8 Wave Reflection

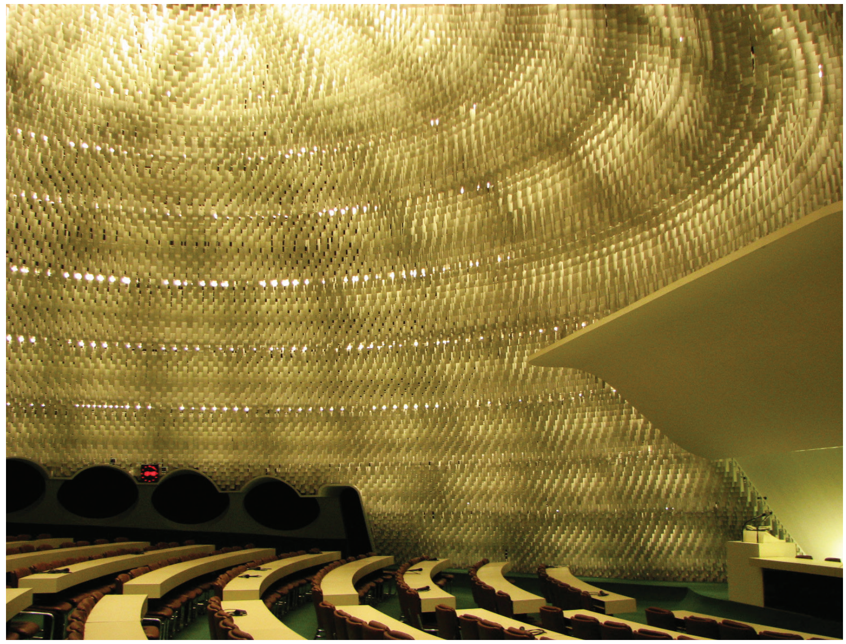
LABORATORY

IN PREVIOUS ACTIVITIES, you explored how waves have certain properties, such as frequency or speed. In this activity, you will explore the wave property of **reflection** the bouncing of a wave off an object. Reflection is a property that applies to all kinds of waves, including both sound and light.

A mirror reflects light off its surface.

GUIDING QUESTION

What kind of surface makes a good reflector?



Acoustical tiles are used in large spaces to reduce the reflection of sound off the ceiling.

MATERIALS

Part A

For each group of four students

2 cardboard tubes

Part B

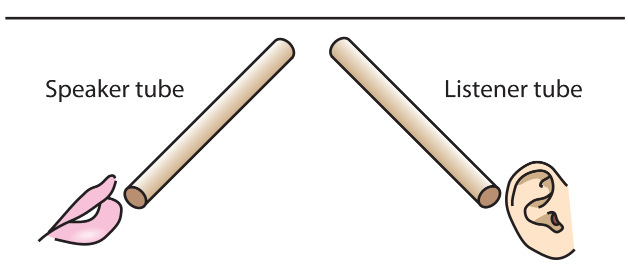
For each group of four students

1 light station
1 single-slit mask
1 triple-slit mask
1 plane mirror
2 plane mirror holders
1 curved mirror
1 curved mirror holder
1 angle card
1 index card

