecule?

Exercise 3.

Calculate the critical angle $\theta_{\mathbf{critical}}$. Can you experimentally measure $\theta_{\mathbf{critical}}$?