Let Us Entertain You

Activity 4

Reflected Light

GOALS
In this activity you will:
• Identify the normal of a mirror.
• Measure angles of incidence and reflection.
• Observe the relationship between the angle of incidence and the angle of reflection.
• Observe changes in the reflections of letters.
• Identify patterns in multiple reflections.

What Do You Think?
Astronauts placed a mirror on the Moon in 1969 so that a light beam sent from Earth could be reflected back to Earth. By timing the return of the beam, scientists found the distance between the Earth and the Moon. They measured this distance to within 30 cm.

• How are you able to see yourself in a mirror?
• If you want to see more of yourself, what can you do?

Record your ideas about these questions in your Active Physics log. Be prepared to discuss your responses with your small group and with your class.

For You To Do
1. Place a piece of paper on your desk. Carefully aim the laser pointer, or the light from a ray box, so the light beam moves horizontally, as shown on the opposite page.
2. Place a glass rod in the light beam so that the beam spreads up and down. Shine the beam on the piece of paper to be sure the beam passes through the glass rod.

3. Carefully stand the plane mirror on your desk in the middle of the piece of paper. Draw a line on the paper along the front edge of the mirror. Now remove the mirror and draw a dotted line perpendicular to the first line, as shown. This dotted line is called the normal.

4. Aim the light source so the beam approaches the mirror along the normal. Be sure the glass rod is in place to spread out the beam.
   a) What happens to the light after it hits the mirror?

5. Make the light hit the mirror at a different angle.
   a) What happens now?
   b) On the paper, mark three or more dots under the beam to show the direction of the beam as it travels to the mirror. The line you traced shows the incident ray. Also make dots to show the light going away from the mirror. This line shows the reflected ray. Label this pair of rays to show they go together.

6. Turn the light source so it starts from the same point but strikes the mirror at different angles. For each angle, mark dots on the paper to show the direction of the incident and reflected rays. Also, label each pair of rays.
7. Most lab mirrors have the reflecting surface on the back. In addition, the light bends as it enters and leaves the glass part of the mirror. In your drawing, the rays may not meet at the mirror surface. Extend the rays until they do meet.
   a) Measure these angles for one pair of your rays.

8. Turn off the light source and remove the paper. Look at one pair of rays. The diagram shows a top view of the mirror, the normal, and an incident and reflected ray. Notice the angle of incidence and the angle of reflection in the drawing. Using a protractor, measure these angles for one pair of rays.
   a) Record your data in a table.
   b) Measure and record the angles of incidence and reflection for all of your pairs of rays.

   ![Diagram of light reflection](image)

   c) What is the relationship between the angles of incidence and reflection?
   d) Look at the reflected rays in your drawing. Extend each ray back behind the mirror. What do you notice when you have extended all the rays? The position where the rays meet is the location of the image of the light source. All of the light rays leave one point in front of the mirror. The reflected rays all seem to emerge from one point behind the mirror. Wherever you observed the reflection, you would see the source at this point behind the mirror.
   e) Tape a copy of your diagram in your log.

9. Hold the light source, or any object, near the mirror and look at the reflection. Now hold the object far away and again look at the reflection.
FOR YOU TO READ

Images in a Plane Mirror

An object like the tip of a nose reflects light in all directions. That is why everybody in a room can see the tip of a nose. Light reflects off a mirror in such a way that the angle of incidence is equal to the angle of reflection. You can look at the light leaving the tip of a nose and hitting a mirror to see how an image is produced and where it is located. Each ray of light leaves the nose at a different angle. Once it hits the mirror, the angle of incidence must equal the angle of reflection. There are now a set of rays diverging from the mirror. If you assume that the light always travels in straight lines, you can extend these rays behind the mirror and find where they “seem” to emerge from. That is the location of the image.

The mirror does such a good job of reflecting that it looks as if there is a tip of a nose (and all other parts of the face) behind the mirror. If you measure the distance of the image behind the mirror, you will find that it is equal to the distance of the nose (object) in front of the mirror. This can also be proved using geometry.

Physics Words

angle of incidence: the angle a ray of light makes with the normal to the surface at the point of incidence.
angle of reflection: the angle a reflected ray makes with the normal to the surface at the point of reflection.
ray: the path followed by a very thin beam of light.
**Diffraction of Light**

As you begin to study the reflection of light rays, it is worthwhile to recognize that light is a wave and has properties similar to sound waves.

In studying sound waves, you learned that sound waves are compressional or longitudinal. The disturbance is parallel to the direction of motion of the wave. In sound waves, the compression of the air is left and right as the wave travels to the right. You saw a similar compressional wave using the compressed Slinky.

