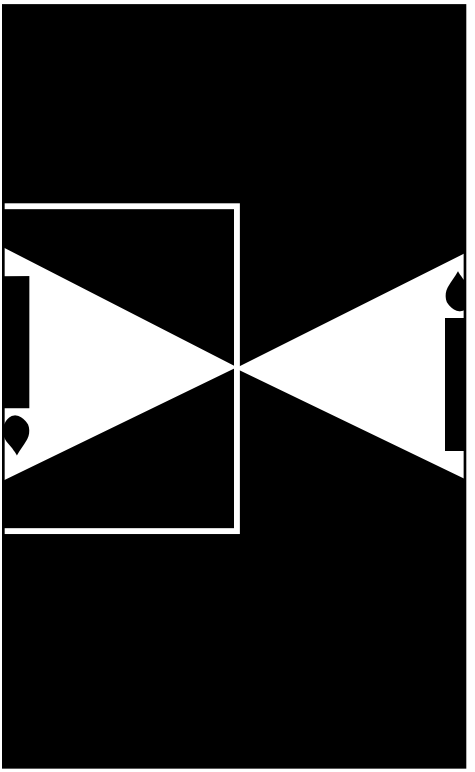


REFLECTION & REFRACTION

65547-05

STUDENT'S WORKBOOK

By Lawrence F. Lowery

STUDENT'S WORKBOOK
REFLECTION, REFRACTION, DIFFRACTION

INTRODUCTION

Light has puzzled mankind for centuries. It is something that you cannot hear or smell. You cannot taste light. You cannot hold it in your hands to study it. You can only see how it affects and is affected by objects.

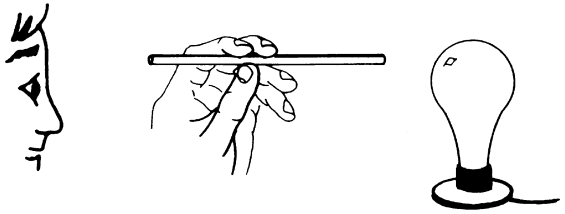
Have you ever wondered what happens when light strikes an object? Have you noticed that some objects "bounce" light? This package of materials will help you make many discoveries about light and how it behaves.

Exploration 1: Observing how Light Travels

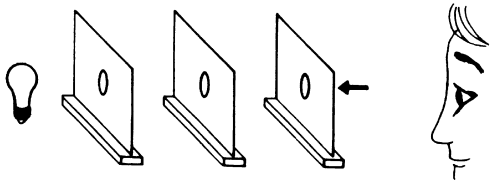
For this exploration you will need a drinking straw and three 2" x 2" squares of cardboard.

Have you ever wondered how light travels? Do you think it travels in straight lines? Or curves? Do you think light always behaves in the same way?

Look through the drinking straw at a light bulb. Is it hard to point the straw directly at the light bulb? What happens if your aim isn't good? Can you see the light bulb if you bend the straw a little bit? Bend the straw a little more. Now can you see the light bulb? Do you have to bend the straw very much before you can't see the light bulb through it? Why do you think this happens?



Punch a small round hole in each of the three pieces of cardboard. Set them in a line in front of a light. Can you see the light bulb through the holes? Why not? What do you have to do to see the light through the three holes?



