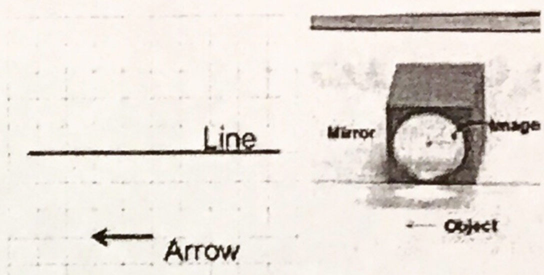
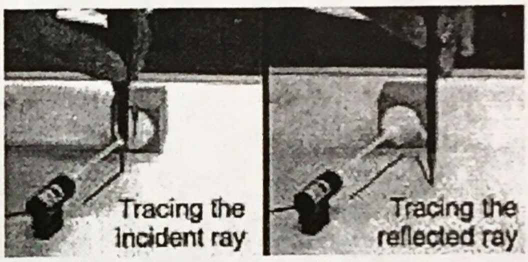
Wilkens

Reflections in a mirror

1. Secure a sheet of graph paper to the optics table with the magnetic strips.
2. Draw a line on the paper to mark where you will place a mirror. Place a mirror along this line.
3. Draw a 1-centimeter-long arrow on the graph paper about 3 centimeters away from your line. The arrow should be parallel to the line.
4. Move your head until you can see the reflection of the arrow in the mirror. The image of the arrow appears to be behind the mirror.



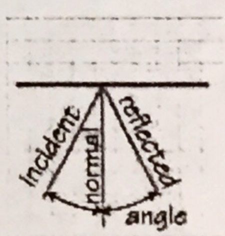
5. Hold your pencil straight up with the point on the tip of your arrow. Use the pencil to set the laser beam so it passes right over the tip of your arrow, and hits the mirror.
6. Trace the laser beam using your pencil as a guide. Trace the beam before it hits the mirror and after it hits the mirror.
7. Move the laser so the beam passes over the tip of your arrow from a different angle, but still hits the mirror. Trace the beam with your pencil like you did in steps 5 and 6.



8. The lines you drew represent rays of light before and after they hit the mirror. The **incident ray** shows the light before it hits the mirror. The **reflected ray** shows the path of the light after it bounces off the mirror.
9. Remove the mirror and use a ruler to extend the two reflected rays. They should meet in a point on the other side of the line where the mirror was. This point is where you saw the image of the tip of the arrow. The image is where all rays that leave the same point on an object meet together again.

Safety Tip: NEVER look directly into a laser beam. Some lasers can cause permanent damage to your eyes.

d. Pick one pair of incident and reflected rays. Draw a straight line perpendicular to the point where the rays hit the mirror. This perpendicular line is called the **normal** in optics. Use a protractor to measure the angle between the incident ray and the normal, and between the reflected ray and the normal. From your angles, what can you say about the relationship between the direction of the incident ray and the direction of the reflected ray?



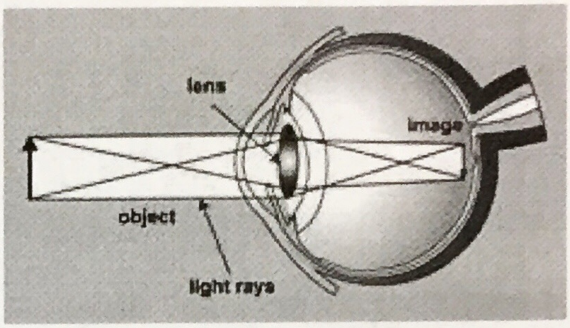
15.2 The Human Eye

Question: How does a lens form an image?

In this Investigation, you will:

1. Trace rays of light through prisms and lenses.
2. Find the focal length of a lens by tracing rays from a laser.
3. Learn how a lens creates an image.

The lens in your eye bends light to form an image on the retina. The lens can change shape so that we can see sharp images close up or far away.

