Reflection and Refraction with the Ray Box

Introduction:

In geometrical optics an assumption is made which is called the ray approximation. It assumes that light consists of plane waves which propagate in straight lines. Rays are lines perpendicular to the wavefronts which define the direction in which light travels.

A light ray that is traveling in some medium is either reflected or refracted or transmitted when it comes to a boundary into a second medium. The rays that are transmitted into the second medium are changed in direction. They are said to be refracted.

A quantity called the "refractive index" is given for any medium. Refractive index is defined as the ratio of the speed of light in vacuum to the speed of light in the medium. In this laboratory light rays from a ray box will be used to accomplish the following objectives:

1. Demonstration that for reflection from a plane surface the angle of incidence is equal to the angle of reflection
2. Studying the reflection of light rays from cylindrical reflecting surfaces
3. Demonstration that rays going from air into a transparent plastic medium are refracted at the plane boundary
4. Determination of the refractive index of a plastic prism from direct measurement of incident and refracted angles of a light ray

Experiment 1:

In this experiment, you will study how light rays are reflected from different types of mirrors. You will measure the focal length of concave mirror and a convex mirror.

Part I : Plane mirror

1. Setup the experiment as shown in the model setup
2. Setup the light source to give a single ray
3. Place the mirror on the paper. Position the plane (flat) surface of the mirror in the path of the incident ray at an angle that allows you to clearly see incident and reflected rays.
4. On the paper, trace and label the surface of the plane mirror and the incident and reflected rays. Indicate the incoming and outgoing rays with arrows in appropriate directions.
5. Remove the paper from the light source. On the paper, draw the normal to the surface (as shown in fig. 1)

6. Measure the angle of incidence and angle of reflection. Measure these angles from the normal, as shown in figure 1. Record these angles in table 1. Repeat the steps 4-5 for 3 different angles of incidence.

Table 1: Plane Mirror Results

Angle of incidence (degrees)	Angle of Reflection (degrees)

Question:

1. What is the relationship between angles of incidence and reflection?

<u>Part II: Cylindrical Mirrors</u>

Theory:

A concave cylindrical mirror focuses incoming parallel rays at its focal point. The focal length f is the distance from the focal point to the center of the mirror surface. The radius of curvature (R) of the mirror is twice the focal length (see figure 2).

Procedure:

1. Turn on the light source to give five parallel rays. Shine the rays straight into the concave mirror so that the light is reflected back towards the ray box (see figure 3). Trace the surface of the mirror and te incident and reflected rays. Indicate the incoming and outgoing rayw with arrows in the appropriate directions (You can now remove the light source and mirror from the paper).

2. The place where the five reflected rays cross each other is the focal point of the mirror. Mark the focal point.

3. Measure the focal length from the center of the concave mirror surface (where the middle ray hit the mirror) to the focal point. Record the result in Table 2.

Table 2: Cylindrical Mirror Results

	Concave Mirror	Convex mirror
Focal length		
Radius of curvature		

Question:

2. What is the focal length of the Concave mirror and Convex mirror?

Experiment 2: Snell's law

Introduction:

The purpose of this experiment is to determine the refractive index of the acrylic trapezoid. For rays entering the trapezoid, you will measure the angles of incidence and refraction and use Snell's law to calculate the refractive index.

Theory:

For light crossing boundary between two transparent materials, Snell's law states that:

$n_1 \sin\theta_1 = n_2 \sin\theta_2$ where θ_1 is the angle of incidence, θ_2 is the angle of refraction, and n_1 and n_2 are the respective indices of refraction of materials (see figure 4).

Procedure:

1. Place the light source in ray-=box mode on a sheet of white paper. Turn the wheel to select a single ray.
2. Place the trapezoid on the paper and position it so the ray passes through the parallesl sides as shown in figure 5.
3. Mark the position of the parallel surfaces of the trapezoid and trace the incident and transmitted rays. Indicate the incoming and the outgoing rays with arrows in the appropriate directions. Carefully mark where the rays enter and leave the trapezoid.
4. Remove the trapezoid and draw a line on the paper connecting the points where the rays entered and left the trapezoid. This line represents the ray inside the trapezoid.

5. Choose either the point where the ray enters the trapezoid or the point where the ray leaves the trapezoid. At this point, draw the normal to the surface.

6. Measure the angle of incidence (θ_i)and the angle of refraction with a protractor. Both of these angles should be measured from the normal. Record the angles in the first row to table 3.

7. On a new sheet of paper, repeat steps 2-6 with different angles of incidence. The first 2 columns of table 3 should now be filled.

Table 3: Data and Results

Angle of incidence	Angle of refraction	Calculated index of refraction of acrylic	Percentage error in measurement $\frac{\text{Calculated R.I - 1.5}}{1.5} \times 100\%$

Average value of R.I. of acrylic is: _______________

(To answer questions 4 and 5, use separate sheets of paper if necessary)

3. A light ray is incident on a plane interface between 2 media. The ray makes an angle of 25 degrees with the normal in a medium with refractive index $n = 1.25$. What is the angle that the refractive index makes with the normal if the second medium has $n = 1.55$? Show your work, along with the ray diagrams involved.

4. A 60^{o} prism has an index of refraction 1.45 as shown in figure 6. A ray is incident at an angle of 60^{o} to the normal of one of the prism faces. Trace the ray on through the prism and mark the angles the rays make with air-glass boundary surfaces all the way until the ray exits the prism.