Introduction:

In this lab you will be exploring the first part of optics, the Reflection and refraction of light at a plane (flat) surface and a curved surface.

Reflection occurs when an incident ray of light bounces o of a smooth surface like a mirror. See Figure 1.

Refraction occurs when a ray of light that is traveling in one medium, let's say air, enters a different medium, let's say glass, and changes the direction of its path. See Figure 2.

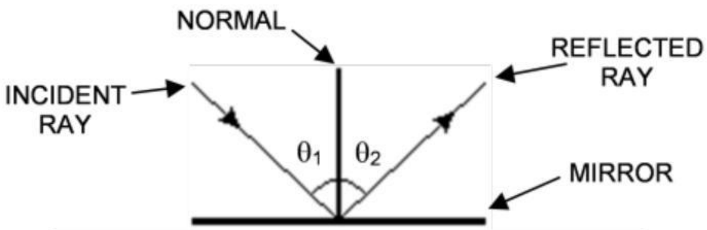

FIGURE 1 - Reflection off of a mirror

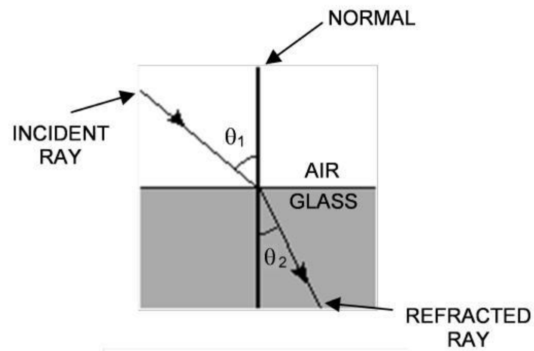

FIGURE 2 - Refraction from air into glass

Plane Surface

In order to describe Reflection or refraction at a plane surface you need to measure angles with respect to a common reference line. The reference line that is used is called a **normal**. A **normal** is a line that is perpendicular to a surface. In Figure 1 you see a ray of light that is incident on a plane surface. The angle of incidence, θ_1, of a ray of light is defined as the angle between the incident ray and the normal. If the surface is a mirror, then the angle of Reflection, θ_2, of a ray of light is defined as the angle between the reflected ray and the normal.

If the light is refracted as in Figure 2, then $\theta_2$is defined as the angle of refraction. (θ_1 is still the angle of incidence). The amount that the ray of light will refract is related to the index of refraction of the medium. The **index of refraction**, *n*, (no units) is defined as the ratio of the speed of light in a vacuum to the speed of light in the medium. In this lab however, we will use a different equation, called Snell's Law, to calculate the index of refraction. Snell's Law is ...

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

Now let's examine Reflection and refraction at a curved surface.

Curved Surfaces

There are two different kinds of curved surfaces that you will be dealing with for reflection; a concave mirror and a convex mirror. Both of these are considered to be spherical mirrors, which means that the mirror is part of the arc of a large circle.

This implies that the mirror has an associated radius of curvature, R. See Figure 3. The center of the mirror is called the vertex. A line drawn through the vertex and the center of curvature, C, is called the principal axis. Halfway between the vertex and the center of curvature is the focal point, F. The distance from the focal point to the vertex of the mirror is the focal length, f. The relationship between the radius of curvature and the focal length is, R = 2f.

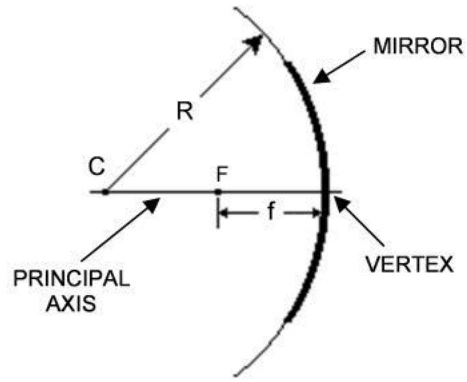

FIGURE 3 - Spherical concave mirror

For a concave mirror, all of the light rays that run parallel to the principal axis will reflect off of the mirror and converge at the focal point. See Figure 4. For a convex mirror, parallel lights rays will re ect o of the mirror and diverge from the focal point. See Figure 5. You can use dashed lines that trace back along the reflected rays to show that the light rays diverge from the focal point.

