Reflection and Refraction

Purpose: To study the reflection of light in a plane mirror and to study refraction of light in glass and water.

Equipment: Plane mirror, protractor, mirror mount, pins, cardboard, rectangular piece of plate glass, ruler, graph paper, clear plastic box.

Part I. Reflection of light by a plane mirror.

Introduction:

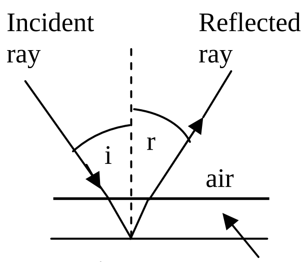

Figure 1

Whenever a ray of light is incident upon a plane reflecting surface, such as a mirror, the ray of light is reflected as shown in figure 1. The angle of incidence, i, is defined as the angle between the incoming ray and the perpendicular to the reflecting surface. Similarly, the angle of refraction, r, is defined to be the angle between the reflected ray and the perpendicular to the surface. The relationship between i and r is given by two laws of reflection:

1) The incident ray, the perpendicular, and the reflected ray all lie in the same plane.
2) The angles of the incidence and reflection are equal (i=r).

Procedure:

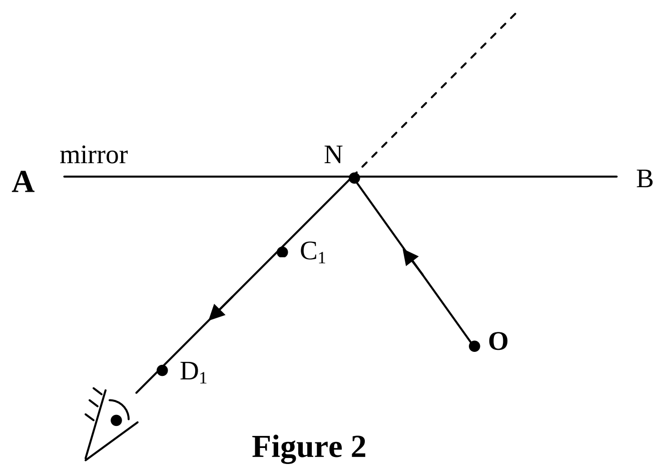

Figure 2

1. Draw a line AB about 20 cm long across the center of a piece of graph paper, place this sheet on a piece of cardboard, and stand the mirror with the edge of its reflecting surface on this line. Stick a pin about 6 or 8 cm from the mirror to act as the object, **O** (see **Figure 2**). Be careful that the pin is as vertical as possible.
2. Stick a second pin near the mirror and few centimeters to one side of the first pin (at a point such as C_1), and another pin (such as at D_1) 6 or 8 cm from $C_1$and exactly on the line that passes through C_1 and the image of the original pin. When this has been accomplished, the third pin will hide the second pin and the image of the first pin. The pins should be as nearly vertical as possible, and the eye in sighting should be placed on a level with the paper so that the line of sight is along the bottoms of the pins. Label the points C_1 and D_1.
3. Without disturbing the position of the mirror or the object at point **O**, determine in the same way two other lines (by choosing points C_2, D_2, etc.) at different angles with AB, one on each side of **O**.
4. Using a straight edge, extend each of the lines CD back behind the mirror (see the dashed line in **Figure 2**). These lines should intersect in the point that is the position of the image of point **O**. Let **I** denote the position of the image. Draw a line connecting **I** and **O**. Measure the

distance (object distance) between point **O** and the mirror. Measure the distance (image distance) between point **I** and the mirror. Find the percent difference between the two distances. Describe a rule giving the position of an image with reference to a mirror and the position of an object.

5. Label the point where the line CD (three lines in all) intersects the mirror N. Draw the incident ray ON and the normal to the mirror at N. Using a protractor, measure and record the angles of incidence and reflection for each of the three light rays.
6. Within what limits (expressed as a percent) do your results agree with the law of reflection?

Part II. Refraction of light through plate glass.

Introduction:

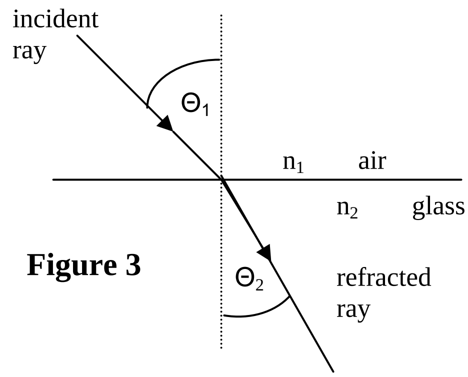

Figure 3

When a ray of light enters a material such a glass from air, its path bends as shown in figure 3. This change in direction of a ray as it passes from one material to another is called refraction. The relationship between the angle of incidence, θ_1 and the angle of refraction, θ_2 is known as Snell's law and it is given by:

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

where n_2 is the index of refraction of glass (or other material) and n_1 is the index of refraction of air. The index of refraction, n, of a material is defined as the ratio of the speed of light in the material, v, to the speed of light in vacuum, c, i.e. n = c/v. Since for air the speed of light is nearly c, the index of refraction is often taken to be equal to one.