PROCEDURE

Part A: Reflecting Sound

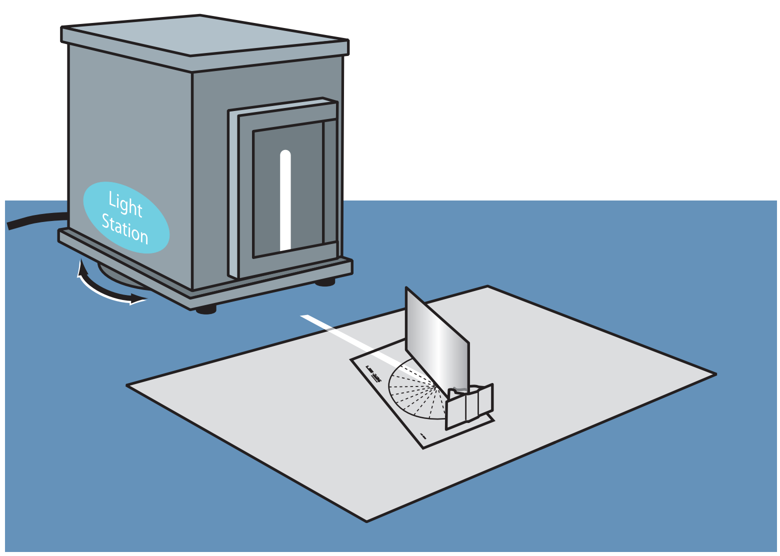
1. In your group of four, find a hard, smooth surface, such as a wall or white board.
2. Position the end of one of the cardboard tubes about 20 cm from the smooth surface, and angle it at about 45 degrees to the surface, as shown in the diagram below.



3. Have one member of your group speak softly into the end of the tube that is farthest from the smooth surface.
4. Have another member of your group listen through the end of the second tube, which is held 20 cm away and pointed towards the smooth surface, as shown in the diagram in Step 2.
5. Keep the speaker tube in the same position while trying to find the position of the listener tube that allows the speaker's voice to be heard the clearest.
6. When you have found the best position for the speaker tube, have another member of your group draw a diagram to record the positions of the two tubes and the smooth surface.
7. Move the listener tube to a different angle from the wall and repeat Steps 3–6. In your science notebook, record any patterns you observe about the positions of the two tubes.
8. Repeat Steps 3–7 using a soft surface instead of a hard surface. Record your observations in your science notebook.

Part B: Reflecting Light

9. Set up the light station using the diagram below.



10. Stand a plane mirror so that it is upright on the mirror line of the angle card.
11. Based on your experiences in Part A, predict where you think the light will go when it is turned on if it travels to the mirror along line 1L.
12. Test your prediction and record your results in your science notebook.
13. Design an investigation to determine the relationship between the incoming light ray and the reflected ray.
14. Get your teacher's approval and conduct your experiment. Record your results in a table.
15. Discuss your findings with your class.
16. Adjust the light station by replacing the single slit with the triple slit.
17. In your group, predict what would happen if you aim the three rays of light from the triple slit at an angle towards the mirror. In your science notebook, draw a diagram to represent your group's prediction. Make sure to include the reasoning behind your prediction.
18. Test your prediction and record your observations by drawing a diagram in your science notebook.
19. Replace the plane mirror with the curved mirror and repeat Steps 17–18.
20. Replace the curved mirror with the white index card and repeat Steps 17–18.

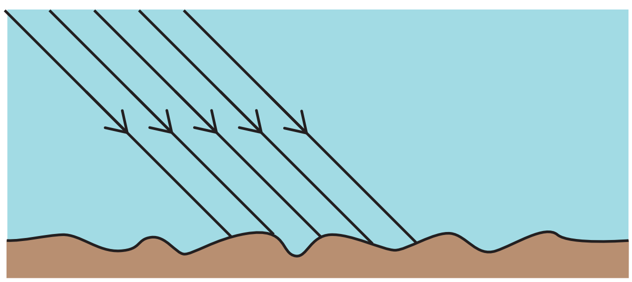
ANALYSIS

1. What patterns did you notice about the angle of the listener tube compared with the angle of the speaker tube?
2. Describe the relationship between the angle that a ray hits a mirror and the angle that the same ray reflects off
   a. a plane mirror.
   b. a curved mirror.

3. Was light reflected off the white index card? Explain how you know.

4. Which surface, a smooth or bumpy one, do you think would be best used for the ceiling of a concert hall? Explain your choice.

5. The diagram below represents a highly magnified image of the surface of the index card. The five lines with arrows represent rays of light hitting the card. Copy the diagram and then
   a. draw the rays of light that are reflected from the card.
   b. explain why the surface of the card does not appear shiny like a mirror.



