

Physics III

Experiment IV

Refraction

Purpose

Study the bending and reflection of light rays at the interface between two media. The index of refraction is also determined through the impedance change at the interface.

Introduction

When the wavelength of a wave is short compared to all other lengths in a physical situation, then the ray theory will usually suffice to describe the wave. At the interface between two media, the ray theory must be corrected to account for reflections (the interface is sharp compared to a wavelength). The propagation direction of a ray will generally change when it crosses an interface (except for normal incidence) and this is called refraction. Both reflection and refraction depend on the change in the index of refraction across the interface and will be used in this experiment to determine the index of refraction.

Procedure

For normal incidence we have the usual formula for the amplitude of the reflected wave:

$$r = I * \frac{z_1 - z_2}{z_1 + z_2}$$

The index of refraction is due to the dielectric constant κ of a material, and this reduces the speed of light by $v = c/\sqrt{\kappa} = c/n$ where n is the index of refraction. The impedance is also affected by the dielectric constant: $z = \mu_0 v = \mu_0 c/n$. The wave power is proportional to the square of the amplitude, so the ratio of the incident to the reflected power of a laser beam should be given by:

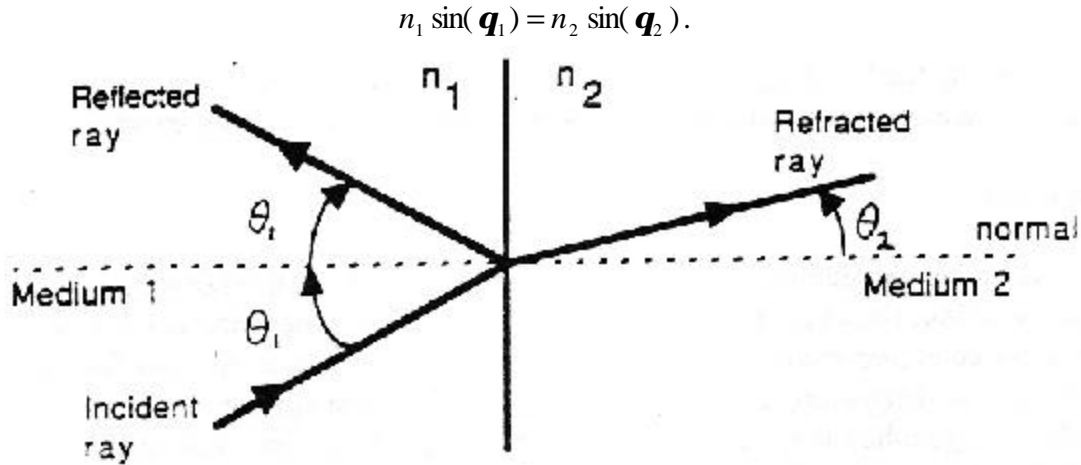
$$c \equiv \frac{P_r}{P_i} = \left(\frac{n_2 - n_1}{n_2 + n_1} \right)^2$$

Thus if you measure the power ratio c , and a laser beam moves from air ($n_0=1$) into a block of material with index of refraction n :

$$n = \left(\frac{1 + \sqrt{c}}{1 - \sqrt{c}} \right).$$

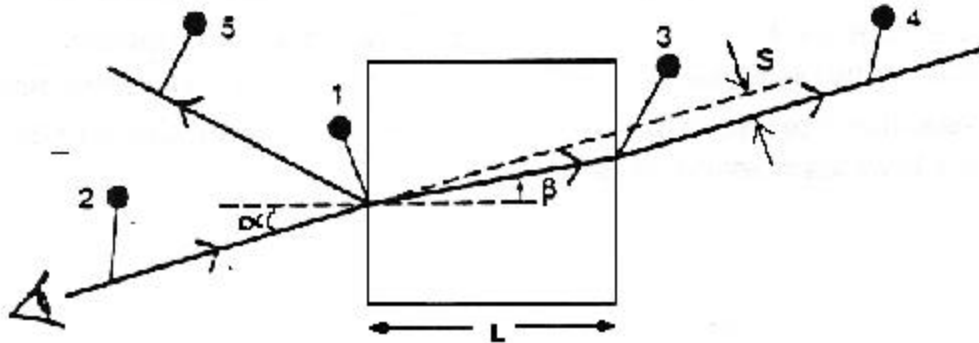
A more complicated situation exists for oblique incidence.

The bending of rays can be determined through the same kind of mathematical analysis that led to the reflection equation. The result is called Snell's Law:



Suggested Problems

- Use a laser beam and a power meter to determine the index of refraction of a block of transparent material. Make the angle of incidence as close to zero as you can.
- Measure the index of refraction by these three related techniques:
 - 1) Trace the path of a laser beam and measure both the incident and the refracted angle.
 - 2) Measure the index of refraction by measuring the deflection of a laser beam through a rectangular block as shown in the figure below:
 - 3) Measure the critical angle for total internal reflection and use this to determine the index of refraction. $n \cdot \sin(\theta_c) = 1$
 - 4) Use the power meter and the laser to determine the index of refraction from **c**.



$$n = \sin(\alpha) \left[1 + \left(\frac{\cot(\alpha)}{1 - \frac{S}{L \sin(\alpha)}} \right)^2 \right]^{1/2}$$