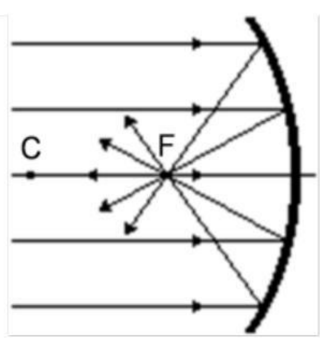

FIGURE 4 – Concave mirror with parallel incoming rays

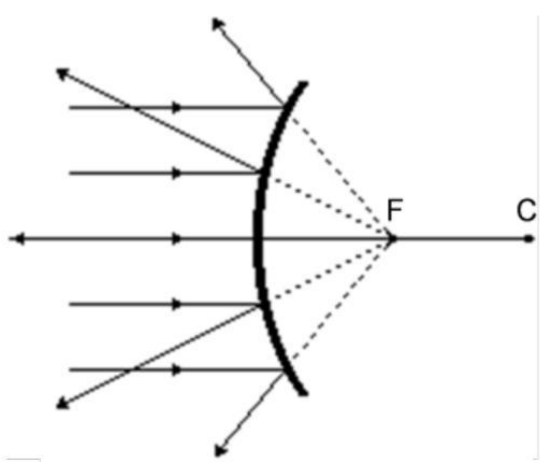

FIGURE 5 - Convex mirror with parallel incoming rays

Both R and f have sign conventions that are given in the chart below. In general though, concave mirrors have a positive focal length and convex mirrors have a negative focal length.

<u>Sign Conventions for Mirrors</u>

Both R and f are + if the center of curvature for the R is in front of the mirror.

Both R and f are - if the center of curvature for the R is in back of the mirror.

Curved surface refraction occurs when light travels through a lens. There are two different types of lenses: a converging lens and a diverging lens. A converging lens has a center that is thicker than its edges while a diverging lens has a center that is thinner than its edges. See Figures 6 & 7.

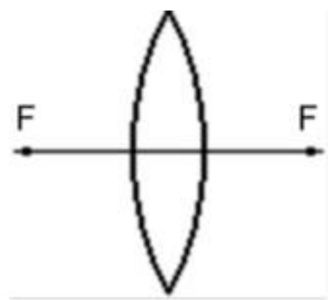

FIGURE 6
Converging lens

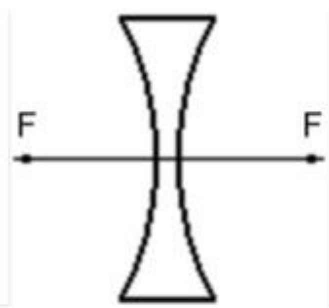

FIGURE 7
Diverging lens

Also notice that there are focal points on both sides of the lens. This does not imply that one focal length is positive and the other negative. The sign conventions are given in the chart below.

<u>Sign Conventions for Lenses</u>

The focal length, f, is + for a converging lens
The focal length, f, is - for a diverging lens

The Equipment

You will be using a Ray Box throughout this lab. The Ray Box will be used as a source of parallel light rays. You can set it for white light rays or for colored light rays. There is a rotating filter on the front of the box that will allow you to control the number of light rays that emerge from the box or view three colors. For white light you can have 1, 3, or 5 light rays. For colored light you will have 3 light rays, each a different color, for the lab you can use anything to block some and isolate any of the three.

Sharing Duty

For much of this lab you will share, with your lab partner, the duty of drawing Light Ray Diagrams (LRDs). This will save time and paper. For example, one person will draw the LRD for the concave mirror and the other person will draw the LRD for the convex mirror. You will SWITCH for the lenses so that each of you will make an LRD for a diverging light-ray case.

NOTE: When tracing a light ray, just put a dot at the beginning of the ray and a dot at the end of the ray. Draw in all of your lines by connecting the dots AFTER you've passed the light box to your partner. ALSO, all data, calculations, and answers to questions should go straight into your report, you can either draw the diagrams on separate paper, or directly into your lab book as directed by your instructor

What You Need To Do:

Reflection - Plane Surface

- **A.)** Plug in your Ray Box. Set the Ray Box up so that a single white light ray is emerging from it.
- **B.)** Take out the three-sided mirror from the Ray Optics container. Place the plane side of the mirror in the path of the light ray.
- **C.)** Trace the incident and reflected light ray. (Again, just use dots for the light rays and then pass the ray box to your partner). Make sure to draw a line for the mirror surface. Also make sure that your light rays are at least 9 cm long.
- **D.)** Using the protractor, make a normal at the point where the ray reflects. The diagram should look similar to Figure 1. Measure the angle of incidence and the angle of Reflection.
- **E.)** Have another partner repeat steps A-D for a different angle of incidence.

Question 1: Based on both of your observations on Reflection, what can you say about the relationship between the angle of incidence and the angle of Reflection?

- **F.)** Switch the Ray Box so that three lights are emerging, use any object to isolate just the red. Overlay the red light ray on top of the incident ray that you already drew. YOU DON'T HAVE TO TRACE IT. Observe how the ray reflects. Try blue. Try green.

Question 2: Does the color of the light affect the relationship that you determined in Question #1?

Reflection - Curved Surface

A.) Set up the Ray Box so that 5 white light rays are emerging from it.

B.) Place the concave side of the mirror in the path of the light rays. Make sure that the center ray is reflecting directly back on itself.

C.) Trace the five incident and reflected rays. Draw a line for the mirror surface.