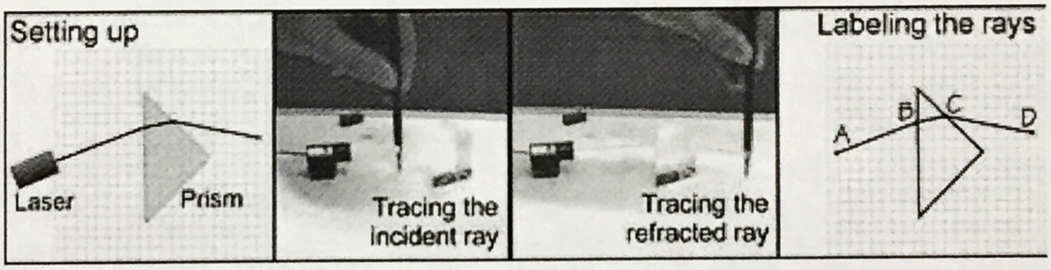


Refraction means "bending light." Any clear material can cause refraction. The amount of bending depends on the type of material and the shape of the surface. In this Investigation, you will explore refraction with prisms and lenses.

Safety Tip: Never look directly at the laser beam, or shine the laser beam at another's person's eyes.

1 Refracting light through a prism

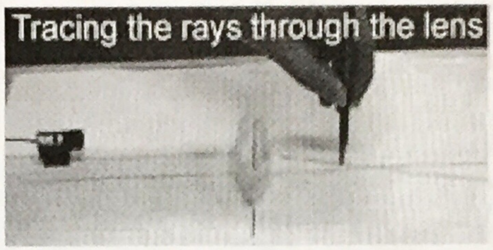
1. Secure a piece of graph paper to your magnetic surface. Put a prism on the center of the paper with the long flat side facing the left of the paper. Trace around the prism with a pencil.



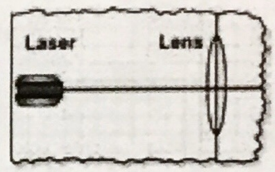
2. Put the laser on the left side of the prism.
3. Shine the laser at the prism and make sure that it comes out the other side of the prism. Use the edge of an index card to locate the beam as it enters and exits the prism. The approximate positions in the diagram will work.
4. Plot several points along the path of the laser beam as it goes into and out of the prism.
5. Remove the prism. Use a ruler to draw straight lines that follow your plot. Extend the lines until they touch the outline of your prism. Draw a third line to connect the lines through the prism. Label the points at the end of each line with the letters A, B, C, and D as shown in the diagram. Line A-B is the **incident ray**. Line B-C is the light ray inside the prism. Line C-D is the **refracted ray**.
6. Try a second time with a different angle for the laser as it approaches the prism. Not all angles will work; for some, the laser beam will not come out of the right side of the prism at all. Find a few angles for which the beam does go through the prism and trace the incident and refracted rays.

2 Refracting light through a lens

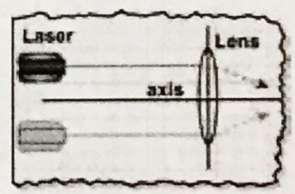
Like a prism, a converging lens bends light. Because the shape of a lens is curved, rays striking different places along the lens are bent different amounts. The laser allows us to follow the path of the incident and refracted rays.



1. Take a large (11 x 17) sheet of graph paper and draw a horizontal line through the center. We will refer to this line as the **axis**. Draw a second line in the middle of the paper perpendicular to the axis.
2. Place your 'flat' lens on the intersection of the two lines as shown.



3. Place the laser to the left of the lens, so that the notch in the base is centered on the axis. Turn on the laser and shine the beam through the lens.
4. If the beam goes through the exact center of the lens, it will not appear to be refracted at all. Adjust the lens so that the beam goes through the exact center. Trace around the border of the lens with your pencil.
5. Now move the laser to a point 15 cm to the left of the vertical line and 2 cm **above** the axis. Shine the laser beam through the lens along a line parallel to the axis. Plot the incident and refracted rays on the graph paper.



