Light Can Be Reflected

This book uses black letters printed on white paper. The black ink is opaque because all the light falling on the ink is absorbed. But the white paper reflects all of the light that falls on it. Does that mean the white paper is a mirror? If so, why can you not see your reflection in the white parts of the page?

To act as a mirror, the surface needs to be smooth compared to the wavelength of the light striking the surface (see Figure 5.8A). Even though the page may feel smooth, a photograph taken through a microscope reveals the surface is actually not very smooth at all (see Figure 5.8B). The ray diagram shows that the light rays bounce off randomly at all angles, giving the paper the appearance of being translucent (see Figure 5.8C).

Suggested Activities

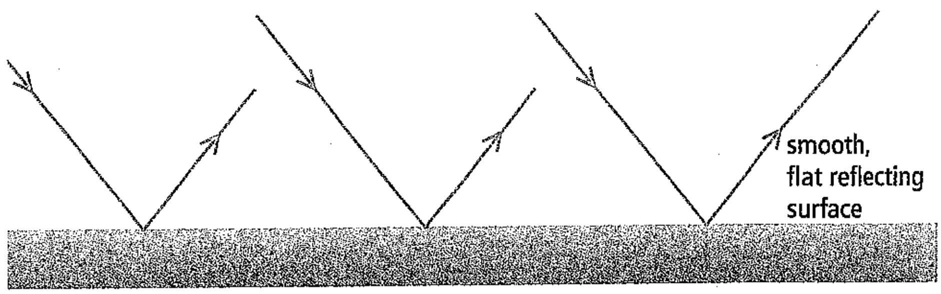
Find Out Activity 5-2 on page 176

Conduct an Investigation 5-5 on page 178

Connection

For more examples of electron micrographs, see Section 1.1.

A

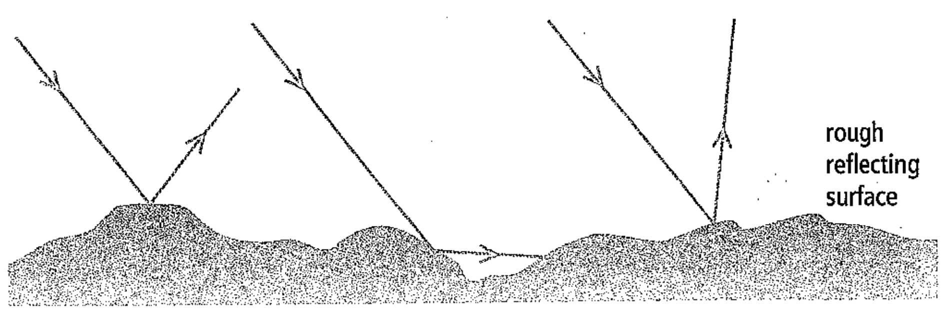


(A) Smooth surfaces reflect all light uniformly.

B

(B) Scanning electron micrograph of the surface of paper

C



(C) Rough surfaces appear to reflect light randomly.

Figure 5.8

The Law of Reflection

How does light reflect off a mirror? It is helpful to think about how a light ray is similar to a water wave bouncing off a solid barrier. Imagine a great rock wall rising high out of the water. If waves strike such a barrier head on, the waves will bounce straight back in the reverse direction. However, if a wave strikes the barrier from an angle, then it will also bounce off at an angle—at precisely the same angle as the incoming wave that struck the barrier.

The incoming ray is called the **incident ray**. The ray that bounces off the barrier is called the **reflected ray**. Notice in Figure 5.9 that a dotted line has been drawn at right angles to the solid barrier. This line is called the **normal**. The normal is an imaginary line that is perpendicular to the boundary between two materials (such as air and glass) and intersects the point at which the incident ray reaches the boundary.

The angle formed by the incident beam and the normal is the **angle of incidence**, labelled *i*. The angle formed by the reflected beam and the normal is the **angle of reflection**, labelled *r*. Notice that the angle is always measured from the normal line to the ray, not from the mirror to the ray. Observations for all types of surfaces have shown, without exception, that the angle of reflection is the same as the angle of incidence. Therefore, this observation is considered to be a law. You can state the **law of reflection** as "the angle of reflection equals the angle of incidence." For example, if the angle of incidence, *i*, is 60° then the angle of reflection, *r*, will be 60°.

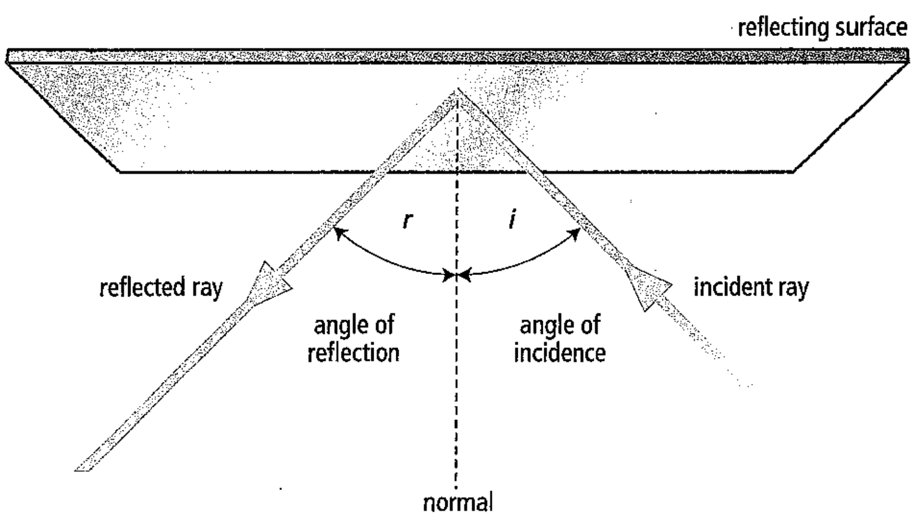


Figure 5.9 Light reflected from any surface follows the law of reflection.