D.) Have another lab partner repeat A-C for the convex mirror.

Notice for the convex lens that the reflected rays do not converge. You will have to draw in dashed lines behind the mirror as in Figure 5.

E.) Measure the focal length of the mirror. (For the convex mirror, all of the light rays might not converge at exactly the same point. Just use the central location of where they all cross as a reference point in measuring the focal length).

F.) Calculate the radius of curvature for each mirror. ***DON'T FORGET THE SIGN CONVENTIONS***

Question 3: Does the color of the light affect your focal length?

Refraction - Plane Surface

A.) Shine a single ray of white light into the rhombus as shown in Figure 9. Make sure the frosted side of the rhombus is face down so that you can see the light ray inside of the rhombus.

B.) Trace a line around the rhombus.

C.) Trace the incident light ray and the outgoing light ray. Make sure each line is at least 9cm long so that you can use the protractor correctly.

D.) Draw a line inside of the rhombus connecting the incident ray and the outgoing ray.

E.) Using the protractor, draw two normal lines as shown in Figure 9.

F.) Measure the angle of incidence and the angle of refraction at the first surface. You will have to extend the light ray inside of the rhombus to measure the angle.

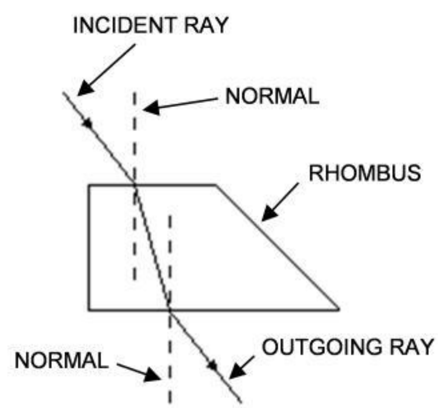

FIGURE 9 – Rhombus with refracting light ray

G.) Use Snell's Law to calculate the index of refraction of the rhombus. The index of refraction of air is 1.0.

H.) Compare the average value to the actual value of 1.5 by calculating a percent error.

$$\% \text{ Error} = \left| \frac{\text{Theoretical Value} - \text{Experimental Value}}{\text{Theoretical Value}} \right| \text{X } 100$$

Theoretical Value = Actual … Known …True Value

Question 4: Notice that the angle of incidence at the first surface is equal to the angle of refraction at the second surface. Prove that this is true algebraically for the general case (Do not use any numbers, only variables, use Snell's Law).

Question 5: Does the color of the light affect the angle of refraction?

Refraction - Curved Surface

A.) Set up the Ray Box so that 5 light rays are emerging.

B.) Place the converging lens in the path of the light rays

C.) Trace a line around the lens. **You will need around 15cm for these so use the page longways.**

D.) Trace the 5 incident rays as well as the 5 refracted rays.

E.) Measure the focal length. **DON'T FORGET THE SIGN CONVENTIONS**

F.) Have another partner repeat steps B through E for the diverging lens

NOTE: For the diverging lens do not use the reflected rays off of the first surface.

Question 6: Do you still get the same focal lengths if you turn the lenses around to face the other way? Did you expect this result? Explain why or why not.

Color – Prism

White light is actually a mixture of all colors. To demonstrate this, put the rhombus in the path of a single white light ray. See Figure 10. Make sure that the ray exiting the rhombus is very close to the surface of the rhombus. What do you see?

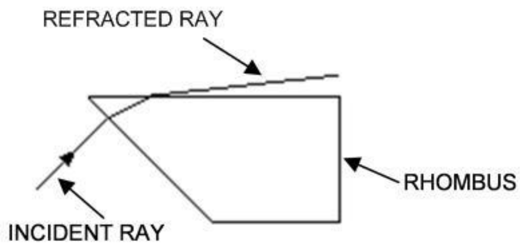

FIGURE 10 – Rhombus with refracting light ray

Question 7: Which color refracts the most? The least? (*Hint: The one that "refracts the most" will have the greatest angle of refraction*

Question 8: Re-examine your answer to Question #5. Re-answer the question now. What is different about this situation?

Color – Mixing

You just saw how light can be separated into colors. Now you will do the reverse. Switch the Ray Box so that the three primary colors appear. Place the converging lens in the path of the colored light. Stand up a white sheet of paper outside of the focal point. Slowly move the paper towards the focal point.

Question 9: What do you see when the paper reaches the focal point?

Question 10: Still using just the converging lens, try combining different pairs of colors together. (The mirror, placed on its side, blocks one of the light rays nicely). What do you see? Did your results turn out how you expected?

What You Need To Turn In:

Include all drawing in your report, if they were on separate sheets tape them into your lab report properly (be sure they're straight and cut to fit etc.). Make sure all your data, like focal lengths, is recorded in your lab report. Answer all the questions in the sections where they are asked. Also include the standard lab parts as your instructor specified.