Experiment 1

Reflection and Refraction of Light – Planar Surfaces

1 Introduction

In this series of experiments we shall study the phenomena of reflection and refraction of light from planar surfaces. We will study Snell's law and the law of reflection experimentally by investigating refraction at interfaces, refraction through a prism and total internal reflection. Throughout this experiment, we will be using the geometrical optics approximation to analyze the behavior of light.

In this experiment you will use a laser!
Be careful not to shine it into your or your neighbor's eye!
Always know where your beam is directed!

2 Background - *see Hecht, Chap. 4 or Pedrotti, Chap. 2, 3*

When an optical ray encounters a boundary between two transparent media, usually part of the light is reflected from the boundary and part enters the second medium. Each medium is characterized by a dimensionless parameter called the index of refraction, the ratio of the speed of light in vacuum to the speed in the medium, designated by n_1 and n_2. A light ray is incident in medium 1 and strikes the interface between the two media at an angle α with respect to the normal to the surface (see Figure 1). The transmitted ray propagates in a different direction than that of the incident ray. This change in direction is called refraction. The angles of the reflected and refracted rays are determined by the following laws:

1. The angle of incidence, α, is equal to the angle of reflection.

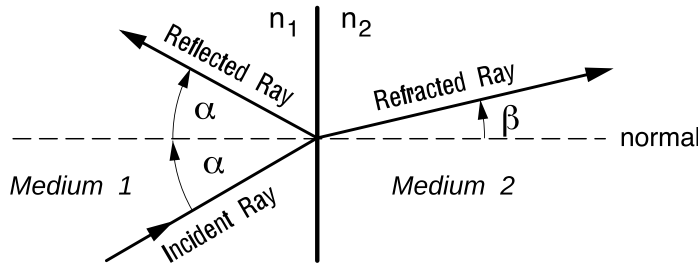

Figure 1: Reflection and refraction of light from an interface.

2. The angles of incidence and refraction are related by

$$n_1 \sin \alpha = n_2 \sin \beta, \tag{1}$$

known as Snell's law.

3. The reflected and refracted rays lie in a plane defined by the incident ray and the normal to the interface at the point of incidence.

3 Experiment

Experimental Hint: To determine angles with respect to the the glass surfaces, use *retro-reflection* - adjust the surface so that the reflected light exactly retraces the laser beam. Then you know the beam was normal to the surface (the Law of Reflection again).

3.1 Reflection and Refraction of a Glass Block

Using a laser beam as a source for your rays, measure appropriate angles to determine the index of refraction of a glass block relative to air.

A way to estimate your uncertainties in measuring angles is is to test your ability to verify the Law of Reflection.

3.2 Total Internal Reflection With a Semi-Circular Block

If light is propagating from medium with n_1 to n_2 and $n_1 > n_2$, Snell's Law no longer has a solution for incidence angles greater than the *critical angle*, where the angle of refraction is 90°. For larger angles, no light is transmitted - it is all *totally internally reflected.* The critical angle is given by

$$\sin \theta_{tir} = \frac{n_o}{n_{tir}} \tag{2}$$

where $n_{tir} > n_0$.

Use a measurement of the critical angle to determine the index of refraction of a semi-circular block of glass (see Figure 2). Why use

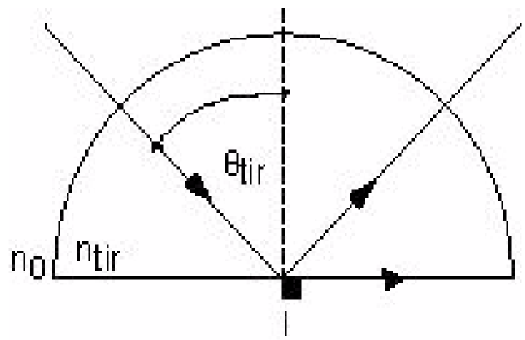

Figure 2: Semi-circular block showing the path of a light ray at the onset of total internal reflection.

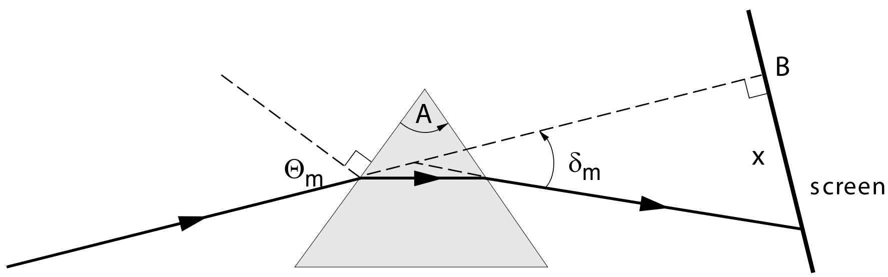

Figure 3: A light ray is shown passing through a prism; it is then projected onto a viewing screen. The angles δ_m and θ_m are as indicated.

a semi-circular block of glass, and not the block from the previous experiment?

3.3 Minimum Deviation Angle in a Prism

In Fig. 3, there is an illustration of a prism and the path of a light ray through the prism. The minimum value of δ (as a function of rotation of the prism) is δ_m and is related to the minimum incident angle, θ_m, by the equation

$$\delta_m = 2\theta_m - A. \tag{3}$$

Furthermore, one can show that the index of refraction of the prism is given by

$$n_{ang} = \frac{\sin\theta_m}{\sin(A/2)}. \tag{4}$$

Thus, to determine n_{ang} of the prism, one must determine θ_m and A.

Find the minimum deviation angle and the index of refraction of the prism. If you plot δ vs. θ you will find it varies quadratically, and you are tasked to find the θ value where δ is smallest. Think about how this will influence your ability to determine the minimum angle and the effect on your uncertainties.