Experiment – Reflection and Refraction

Introduction:

The travel of light is often represented in geometric optics by a light ray, a line that is drawn to represent the straight-line movement of light. The line represents an imaginary thin beam of light that can be used to illustrate the laws of reflection and refraction, the topics of this laboratory investigation.

A light ray travels in a straight line from a source through a uniform media or vacuum until it encounters some object or change in the media. What happens next depends on several factors, including the nature of the material making up the object or media, the smoothness of the surface encountered, and the angle at which the light ray strikes the surface. If the surface is extremely smooth, meaning the size of imperfections are much smaller than the wavelength of light, then rays are bent in a specular "reflection". If the material is transparent, then rays will be transmitted through the material, most often undergoing a change in direction or bend known as "refraction" at the boundary between materials (such as between air and glass).

Light rays traveling from a source, before they are reflected or refracted, are called incident rays. If an incident ray undergoes reflection, it is called a reflected ray. Likewise, an incident ray that undergoes refraction is called a refracted ray. In either case, a line perpendicular to the surface, at the point where the ray strikes is called the normal line. The angle between an incident ray and the normal is called the angle of incidence. The angle between a reflected ray and the normal is called the angle of reflection. The angle between a refracted ray and the normal is called the angle of refraction. These terms are descriptive of their meaning, but in each case you will need to remember that the angle is always measured from the **normal**. Virtual images seen by the eye always appear to exist at the point from which diverging rays seem to emerge. Real images observed always exist at the point where rays actually converge.

Objective:
The Purpose of this experiment is to study the basic optics of mirror reflection and refraction through materials.

Apparatus:
Flat mirror, mirror stand, straight pins, Styrofoam block, paper, rulers, protractors, rectangular acrylic plastic block, triangular acrylic plastic block, laser, lab jack.

Theory:
The angle of reflection equals the angle of incidence. For a material the index of refraction $n = \dfrac{c}{v}$ where c = speed of light in a vacuum and v = speed of light in the material. For refraction through a material, Snell's Law states: $n_1 \sin \vartheta_1 = n_2 \sin \vartheta_2$

(See Figure.)

$$n_1 = 1.0003 \text{ (Air)}$$

$$n_2 = \text{Refraction Block}$$
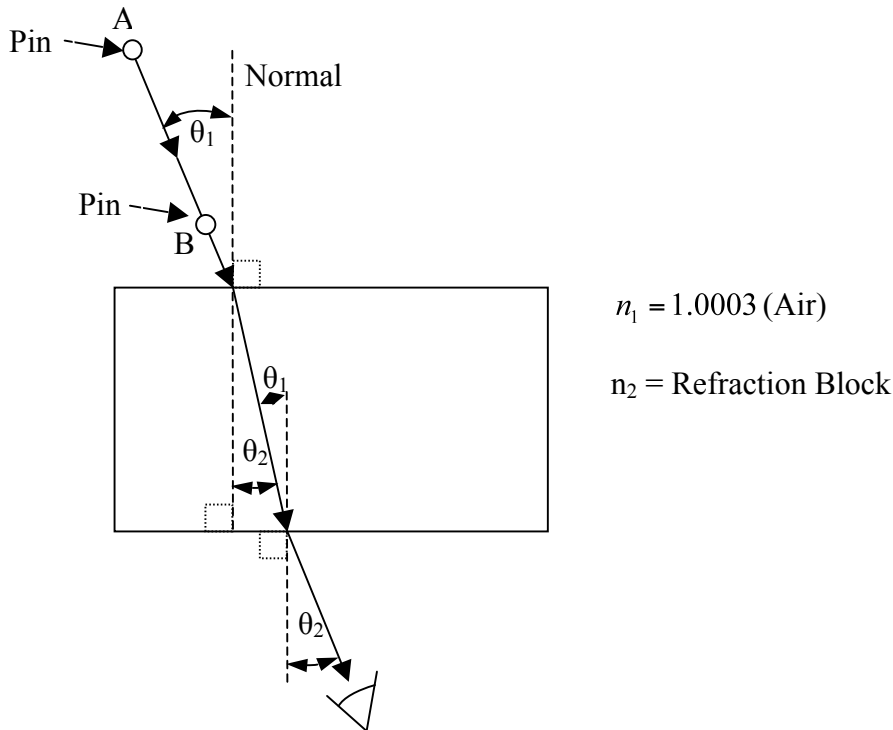
Procedure

For all diagrams, you must include labels, arrowheads, dotted normal lines, and precisely measured angles for all rays shown. Also note clearly which partner drew which diagrams.