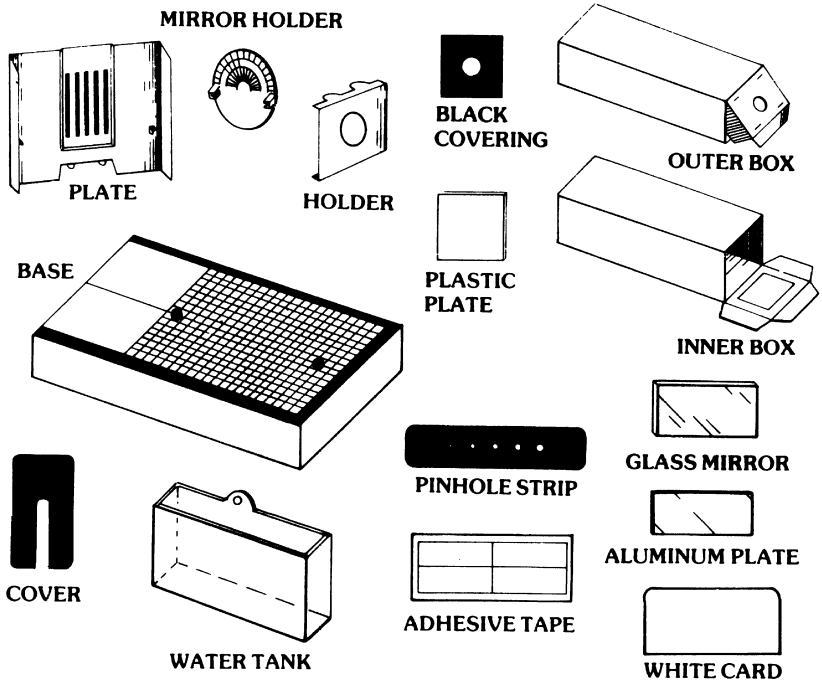
Do you think light travels in curved lines or straight lines? Can you prove your answer?

Additional Exploration

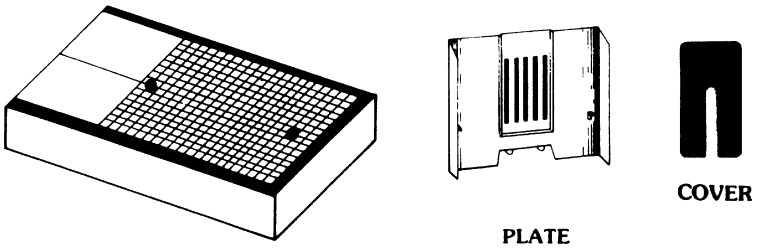
In a darkened room, shine a flashlight on the nearest wall. Can you see the path of light in the air? Now shine the light on the far wall. Does the light make a straight path or a curved one?

Exploration 2: Observing Beams of Light

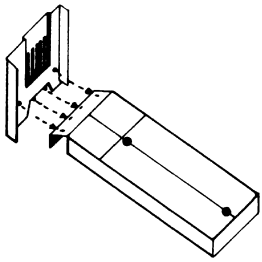
Take the parts out of your kit and compare them to the illustration below. Match them up with their pictures. By doing this, you will learn the names of all the parts, so that putting them together will be easier.



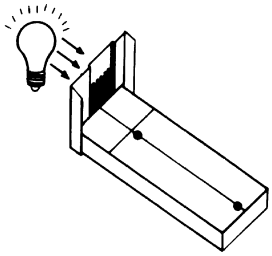
For this exploration, you will need only the base, the plate, and the cover.



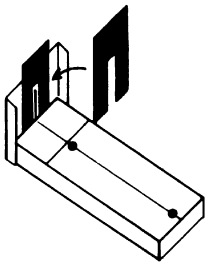
One end of the base has punchouts into which the tabs on the plate fit. Push the tabs into the base and bend them over. Tuck both end flaps into the base.



Hold the base so the light from the sun or a bright light bulb (more than five feet away) passes through the slits in the plate and across the top of the base. Do the light beams seem to travel in a straight line or do they bend? Turn the base from side to side, holding it so the beams still shine on the top of the base. What happens to the beams of light? Do they still seem straight or do they bend? Observe them carefully.



Slip the cover into the plate so that it covers all the slits except the middle one. How does one beam of light look as it travels through the opening and across the top of the base?



Hold the base near a clear (not frosted) light bulb so the light beam travels down the center of the top of the base. Turn the base from side to side. What happens to the light from the slit?