6. Explain why the ears of some mammals are bowl-shaped.

7. If only some of the light that hits an object is reflected, predict what might happen to the rest of the light.

9 Refraction Of Light

LABORATORY

In general, light travels in a straight line. This occurs when light is **transmitted**, which is when light passes through a vacuum or a material. However, at the boundary between two transparent materials, the light can be redirected. This phenomenon is called **refraction**. Refraction occurs when a wave passes from one material to another, such as from air to glass. Upon entering the second material, the light travels at a higher or lower speed depending on the properties of the second material such as temperature, pressure, and density. As the speed changes, the direction of travel through the material also changes if it hits the boundary at an angle other than perpendicular. This can be observed when a pencil inserted in a glass of water appears to bend at the boundary where the water meets the air.

GUIDING QUESTION

How does light behave at the boundary between two different materials?

MATERIALS

For each group of four students

1 light station
1 single-slit mask
1 beam blocker with stand
1 semicircular container
1 protractor
1 ruler
1 sheet of white paper
milky water

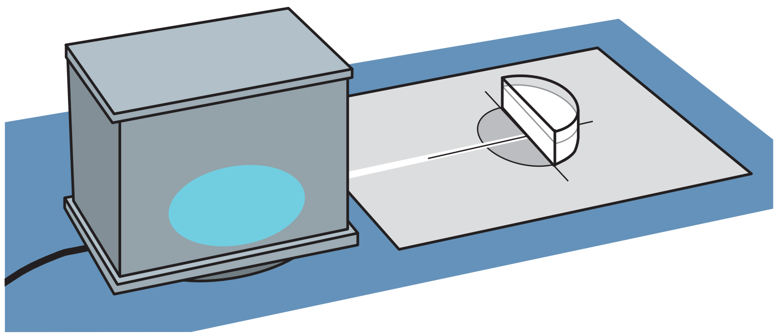
For each student

1 Student Sheet 9.1, "Refraction Measurements"
1 Student Sheet 9.2, "Total Internal Reflection Measurements"
1 sheet graph paper

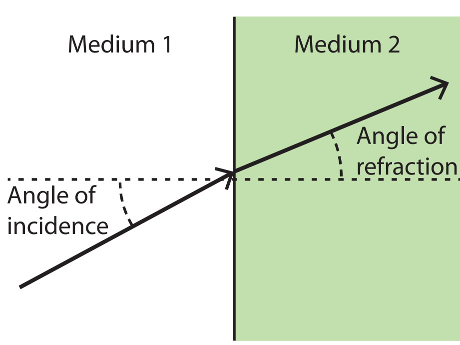
PROCEDURE

Part A: Refraction

1. Place the container with milky water on Student Sheet 9.1, "Refraction Measurements."
2. With your partner, predict what will happen to the path of a beam of light when it is pointed directly down the center line toward the dot and through the container full of milky water, as shown in the diagram below.



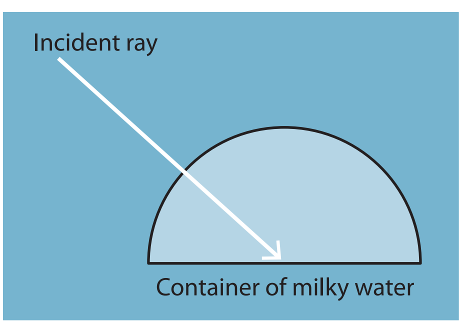
3. Test your prediction and record your results on Student Sheet 9.1.
4. Design an investigation to learn what happens to the direction of the beam of light when it hits the boundary of the glass or container at an angle between 0 and 90 degrees. In your investigation, make sure to measure the
   - **angle of incidence**, or the angle between the incoming light ray and the normal line.
   - **angle of refraction**, or the angle between the normal line and the path the light travels in the new medium.