Part A: Reflection

1) Use a straight edge to draw a line near the center of a blank page. Place the reflecting edge of the mirror on this line.
2) Use two pins (A,B) to define and draw an incident ray. (see below)
3) Align two pins (C,D) with the reflected image of the ray from A to B. Draw the reflected CD ray. Label the positions of all the pins on the paper.
4) Use a protractor to draw a normal where the AB ray strikes the mirror. Measure the angles of incidence and reflection. Write them clearly where they occur.
5) On the same piece of paper, with the same mirror position, repeat the entire procedure with a different position for pin B (which will be labeled B'), but keep pin A in exactly the same position.
6) Find the position of the apparent virtual image of pin A. Mark it on your drawing.

Part B: Refraction

1) Trace the outline of the refraction block near the center of a blank page.

2) Use two pins (A,B) to define an incident ray, striking the top surface of the block near the upper left. (see below)
3) Look through the block and place two pins (C,D) along the existing ray in line with the apparent positions of (A,B).
4) Remove the block, trace the rays completely through the block and calculate the index of refraction for the entire material. (Trial 1)
5) Repeat for an entirely different location of pin B and angle of incidence, but keeping pin A in the same place. Again calculate the index of refraction of the material. (Trial 2)
6) Find and mark the location of the final image of pin A.
7) Find the average index of refraction. Use this to calculate the speed of light within the material.

Part C: Total Internal Reflection

1) Change orientation of the triangular block until you achieve total internal reflection with the incident ray positioned precisely at the critical angle, i.e. refracted ray disappears as the angle of the incident ray is increased from zero.
2) Trace the outline of the block, mark the first two points of incidence; find, draw and label all rays present at each.
3) Using a protractor, measure the critical angle for total internal reflection.
4) Use Snell's Law to solve for the critical angle and compare to your experimental value.

Normal

Refracted Beam @90˚

Incident
Beam

θ_c

Block

Laser Beam
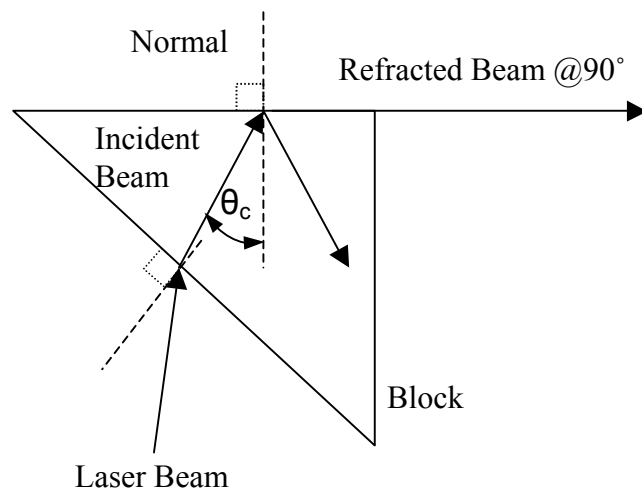
Results

1) Describe any pattern you found in the data between the angle of incidence and the angle of reflection.

2) Describe what happened to a light ray as it crossed, (a) from air to the block and (b) from the block into air.

3) Assuming that light travels faster through air than it does through glass or plastic, make a generalized statement about what happens to a light ray with respect to the normal as it moves from a lower speed in one material to a greater speed in another.

4) What rules or generalizations do your findings suggest about reflection? In what way do we use or experience reflection, refraction, and/or total internal reflection in everyday life?

5) What rules or generalizations do your findings suggest about refraction? How much more data would be required to make this a valid generalization.

Helpful Equations and Indices of Refraction

θ_1 $n_1 \sin \vartheta_1 = n_2 \sin \vartheta_2$

θ_1 $n = \dfrac{c}{v} = \dfrac{2.9979 \times 10^8 \, \frac{m}{s}}{v}$ or $v = \dfrac{2.9979 \times 10^8 \, \frac{m}{s}}{n}$

θ_1 $c = 2.99792458 \times 10^8 \, \dfrac{m}{s} \approx 3.0 \times 10^8 \, \dfrac{m}{s}$

θ_1 $n_{air} = 1.0003$

θ_1 $n_{water} = 1.33$

θ_1 $n_{acrylic} = 1.50$

θ_1 $n_{diamond} = 2.42$