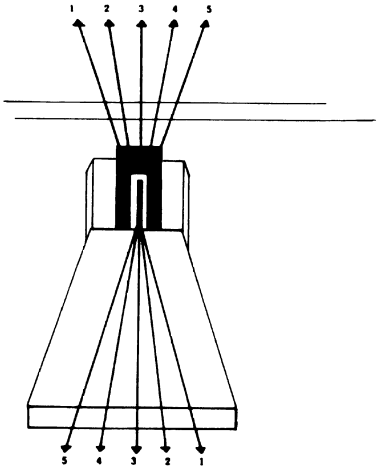
Using only one eye, look straight through the slit at something in the room. Does the light from the object come straight through to your eye? Without moving your head or the base, can you see anything around the edge of the opening?

Hold the base steady and move your head slightly to the right. What do you see now? Move your head to the left. Now what do you see? Do you think light travels in a straight line?

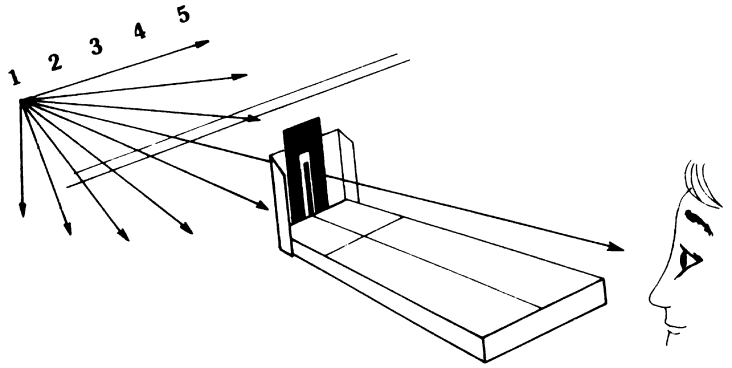
In air, light usually travels in straight lines. If it didn't, you would have been able to see the object you were looking at around the edge of the opening. You could see around corners!

Exploration 3: Observing Light Passing through a Narrow Slit

On a chalkboard or large sheet of paper, write numerals from 1 through 5 about one foot apart. Stand about 12 feet away, and look through the opening in the plate at numeral 3. With a pencil, lightly mark a 3 on the top of the base in front of your eye. Without moving the base, move your head until you can see numeral 2 with the same eye. Mark a 2 on the top of the base in front of your eye. Be sure to hold the base steady while you do the same for the other numerals. When you are finished, your base should look something like the picture.



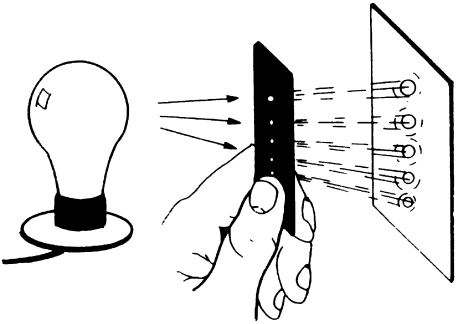
What do you notice about the numerals you wrote on the base and the ones on the chalkboard? Why do you think this happened? Does the fact that light travels in a straight line help explain the way numerals are arranged on the base?
Walk back and forth in front of the chalkboard. Can you see the numerals from many places as you walk? Notice that light comes off the numerals in every direction. Hold the base between your eye and the numerals. Move it slowly to one side until you can see the numeral 1. Only the beam of light that is in a straight line with your eye can be seen.



Look at any object through the slit. move your eye to the right. Do you see more of the right side or the left side of the object? Is this like what happened when you wrote down the numerals? Because light travels in a straight line, things on the right side of an opening are seen on the left, and things on the left side of an opening are seen on the right.

Exploration 4: Observing Light Passing through a Pinhole

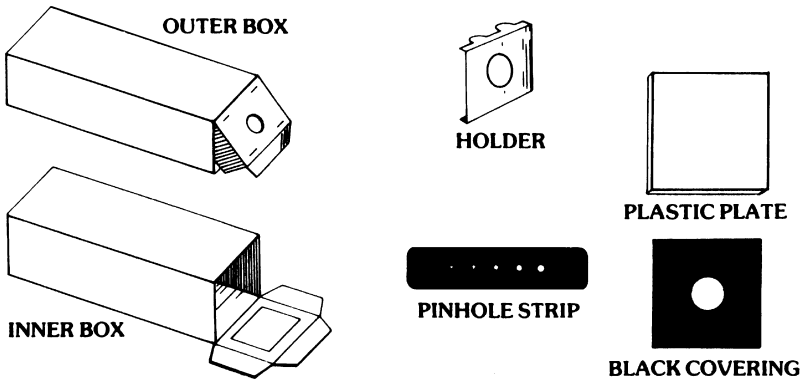
Take the pinholes strip and the white card from your kit. Hold the strip 6 to 12 inches away from a clear (not frosted) light bulb. Hold the white card about an inch away from the strip. What do you see? Move the card closer and then further away from the pinhole strip. What happens?