5. After getting approval from your teacher, conduct the investigation and record your results.
6. Graph the angle of incidence (x-axis) vs. the angle of refraction (y-axis).
7. With your group, make a statement that explains the pattern in your results, and record the statement in your science notebook.

Part B: Total Internal Reflection

8. With your partner, design an investigation to find the critical angle of the milky water. The **critical angle** is equal to the angle of incidence that produces a 90-degree angle of refraction. When the incident ray is greater than the critical angle, the light traveling from an optically denser to less dense medium no longer transmits through the material. Instead, it is completely reflected back into the denser material. When the light no longer travels through to the next medium in this way, it is called **total internal reflection**. In this activity, the optically denser medium is the milky water and the less dense medium is the air.



9. Use Student Sheet 9.2, "Total Internal Reflection Measurements," to collect your data.
10. Share your results with the class.

ANALYSIS

1. Draw a diagram with labels that shows how the light traveled through the milky water when it was

   a. directed down the normal line.

   b. directed at an angle.

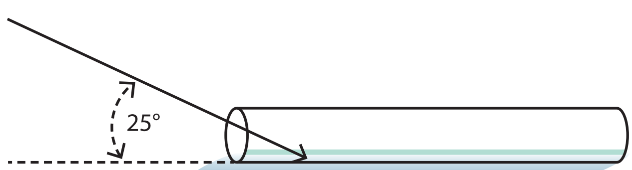
2. Look at the data below that show the refraction of light from one medium to another for various materials.

Refraction of common materials

Material	Critical angle (degrees)	Optical Density (index of refraction)	Incident angle (degrees)	Refraction angle (degrees)
Water	50	1.3	20	15.2
Sugar solution (40%)	46	1.4	20	14.1
Acrylic	42	1.5	20	13.2
Flint glass	39	1.6	20	12.3

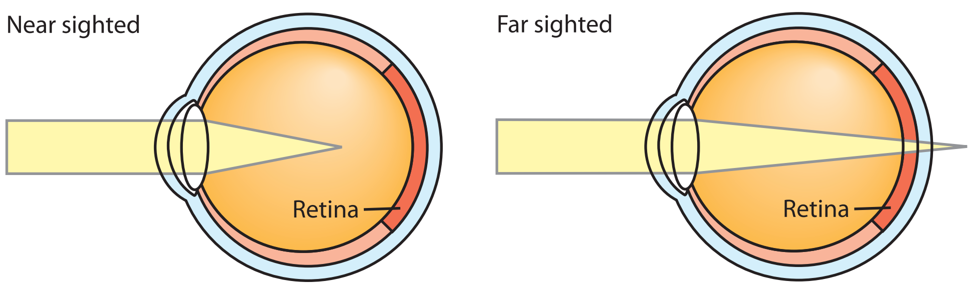
   Your friend looks at these data and says, "I see a general trend showing that as the optical density of a material increases, the critical angle also increases." Do you agree or disagree with your friend? Explain your opinion using evidence from the table.

3. The principle of total internal reflection is used in fiber optic technology. A wave signal is sent down a glass tube at greater than the critical angle so that it is reflected off the interior of the tube as it travels. Copy the close-up diagram of a fiber optic cable below. Draw arrow(s) that show a possible ray that is totally internally reflected through the tube.

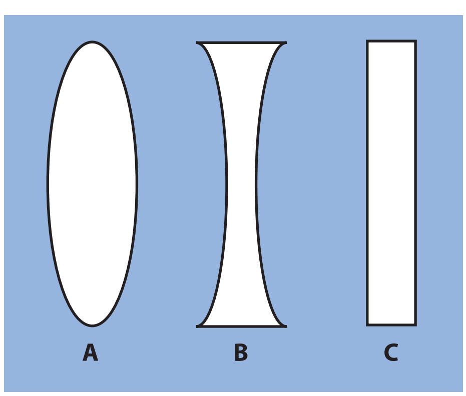


4. The functioning of the human eyeball depends on the refraction of light. When light comes into the eye, first the cornea and then the lens refracts the light so that it focuses on the retina. The lens is flexible and is controlled by muscles in the eye. The curvature of the lens changes in order to focus objects at different distances. If the lens does not refract properly, the light rays do not come together at a point on the retina.