6. Repeat step 5 with the laser 2 cm **below** the axis. Plot the incident and refracted rays.

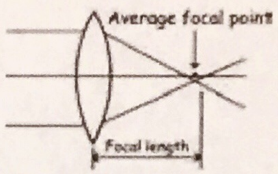
a. Describe the path of the laser beam as it travels along the axis and through the lens. Compare the paths of the incident and the refracted rays.

b. Describe the path of the laser beam as it travels parallel to the axis, above or below the axis. Compare the paths of the incident and refracted rays.

c. How is the path of light through a converging lens like the path of light through a prism?

3 Finding the focal point

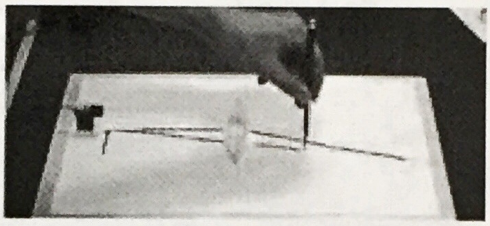
Rays that approach a lens *parallel to the axis* meet at a point called the **focal point**. The distance between the center of the lens and the focal point is called the **focal length**.

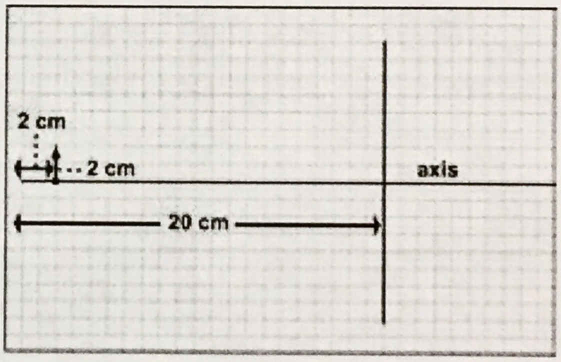


1. The two refracted rays that you traced in part 2 crossed the axis. Mark the axis where these rays crossed. This is the focal point for your lens. Due to imperfections in the lens, these two rays may not meet in exactly one point. In this case, choose the midpoint between the two points as your focal point.
2. Measure the distance between the focal point and the center of your lens. This distance is the focal length of your lens.
3. Label the focal point and focal length on your ray diagram.

4 Finding an image

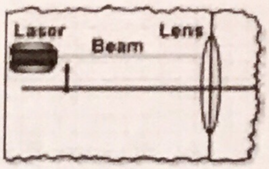
When all the rays from a point on an object meet again, they form an **image**. You can use the laser to locate images formed by your lens.



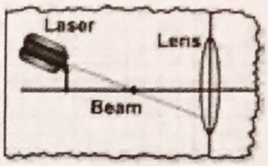


1. Tape two large (11 × 17 inches) sheets of graph paper together so that you have a new (11 × 34 inches) working surface. Draw a horizontal axis all the way across the graph paper.
2. Now draw a vertical line 20 cm from the left side of the page. Place the lens at the intersection of the lines.
3. Use the laser to center the lens, just as you did in steps 3 and 4 of part 2. Trace around the lens with your pencil.
4. Draw a vertical arrow 2 cm from the left edge of the graph paper. The base of the arrow should be on the axis. The tip of the arrow should be 2 cm above the axis. This arrow will serve as your "object."

5. Place the laser at the tip of the arrow. Shine the beam through the lens in a line parallel to the axis. Trace the incident and refracted rays.



6. Check to see that the lens is still centered on the axis.On the left side of the lens, make a dot on the axis that marks off a length equal to the focal length.
7. Place the laser at the tip of the arrow. Turn the laser so that the beam passes through the dot you made in step 6. Verify that this is happening by placing the edge of your index card at the location of the dot.



8. Trace the incident and refracted rays.
9. The two refracted rays that you have drawn should intersect somewhere on the right side of the lens. Mark the intersection with an upside down arrowhead. You have just plotted the image of the tip of your arrow!
10. Draw a vertical line from your "image" arrowhead to the axis. You have now drawn the image of your arrow.