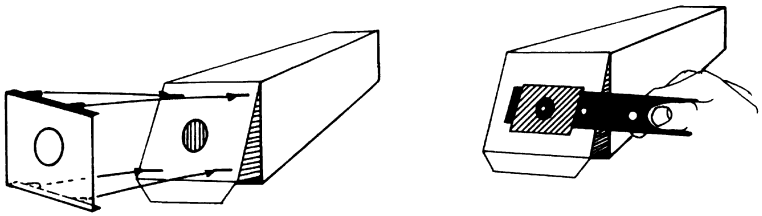
When you move the card away from the pinhole strip, do the images get larger or smaller? Notice that the bright images from each pinhole are surrounded by a dimmer, fainter image. What happens to the bright spot and the dim spot as you change the distance between the pinhole strip and the card? Does the size of the bright and dim spots change the same amount as you change the distance from the pinhole to the card?
Move the card closer and further from the pinhole strip, each time watching the light images from different pinholes. Do all the images change in the same way? Are some images brighter than others? What happens when you move the card and the pinhole towards and away from the light?

Exploration 5: Making a Pinhole Viewer

For this exploration you will need the outer box, the inner box, the holder, the black covering, the plastic plate, and the pinhole strip. You will also need some paste, glue or rubber cement.



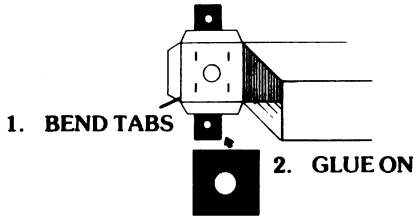
Punch out the circle in the lid of the outer box. Slip the tabs on the holder into the slots in the lid. Slide the pinhole strip into the holder, and then bend the tabs on the holder to hold it in place.

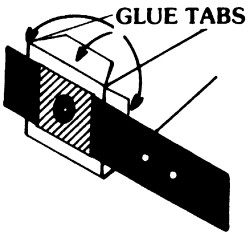


Paste, glue, or cement can be used in assembling the rest of these parts. Rubber cement is best, but it is a little harder to use. Use it this way:
1) Spread a thin coat of rubber cement on the parts you wish to cement together.
2) Wait until they are sticky to the touch and aren't shiny.
3) Carefully fit the parts together. Rubber cement sticks quickly, so be careful.
4) If rubber cement is smeared where you don't want it, rub it off with your fingers.

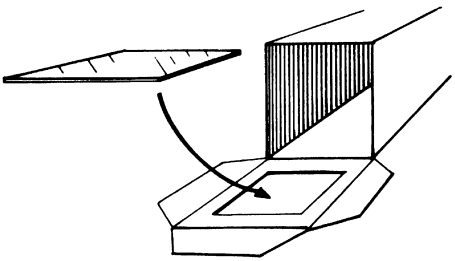
Punch the middle out of the black covering, and glue the covering over the tabs on the inside of the lid. Make sure the black side is toward the inside of the box, and that the center holes are lined up.

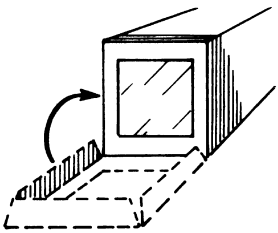
Fold the lid and glue the tabs in place on the outside of the outer box.