   When the light focuses past the retina, the person will have blurry vision at close distances. This person would be considered farsighted. Farsightedness can be corrected with eyeglasses or contact lenses that refract the light inwards before it enters the eye. The opposite problem, or nearsightedness, occurs when the light entering the eye comes to a point before it hits the retina. It results in blurry vision at farther distances. This is corrected by refracting the light outwards before it enters the eye.



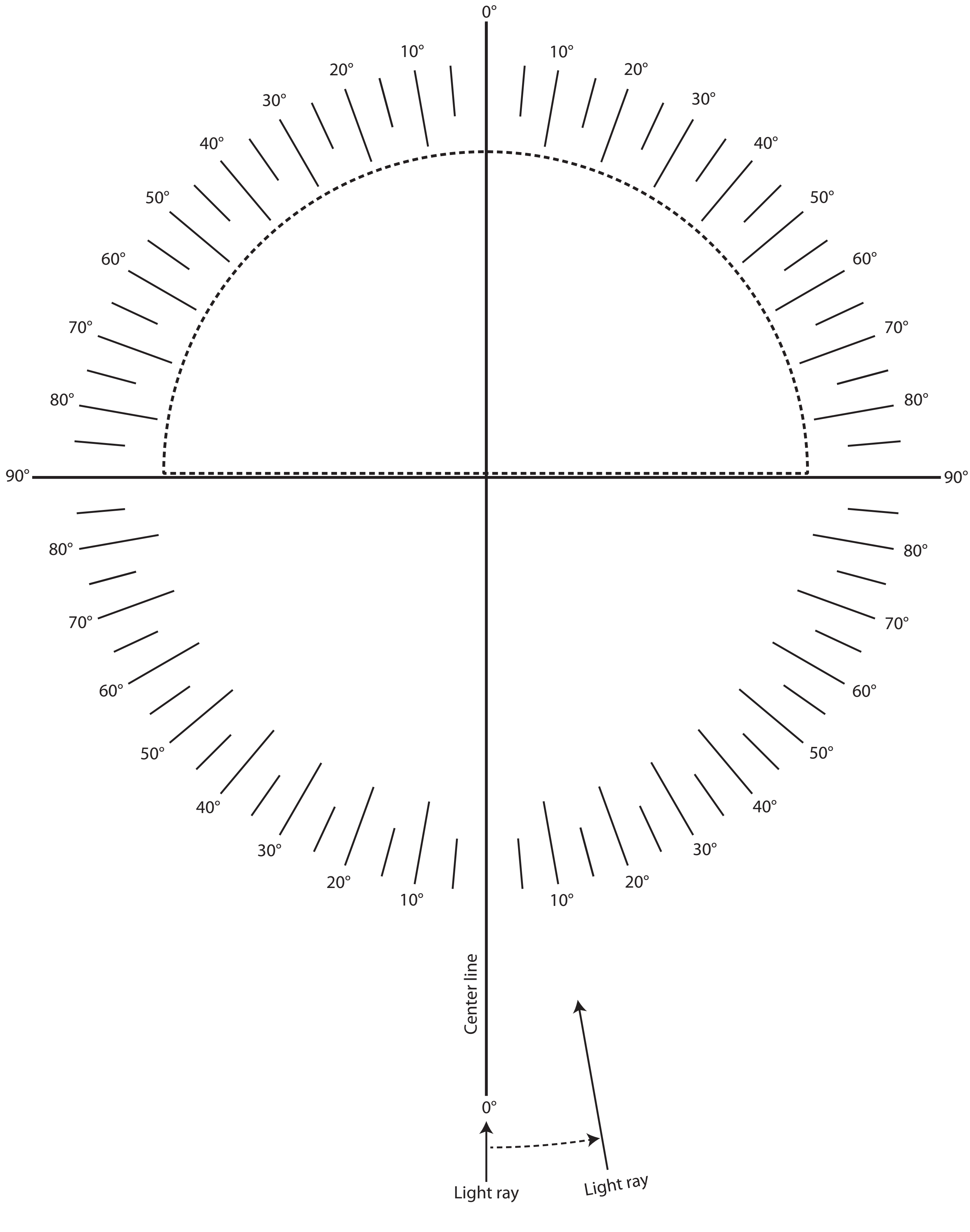
   Which one of the following eyeglass lenses can be used to make the light fall on the retina of a nearsighted person? Draw a diagram that shows the lens, the eye, and two rays of light converging on the retina.



