Physics 202 Lab 6
Mirrors and Lenses

May 20, 2013

Equipment

- Pins
- Pieces of cardboard
- Light box & optical set
- Power supplies
- 12" rulers
- Protractors

Reflection

Flat Plane Mirror

Place the ray box on top of a piece of paper so that you will have a surface upon which to trace the rays. Using the appropriate slit forming plate at the end of the ray box farthest from the bulb, project a single, narrow light ray upon the plane mirror at an angle.

Trace the incident ray, the reflected ray, and the mirror surface. Draw a line (the normal) perpendicular to the mirror at the point where the ray is reflected. Measure the angle of incidence and the angle of reflection, and verify the law of reflection.

Now verify the same law the old-fashioned way (without the ray box): Place the mirror on another piece of paper which has cardboard underneath it. Place a pin about 2 inches in front of the mirror, and use a straight edge to draw a sighting line aimed at the pin's image. The sighting line is the path of the reflected ray of light. The line from the pin to the mirror is the path of the incident ray. Draw the normal and verify the law of reflection. Keep this set up for the next part.

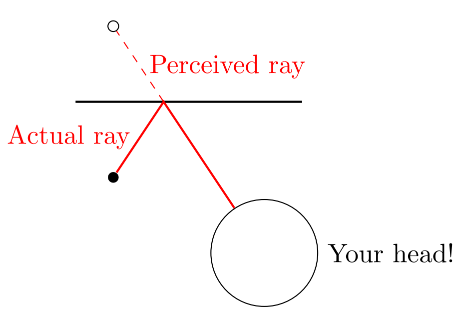

Figure 1: Ray Tracing

Using the same setup, draw another sighting line from a second position. Extend both sighting lines behind the mirror until they intersect (see Figure 2). This is the position of the image. How does the image position compare with the object position? Now, as a visual check on your results, place a second pin at the image position. Part of the second pin should now be visible above the mirror. If the second pin is at the correct image position, it will appear continuous with the image of the first pin, no matter what viewing position you choose. Verify that this is so.

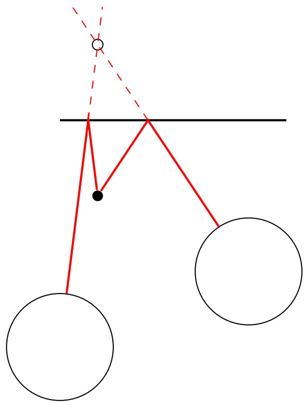

Figure 2: Finding the Image

Concave Spherical Mirror

Select the semi-circular concave mirror. Aim a set of four parallel rays into the center of the inside curve of the mirror so that the rays are parallel to the axis of symmetry of the mirror. Trace the incident and reflected rays, and note where the reflected rays meet. This point is called the focal point (or focus) of the mirror. Carefully measure the distance from the mirror to the focal point.

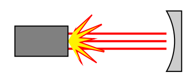

Figure 3: Concave Mirror Set Up

If the focal point appears blurred and broad, with too many rays overlapping through it, block the outer rays as they leave the light box and use only the central ones. The fact that the outer rays do not meet exactly at the focal point is referred to as spherical aberration, and can be corrected by using a parabolic mirror instead, as we will see below.

Now, set the semi-circular mirror on a piece of paper and trace the inside reflecting surface. Move the mirror around the curve and continue tracing until you have a complete circle. Measure the diameter of this circle in several directions and calculate an average diameter. How does the radius, R, compare with the focal length, f, above?

Convex Spherical Mirror

Project a number of parallel rays to strike the outside surface of the semi-circular mirror, parallel to its axis.

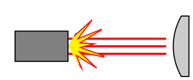

Figure 4: Convex Mirror Set Up

Trace the mirror position and ray paths and indicate the ray directions with arrow heads. Where do the diverging rays appear to come from? Locate this point by drawing the diverging rays backward through the mirror position. This is the focal point. Measure the focal length for the convex mirror. This focal length should be comparable with the concave side of the mirror. What possible sources of error might account for any difference in results?

Concave Parabolic Mirror

A parabolic mirror follows the curve produced by graphing the equation $y = x^2$.

Aim a set of four parallel rays into a parabolic reflector along paths parallel to the axis of symmetry of the mirror. Notice the sharpness of the focal point, in comparison to the spherical mirror.

Move the mirror perpedicualr to the beam (so the beam strikes off-center). Notice how the focal point is still sharp. Compare this with the spherical mirror.

This sharp focus is how such sharp images of stars that are very far away are formed. You'll notice that this parabolic shape is also used in radar antennae, radio-telescopes and car headlamp reflectors. In all of these examples, where would you put the receiving or transmitting device?

Refraction

Snell's Law

Place the ray box on top of a piece of paper so that you will have a surface upon which to trace the rays. Project a single light ray upon the clear plastic, rectangular object so that the ray makes a large angle with the normal. Trace the object, the incident ray, and the ray that emerges from the opposite side. Then remove the object and use the straight edge to complete drawing the path of the refracted ray. Also, draw the normals at each plastic/air interface.

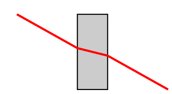

Figure 5: Refraction Through Slab

Upon entering the plastic, does the ray bend toward or away from the normal? Upon leaving the plastic, does the ray bend toward or away from the normal?

Snell' law states that for each plastic/air interface,

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

where n_1 and n_2 are the different indices of refraction for the two media 1 and 2 and are the respective angles each ray makes with the normal.

Consider first the point where the ray enters the plastic. Carefully measure the two angles with respect to the normal. Then, using $n_{\text{air}} = 1.00$, solve for n_{plastic}. Repeat the process for the point where the ray leaves the plastic. Your two values for n_{plastic} should compare favorably.

All lenses in your kit have the same index of refraction, so you can use this value throughout the lab.

Total Internal Reflection

When a light ray is emerging from a medium of higher index of refraction into one of lower index of refraction, if the angle it makes with the normal is large enough, it will be totally internally reflected. This critical angle is given by

$$\theta_c = \sin^{-1}(n_1/n_2)$$

where $n_1 > n_2$.

Use the value for n_{plastic} that you just calculated to determine the critical angle for the plastic/air interface.

Now we will determine this value experimentally. Aim a single beam of light at the shortest side of the 30-60-90 prism, so that the refracted beam inside the prism strikes the hypotenuse as shown.

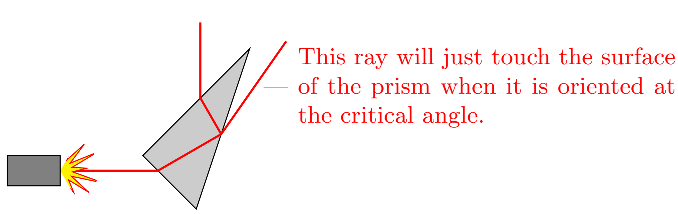

Figure 6: Measuring Critical Angle

Adjust the light box and prism positions until total internal reflection occurs and the ray emerges through the third side. Record the first position at which this occurs and measure the angle of incidence from the normal to the hypotenuse. This should be the same angle that you calculated a moment ago.

Dispersion

Have you noticed anything regarding the color of a light ray after it is refracted several times? Aim a single ray at the 60-60-60 prism in this manner:

Is the original beam white or colored? Is the emergent beam white or colored? For which color must the index of refraction in the plastic be the greatest? The least?

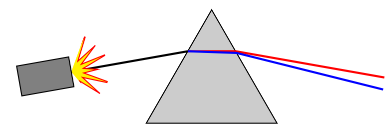

Figure 7: Making Rainbows