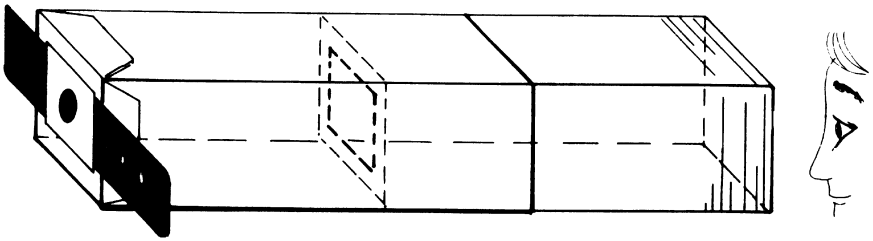
Slide the pinhole strip until the largest hole is over the opening. Look into the box from the open end. Do you see a spot of light? How is this hole like the openings you used in earlier explorations? Is it different in any way?
Now take the inner box, punch out the perforated square, and glue the square plastic plate, rough side down, to the inside of the lid. Be careful not to get any glue in the center of the plastic plate. Fold the lid and glue the tabs in place on the inside of the inner box.





When the glue is thoroughly dry, slip the inner box into the outer box so that the square plastic plate is near the pinhole strip.

Put the open end of the inner box close to your eye and look towards the window. Slide the inner box in and out until you can see part of the window clearly. How does it look? (This works best when you are in a dimly lighted room, and it is sunny outside.)



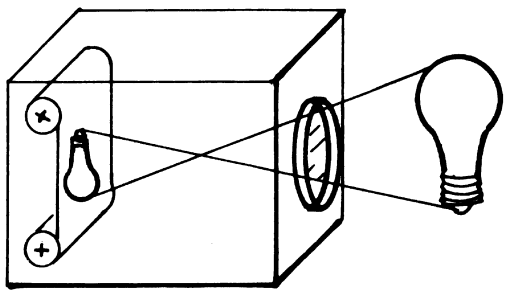
Look through the boxes at a light bulb. Slide the inner box in and out until the light can be seen clearly. Can you explain why it looks upside down? Is this in any way like the numbers on the chalkboard in Exploration 3? Why were those numerals reversed in sequence?

Move the pinhole strip to another hole. Look at the light again through the boxes. Slide the inner box in and out until you get the clearest image. Is this the same position that you got the clearest image before? Move the pinhole strip to other positions, each time looking at the light and adjusting the inner box. Are there differences in what you see with smaller openings and larger openings? Does what you see get clearer or not? Is the image brighter or dimmer?

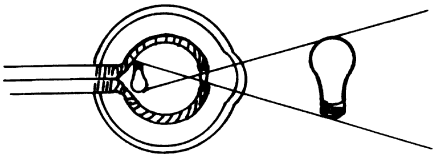
This pinhole viewer is like a pinhole camera. If you could put unexposed film where the square plastic is, you could expose it by uncovering the pinhole. A pinhole camera is fun to make, and can be used to take good pictures of objects.

The cameras most people use have a lens instead of a pinhole. A lens is used because it gathers more light than a pinhole and makes a sharper picture.

Look through your pinhole viewer at a light bulb. Change the size of the pinhole in front of the opening. Does the image get brighter or dimmer as you go from the smallest pinhole to the largest?



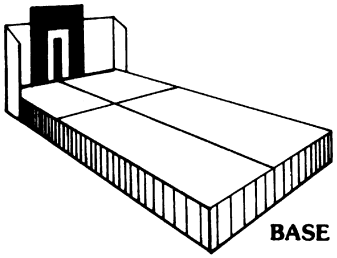
In most cameras, there is a way to let more or less light through the lens. Why do you think this is necessary? Do you think the picture on the film is upside down or right side up when it is in the camera? Why do you think this? The camera and the pinhole viewer work like your own eye. Your eye is like a living lens, and can gather much more light than a pinhole viewer. Light enters an opening in the front of your eye and makes an upside down image at the back.

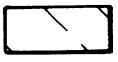


What is the opening of your eye called? Can your eyes adjust themselves to bright or dim light? How do you know?