STUDENT SHEET 9.1

REFRACTION MEASUREMENTS

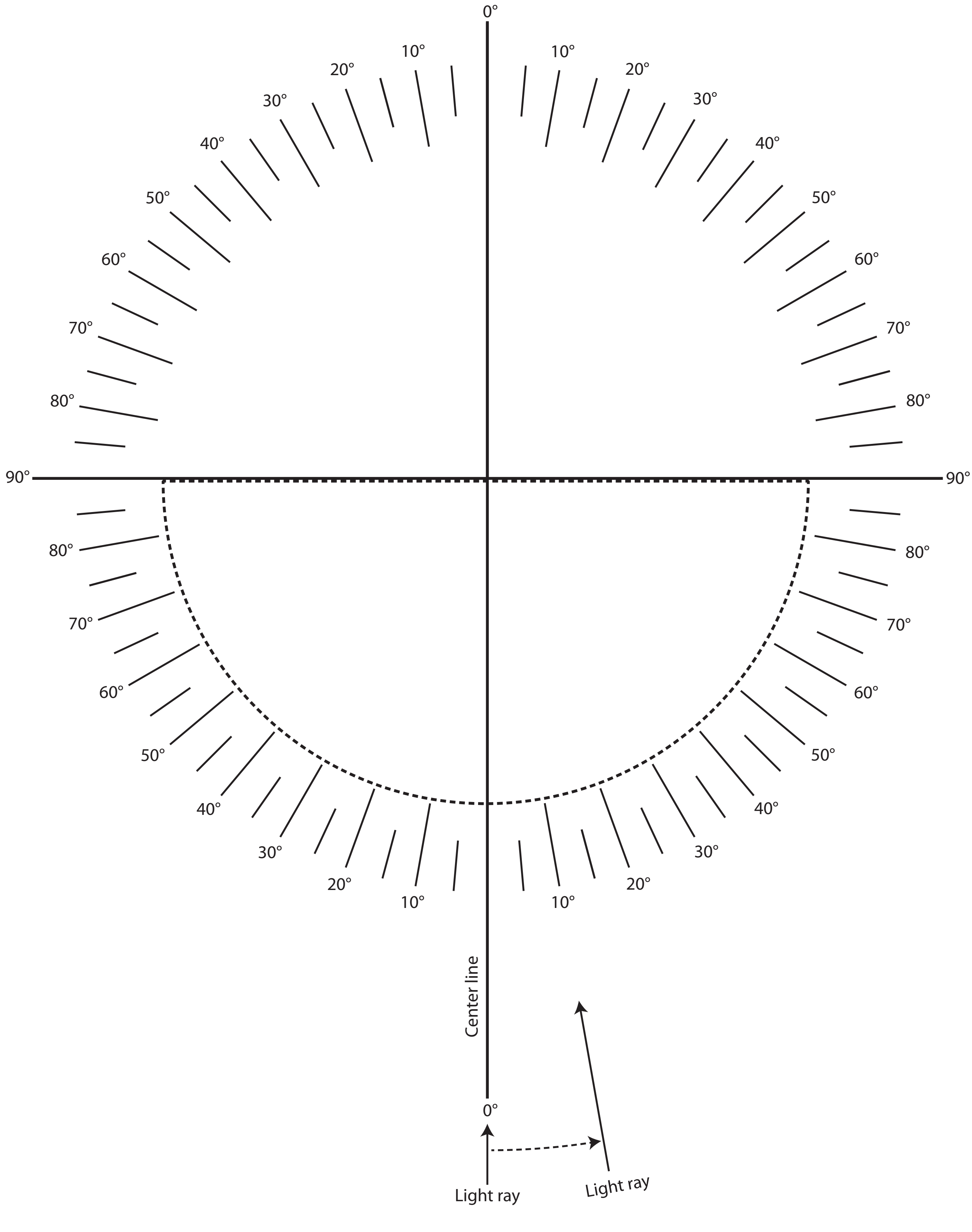
Name____ Date____________



STUDENT SHEET 9.2

TOTAL INTERNAL REFLECTION MEASUREMENTS

Name____ Date___________



10 Comparing Colors

LABORATORY

*D**URING FIRST PERIOD**, Jenna noticed that her friend José looked worried. After class she asked, "José, is everything okay with you?"*

José replied, "Well, actually, I'm a little distracted because my favorite great-aunt, Tía Ana, is having eye surgery."

"Surgery!" replied Jenna. "What happened?"

José explained, "Everything began to look a bit blurry and she became sensitive to the glare of lights, especially at night. When she went to her doctor, she learned that the lens in one of her eyes had developed a cataract. Today the eye surgeon is going to take out the cloudy lens in her right eye and put in an artificial one. I know it is a common procedure, but I am worried anyway."

Sighted people use their eyes for almost everything they do, and so it is important to take care of them. One thing that hurts our eyes is too much exposure to the sun. Even people with limited vision may damage their eyes further by exposing them to too much sunlight.

In this activity, you will explore some of the characteristics of white light to investigate what might have damaged Tía Ana's eyesight. White light can be separated into the **visible light spectrum**, which is the scientific name for the colors of the rainbow.

