EXPERIMENT 7
RAY TRACING

I. THEORY

When light travels from a medium with index of refraction n_1 into a medium with index of refraction n_2, Snell's Law must be satisfied, $n_1 \sin\theta_1 = n_2 \sin\theta_2$. If n_1 is larger than n_2, there will be some values of θ_1 for which Snell's Law has no solution for θ_2. In these cases, there is no refracted ray and all of the light reflects at the boundary between the mediums.

If paraxial rays strike a parabolic mirror, the reflected rays will either converge to a point or diverge from a point. This point is defined to be the focal point of the mirror. A lens has a focal point defined in the same way for parallel rays ***refracted*** through it.

For a narrow beam of paraxial rays, the reflected light from a spherical mirror will also converge (or diverge) from a point. This focal point is theoretically a distance R/2 from the vertex of the lens, where R is the radius of curvature of the mirror.

In this experiment we will use Snell's Law to calculate the index of refraction of a plastic material. We will observe the reflection of parallel rays from a curved mirror and the refraction of parallel rays through a plastic lens. From the observations, we will determine focal lengths.

II. LABORATORY PROCEDURE

1. Place the ray box, label side up, on a smooth section of the laboratory table. Plug the box in and adjust the box so one white ray is showing. The number of rays produced is adjusted by sliding the mask as shown on the label.

2. Place a sheet of paper in front of the ray box, in the path of the ray. A couple of short strips of masking tape may be used to keep the paper in place. Label the sheet 2, for step 2. Place the front of the ray box on the edge of the sheet of paper to hold it in place. Place the plastic rectangle on the paper so that the ray strikes a long side of the rectangle ***near*** (not at) a corner. Rotate the rectangle until the light emerges from the opposite side of the rectangle, ***near*** (not at) a diagonally opposite corner, without first reflecting internally from another side of the rectangle. Trace entirely around the rectangle. Make two small marks as far apart as possible on the incident ray and on the refracted ray. Remove the rectangle. Using a straightedge, draw in the three segments which comprise the complete ray. Add arrowheads to indicate the direction in which the light travels.

3. Take a new sheet of paper, label it 3, and place the plastic semicircle on it. Locate the semicircle so that the light ray strikes the ***center*** of the straight side. Rotate the semicircle so that there is considerable bending of the ray as it enters the plastic. There should be no bending of the ray as it leaves the semicircle, because it should strike the

curved side at normal incidence. Trace completely around the semicircle. As in step #2, trace the complete path of the ray, and add arrowheads.

4. Take a new sheet of paper, label it 4, and locate the semicircle on it so that the ray of light enters the curved side and leaves at the ***center*** of the straight side. Slowly rotate the semicircle until the emerging ray just disappears, and total internal reflection occurs. Trace completely around the semicircle and make a dot at the center of the straight side. As before, trace the complete path of the ray, inside and outside the plastic, and add arrowheads.

5. Adjust the ray box so that three white lines are produced. Take a new sheet of paper, label it 5, and place the circular concave mirror on it. (The circular mirror is a complete half-circle, in contrast to the parabolic mirror, which is a considerably smaller arc.) Adjust the mirror so that the central ray reflects back upon itself. Trace completely around the mirror. Trace the incident and reflected rays, and add arrowheads.

6. Take a new sheet of paper, label it 6, and place the thin converging lens on it. Adjust the lens so that the central ray passes through the lens in a straight line, and all three rays come to a focus on the sheet. Trace completely around the lens. Trace the incident and refracted rays, and add arrowheads. Ignore reflected rays.

7. Take a new sheet of paper, label it 7, and repeat step #6 with the diverging lens. In this case, the lens must be placed so that the refracted rays, when extended backward, meet on the data sheet. Again, ignore reflected rays.

8. Adjust the ray box so that five white lines are produced. Place the circular concave mirror on a sheet of paper in the path of the rays. Again, adjust the mirror so that the central ray reflects back upon itself. Note that the outermost rays converge to a point closer to the mirror than the inner rays; this is spherical aberration. Do not trace the mirror or rays.

9. Replace the circular concave mirror by the parabolic mirror, using the concave side. Note that all five rays focus very nearly at the same point. Do not trace the mirror or rays.

10. Obtain your instructor’s initials on each data sheet. Make copies of all data sheets for everyone in your group.

III. CALCULATIONS

NOTE: PERFORM ALL CALCULATIONS ON THE DATA SHEETS.
SHOW ALL MEASURED DISTANCES ON THE DATA SHEETS.
EXPRESS ALL DISTANCES IN CENTIMETERS.

1. Using the data of II-2, draw in normal lines for both refractions. Measure the angles of incidence and refraction. Calculate the refractive index of the plastic for each refraction. Average the two values.

2. Using the data of II-3, draw in the normal line and measure the angle of incidence and the angle of refraction. Calculate the refractive index of the plastic.

3. Using the data of II-4, draw in the normal line, measure the angle of incidence, and calculate the refractive index. What value should be used for the angle of refraction?

4. Using the data of II-5, measure the experimental focal length of the mirror. Measure the radius of curvature of the mirror and calculate the theoretical focal length of the mirror. Find the percent difference between the two values.

5. Using the data of II-6, measure the focal length of the converging lens. Measure from the ***center*** of the lens.

6. Using the data of II-7, measure the focal length of the diverging lens. Express the result as a negative number.