Light waves are transverse waves. They are similar to the transverse waves of the Slinky. In a transverse wave, the disturbance is perpendicular to the direction of the wave. In the Slinky, the disturbance was up and down as the wave traveled to the right. In light, the fields (the disturbance) are perpendicular to the direction of motion of the waves.

You also read that sound waves diffract—they spread out as they emerge from small openings. You can find out if light waves spread out as they emerge from a small opening. Try this: Take a piece of aluminum foil. Pierce the foil with a pin to create a succession of holes, one smaller than the next. Shine the laser beam through each hole and observe its appearance on a distant wall. You will be able to observe the diffraction of light.

**Sample Problem**

Light is incident upon the surface of a mirror at an angle of 40°.

a) Sketch the reflection of the ray.

**Strategy:** The angles of incidence and reflection are always measured from the normal. The Law of Reflection states that the angle of incidence is equal to the angle of reflection. Since the angle of incidence is equal to 40°, the angle of reflection is also 40°.

**Given:**

\[ \theta_i = 40° \]

**Solution:**

![Diagram of light reflection](image)

b) At what angle, as measured from the surface of the mirror, did the beam strike the mirror?

**Strategy:** The angle of incidence is measured from the normal. The question is asking for the complementary angle.

**Solution:**

\[ \theta_i = \theta_r = 40° \]

\[ 90° - 40° = 50° \]

The angle between the light beam and the mirror is 50°.
Reflecting on the Activity and the Challenge

In this activity you aimed light rays at mirrors and observed the reflections. From the experiment you discovered that the angle of incidence is equal to the angle of reflection. Therefore, you can now predict the path of a reflected light beam. You also experimented with reflections from two mirrors. When you observed the reflection in two mirrors, you found many images that made interesting patterns.

This activity has given you experience with many interesting effects that you can use in your sound and light show. For instance, you may want to show the audience a reflection in one mirror or two mirrors placed at angles. You can probably create a kaleidoscope. You will also be able to explain the physics concept you use in terms of reflected light.

Physics To Go

1. How is the way light reflects from a mirror similar to the way a tennis ball bounces off a wall?

2. a) What is the normal to a plane mirror?
   b) When a light beam reflects from a plane mirror, how do you measure the angle of incidence?
   c) How do you measure the angle of reflection?
   d) What is the relationship between the angle of incidence and the angle of reflection?

3. Make a top-view drawing to show the relationships among the normal, the angle of incidence, and the angle of reflection.

4. a) Suppose you are experimenting with a mirror mounted vertically on a table, like the one you used in this activity. Make a top-view drawing, with a heavy line to represent the mirror and a dotted line to represent the normal.
   b) Show light beams that make angles of incidence of 0°, 30°, 45°, and 60° to the normal.
   c) For each of the above beams, draw the reflected ray. Add a label if necessary to show where the rays are.
5. a) Stand in front of a mirror.
   b) Move your hand toward the mirror. Which way does the reflection move?
   c) Move your hand away from the mirror. Which way does the reflection move?
   d) Use what you learned about the position of the mirror image to explain your answers to Parts (b) and (c).

6. Suppose you wrote the whole alphabet along the normal to a mirror in the way you wrote your name in Step 10 of For You To Do.
   a) Which letters would look just like their reflections?
   b) Write three words that would look just like their reflections.
   c) Write three letters that would look different than their reflections.
   d) Draw the reflection of each letter you gave in Part (c).

7. Why is the word Ambulance written in an unusual way on the front of an ambulance?

8. Use a ruler and protractor and a ray diagram to locate the image of an object placed in front of a plane mirror. Be careful! You must measure as carefully as you can to obtain the most accurate answer.

9. Locate the image of the lamp shown in the diagram.
10. After reflecting off mirrors A, B, and C, which target will the ray of light hit?

**Stretching Exercises**

1. Carefully tape together three small mirrors to make a corner reflector. Shine a flashlight down into the corner. Where does the reflected beam go?

2. Build a kaleidoscope by *carefully* inserting two mirrors inside a paper towel holder. You can also use three identical mirrors. Do not force the mirrors into the tube. Tape the edges of the mirrors together, with the mirrored surfaces inside. Describe what you see through your kaleidoscope.

3. Carefully tape together one edge of two mirrors so they can move like a hinge, with the mirrored surfaces facing each other. Place a small object between the mirrors. Investigate how the number of images you see depends on the angle between the mirrors. You will need a protractor to measure this angle. Plot a graph of the results. What mathematical relationship can you find between the angle and the number of images?