GUIDING QUESTION

How are the colors of the visible light spectrum similar to and different from each other?

MATERIALS

For each pair of students

1 Phospho-box
1 card with a star-shaped cutout
1 colored-film card
1 timer

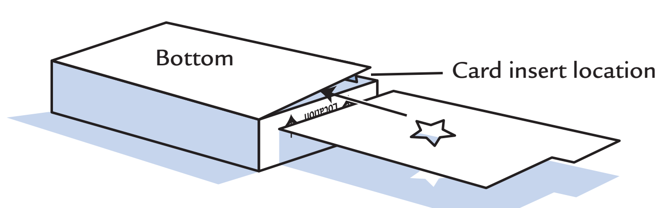
PROCEDURE

Part A: The Visible Light Spectrum

1. Observe how your teacher splits white light into the colors of the visible spectrum.
2. List the colors that you see in the order that they appear.
3. Describe whether the colors blend from one to the next or have distinct boundaries between them.
4. Which color of light seems to be
   a. the brightest?
   b. the least bright?

Part B: Colored Light

5. Open the lid of the Phospho-box and examine the bottom of the box. The strip on the bottom of the Phospho-box is sensitive to a particular short-wavelength wave. Sketch and describe what you observe.
6. Close the Phospho-box and turn it over so that the top with the viewing slit is on the table. Slip the card with the star-shaped cutout into the card-insert location at the bottom of the box, as shown below. Leave the box in this position for 30 s.
7. Turn the Phospho-box right side up, open the top, and let light hit the entire bottom of the box for 20 s.