5 Characteristics of the image

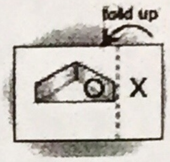
Compare the image of the arrow to the original arrow.

a. Is the image larger or smaller? Calculate the magnification by dividing the length of the image by the length of the original arrow.

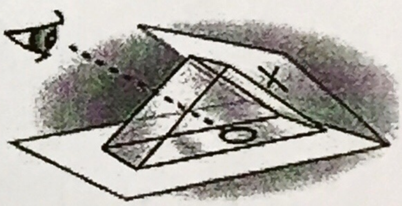
b. Is the image right side up, or is it inverted?

c. Is the image closer to the lens than the original arrow, or is it farther away?

1 The critical angle of refraction



1. Take a piece of graph paper and draw a line about 5 centimeters from one edge. Draw an X and an O about the same distance from the line.
2. Fold the paper on the line until it makes an angle greater than 90 degrees. Place one side of the fold on the table. The other side of the fold will be off the table.
3. Place your prism on the graph paper on top of the O. The long face of the prism should be on the paper and the edge aligned with the fold.
4. Look into the prism. Move your head up and down to change the angle at which you look. Answer question 1(a).



Both refraction and reflection are possible when light hits a boundary between a high index of refraction (like glass) and a lower index of refraction (like air). Whether the light is reflected or refracted depends on the angle. The critical angle is the angle at which the switch from reflection to refraction occurs.

a. What happens to the image you see through the prism? Is it an X or an O?

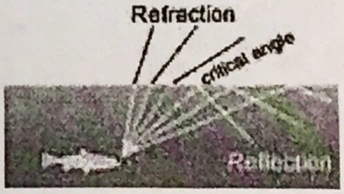
b. Draw a diagram showing the path of the light rays when you see the X.

c. Draw a diagram showing the path of the light rays when you see the O.

d. Is the image in the prism always reflected or refracted, or can there be both reflection and refraction at the same time?

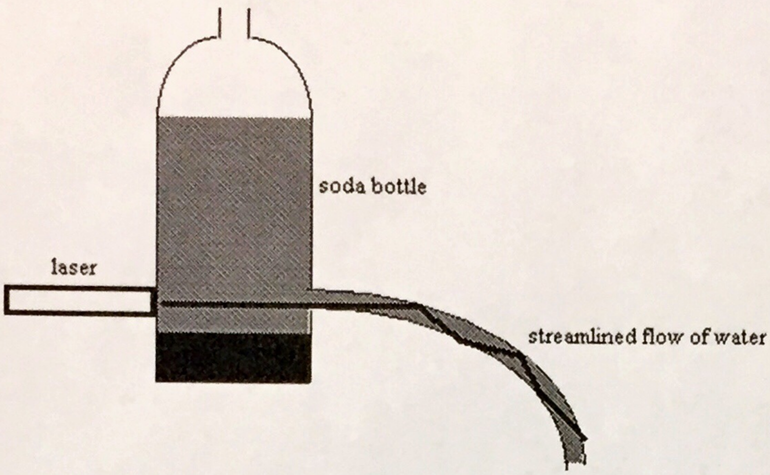
e. Think about being outside in the bright sun looking into a glass window where it is darker inside the window. Do you see reflection, refraction, or both?

When light is reflected by the boundary between glass and air we call it total internal reflection. The same thing can happen at the boundary between water and air. A fish looking up at the surface of the water from below does not see only the sky! The fish sees reflected rays from the water from part of the surface, and refracted rays from the air from part of the surface.



Total Internal Reflection:

- Use your laser and a 2-liter bottle to do the following at one of the sinks around the room.



Define the following terms:

1. Reflection
2. Refraction
3. Diffraction
4. Absorption
5. Destructive Interference
6. Constructive Interference