Procedure:

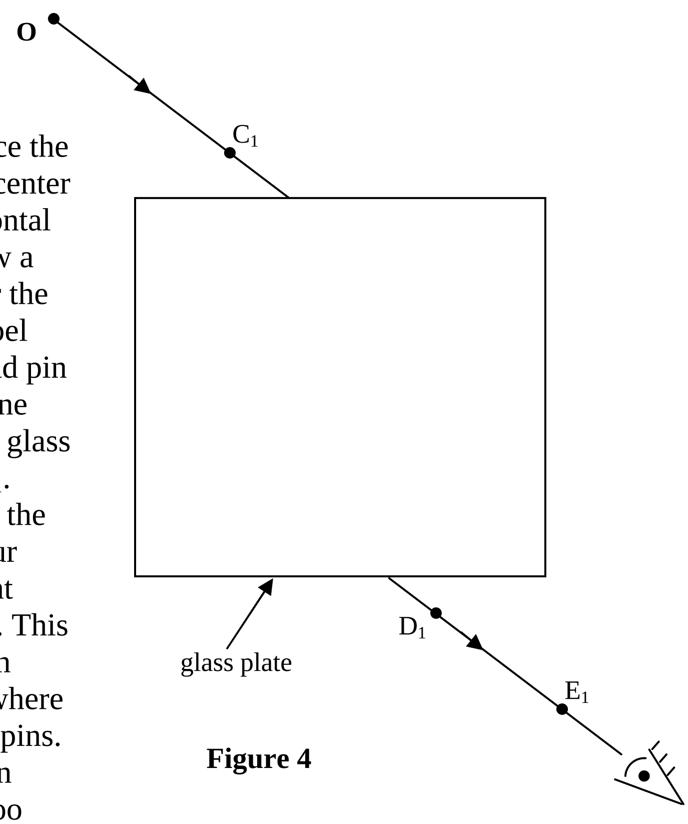

Figure 4

1. Place a sheet of graph paper on the platform. Place the rectangular glass plate flat on the paper near the center in such a way that one edge is parallel to a horizontal line on the graph paper. With a sharp pencil, draw a line around the glass plate. Now, place a pin near the top of the page and to one side of the center. Label this point **O** as shown in **Figure 4**. Place a second pin a few centimeters further down the page and to one side so that the line connecting them contacts the glass plate at a small angle. Label this second point C_1.
2. Looking through the glass from the lower side of the page, you should see both pins. As you move your head from side to side, you can find a line of sight along which the pins appear to be directly in line. This line of sight may be defined by placing a third pin (point D_1) between your eye and the glass plate where it appears to fall on the same line as the first two pins. This step must be repeated by placing a fourth pin (point E_1) near the bottom of the page so that it too appears to fall in this line of sight.

3. Using a straightedge, draw a line through **O** and C_1 that continues to the edge of the glass plate. This line traces the path of the incident ray of light. Repeat this procedure by drawing a line from the lower edge of the glass plate through points D_1 and E_1. This line traces the path of the ray after it has passed through the glass. Connect the two lines with a third line that passes through the glass. This represents the path of the light rays that travels through the glass.
4. Measure the angle of incidence and the angle of refraction of the light ray that enters the glass and show them on the paper. Obtain the index of refraction of the glass from your instructor and check the validity of Snell's Law. Also check the law for the ray that leaves the glass and comes out into the air.

Part III. Refraction of Light Through a Liquid

Introduction:

The apparent depth, d, as seen from directly above a container filled with a liquid varies with the index of refraction, n, of the liquid as

$$d = D/n$$

where D is the actual depth as shown in the drawing below.

Procedure:

1. Obtain a clear plastic box and draw a straight centerline across the bottom of the box. Fill the cup with the liquid whose index of refraction is to be measured and placed the tip of a pencil to the outside of the box so that it appears to be in pointing at the centerline. Using parallax, determine, by sighting from above with one eye, the position at which the pencil and the line on the bottom of the box appear stationary as the eye is slowly moved back and forth. In order to find this position you will need to move the pencil slowly up or down while moving the eye back and forth until there is no relative motion between the pencil and the centerline. Measure the actual depth and the apparent depth and then determine the index of refraction from the above equation. Compare with the accepted value for the liquid.