8. Close the top of the Phospho-box and remove the card with the star-shaped cutout. Quickly look through the viewing slit and record your observations.
9. Turn over the Phospho-box as you did in Step 6. Lay the colored-film card on top of the Phospho-box.
10. Describe or sketch what you see. Rank the colors from brightest to least bright.
11. Describe or sketch what you predict you will observe if you repeat Steps 6–8 using the colored-film card instead of the card with the star-shaped cutout.
12. Repeat Steps 6–8, but use the colored-film card instead of the card with the star-shaped cutout.
13. Rank each color of the cutout shape according to how brightly it caused the strip on the bottom of the Phospho-box to glow.
14. Describe or sketch what you predict you will observe if you repeat Steps 6–8 with the colored-film card, but this time let the sunlight hit the bottom of the box for 40 s.
15. Repeat Steps 6–8 with the colored-film card, but this time let the light hit the bottom of the Phospho-box for 40 s. Record your results in your science notebook.

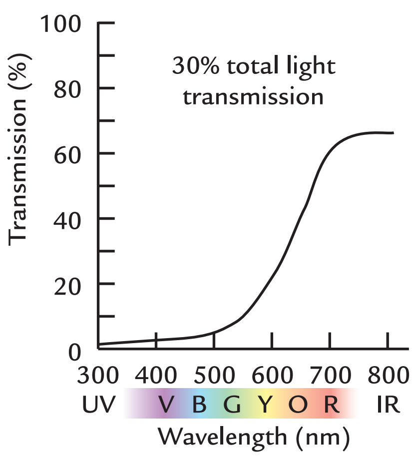
A rainbow shows the colors of the visible light spectrum.

ANALYSIS

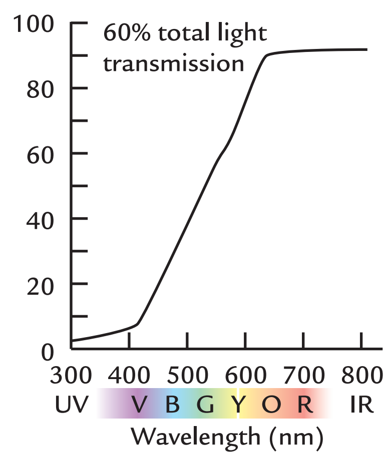
1. What is the purpose of the card with the star-shaped cutout?
2. How do you think the colored-film card changes the white light into colored light? Describe how you might test your ideas to see if they are correct.
3. Why do you think only some colors make the strip on the bottom of the Phospho-box glow? Explain.

4. Is there enough evidence—information that supports or refutes a claim—that supports the idea that the higher-energy colors of white light are damaging Tía Ana's eyes? Explain your answer.
5. Which characteristic of a light wave explored in this activity affects the amount of energy that it carries?
6. Sunglass lenses are an example of a material that blocks some white light and some other short-wavelength light that is harmful to the eyes. Examine the transmission graphs about three pairs of sunglasses below.

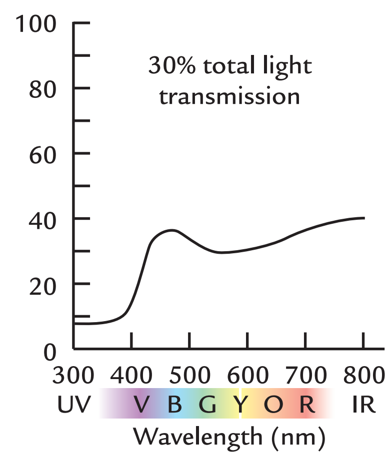
Lens 1



Lens 2



Lens 3



a. Which lens has the best protection for the eyes against high-energy waves? Explain how you decided.

b. The price for each pair of sunglasses is shown below. Which pair would you buy? Why? Describe any trade-offs you made in your choice. A trade-off is an outcome given up to gain another outcome.

Lens 1: $80

Lens 2: $10

Lens 3: $20