Exploration 6: Observing Light Reflecting from a Flat Surface

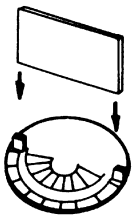
For the next two explorations, you will need the base, the mirror holder, the glass mirror, and the aluminum plate.



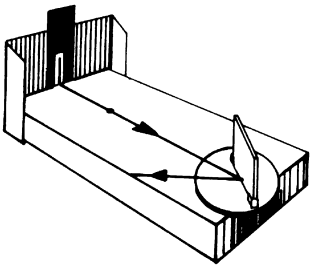


Have you ever "bounced" light with a mirror? Use the mirror in your kit to bounce light on a wall. How could you use light and a mirror to send messages? Do light messages travel very fast? Can they travel very far?

Carefully slip the mirror into the mirror holder so that it faces the numbers. Set the mirror holder into the small hole on the base away from the black plate. Let a beam of light shine through the slit onto the mirror.

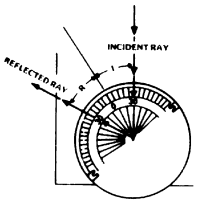


While still pointing the slit at the light, turn the mirror holder to the right and then to the left. What happened to the beam of light when you turned the holder to the left? When you turned the beam holder to the right?



The mirror holder has marks on it indicating 5 degrees; every other one of the marks is numbered, indicating 10 degrees or multiples of ten degrees. These markings can be used to measure how much of an angle the mirror is turned, and how a beam of light is reflected or bounced.

Line up the mirror so that 0 degrees is in line with the beam of light. Where does the beam of light reflect to? Turn the mirror 10 degrees to the right. The light beam now strikes the mirror at an angle of 10 degrees. This is called the "angle of incidence". At what angle does the light beam bounce away, or reflect, from the mirror? This is called the "angle of reflection".



Are the angles the same or different sizes? Make a chart like the one shown below. Turn the mirror to 20 degrees, 30 degrees, and then 40 degrees. List your findings on the chart.

LIGHT REFLECTION TABLE		
ANGLE OF INCIDENCE	ANGLE OF REFLECTION	TOTAL ANGLE
10°	10°	20°
20°	-	-
30°	-	-
40°	-	-
-	-	-

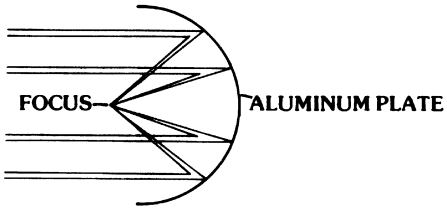
Can you make up a rule about the reflection of light? Does the rule hold true if you turn the mirror in the opposite direction?

Exploration 7: Observing Light Reflecting from a Curved Surface

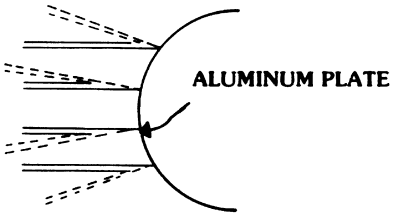
Remove the mirror from the mirror holder and replace it with the aluminum plate. Remove the cover from the slits. Point the slits at a light. How are the beams of light reflected? Is it the same way as with a mirror?

Remove the mirror holder from the base and take the aluminum plate out of the holder. Hold the aluminum plate between your thumb and forefinger near the middle of the base, facing the slits. Put the cover over the slits and point the base at a bright light so that it shines through the single slit onto the aluminum plate. Is the plate in the 0 degree position? How can you tell? Are the reflected beams straight?

Remove the cover from the slits. Push gently at the center of the aluminum plate so that it curves slightly towards the slits. What do the rays do? Squeeze your fingers together so the aluminum plate curves more. Try to do this without creasing the aluminum plate. This type of mirror is called "concave" because it bends inward. It focuses beams of light. This principle is used in astronomical telescopes and magnifying mirrors.

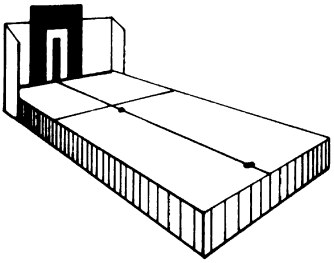


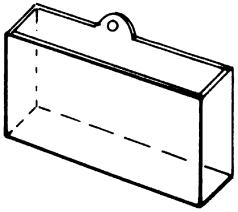
Relax your fingers so the aluminum plate straightens out. Now push on the side of the plate away from the slit so the mirror bends the other way. Hold the plate in position on the base and point the slits at the light. What do the beams of light do? Make the curve sharper. What happens to the beams? This type of mirror is called "convex" because it bends outward. It causes light beams to spread apart. Some truck rearview mirrors are curved like this. Such a mirror lets you see more than a flat mirror would show.



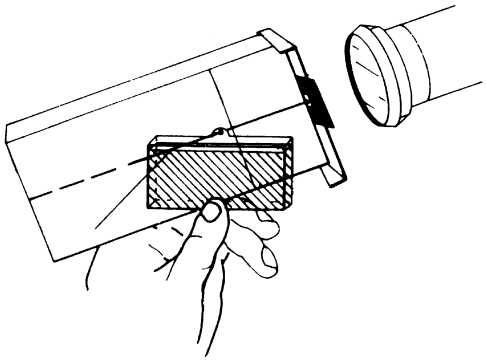
Exploration 8: Observing Light Passing through Air and Water

You have found that light travels through the air in straight lines. How do you think it travels in water? In this exploration, you will be able to see how light travels when it moves from air to water and into air again. To do this, you will need the base with the cover on the slits and the water tank.



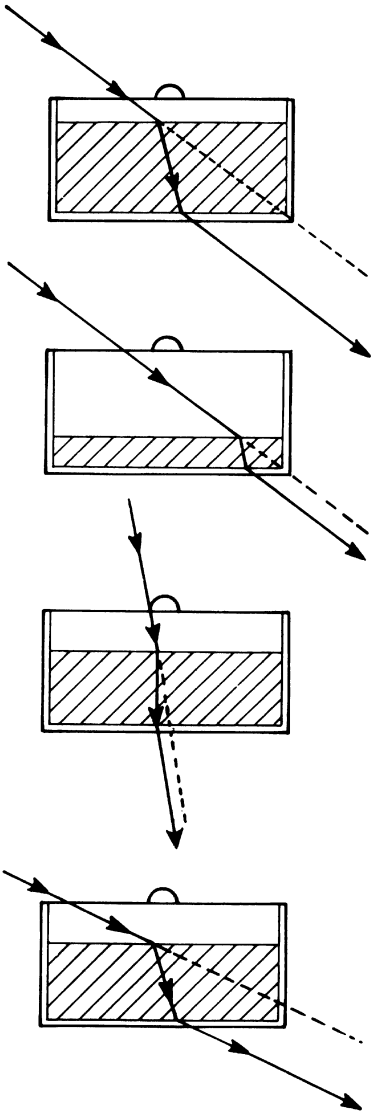


Fill the tank almost full of water. Add a few drops of milk. This will make the light beam more easily seen as it travels through the water. Set the base so the plate is on its side and set the tank on it as shown. Turn your light until a beam enters the slit and travels into the tank of water. Does it travel in the water in the same straight line it does in air? How would you describe the line made by the beam as it goes from water to air? How would you describe the light beam when it enters the water?



Hold the tank so it won't spill while you change the angle of the base until the light enters the water at a different angle. Does this make any difference to the angles made by the light? Is the light beam, as it goes through the water, parallel to the beam in air? Or is it at an angle? What about the beam that exits from the other side? Is it parallel to the incoming beam?

Change the angle at which the beam enters the water. Draw a picture of how the light beam travels.



When the light goes from air into some other substance, like water, it is bent. This is called "refraction". Have you ever noticed how a straw looks in a glass of water? Does refraction explain why the straw looks that way?
What other examples of refraction can you see around your school or home?

Dr. Lawrence F. Lowery is a professor of science education at the University of California, Berkeley. He has had extensive elementary and junior high school teaching experience, has written numerous books and made films on science and has written many articles for teachers on science instruction.

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