Did You Know?

Objects that bounce off a surface sometimes behave like waves that are reflected from a surface. For example, suppose you throw a bounce pass while playing basketball. The angle between the ball's direction and the normal to the floor is the same before and after it bounces.

internet connect

Neil Armstrong, the first person to walk on the Moon, placed a special kind of mirror on the Moon's surface. Scientists on Earth regularly shine a laser on this mirror to measure the distance from Earth to the Moon. Find out how this special mirror works. Go to **www.bcscience8.ca.**

Light Can Be Refracted

Recall from Chapter 4 that light can be bent, or refracted, if it changes speed as it travels from one medium into another. You can picture this process by imagining five friends all walking abreast with their elbows locked (see Figure 5.10). If the people on one end of the line slow down, but the people on the other end do not, the line will turn. Then, if they all slow to the same speed, they will continue to move in the new direction.

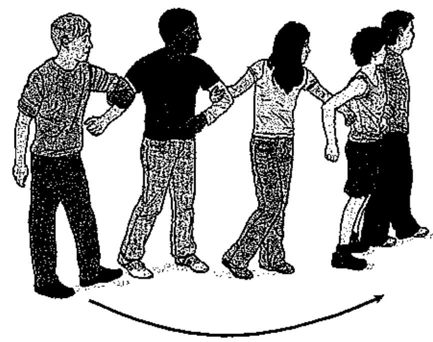


Figure 5.10 If only one part of a line slows down, the line changes direction.

Word Connect

Density is a measure of how closely the particles in a material are packed together.

Connection

Section 7.2 has more information about density.

When light rays move from air into glass, they slow down and change direction because the glass is *denser* than air. Once inside the glass, the light rays move in a straight line. But if the light rays leave the glass and move back into the air, where they can travel faster, they will change direction again. The **angle of refraction (*R*)** is the angle of a ray of light emerging from the boundary between two materials, such as from air into glass, measured between the refracted ray and the normal.

Figure 5.11A shows what happens when a light ray passes into a medium in which it slows down. The light ray is refracted toward the normal. Figure 5.11B shows what happens when a light ray passes into a medium in which it speeds up. Then the light ray is refracted away from the normal.

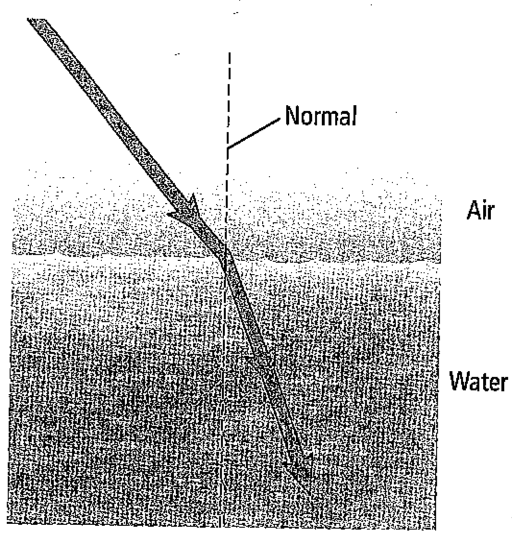


Figure 5.11A When light rays travel from air to water, they slow down and bend toward normal.

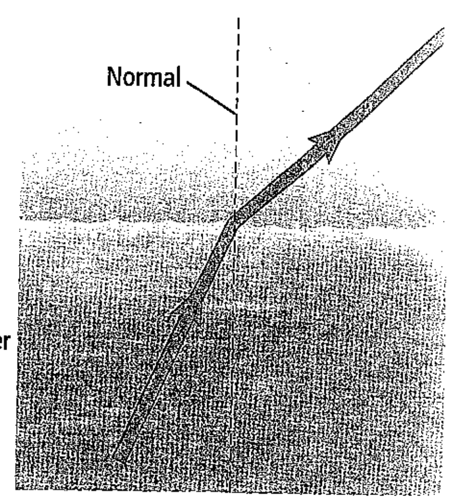


Figure 5.11B When light rays travel from water to air, they speed up and bend away from normal.

Refraction of Light in Water

If you have ever stood in a pool or water and tried to reach an object on the bottom, you may have been surprised that the object was not where you expected it to be. Figure 5.12 shows how refraction causes this illusion. The light rays reflected from the fish in Figure 5.12 are refracted away from the normal as they pass from water to air and enter your eyes. However, your brain assumes that all light rays have travelled in a straight line. The light rays that enter your eyes seem to have come from a fish that was higher in the water.

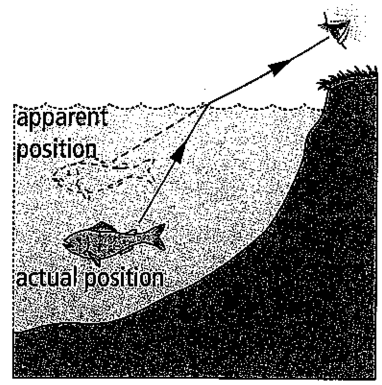


Figure 5.12 Light rays from the fish bend away from the normal as they pass from water to air. This makes the fish seem closer to the surface than it really is.

Refraction of Light in Air

Refraction can also occur when light travels through air at different temperatures. Warm air is less dense than cold air. Light bends as it travels through different densities of air. The refraction of light through air can result in a **mirage**, which is a misleading appearance or illusion.

Have you ever been driving along a highway on a hot summer day and noticed what looked like pools of water lying ahead? However, when you got close to the pools, they mysteriously disappeared. You were seeing a mirage. In this example, the air closer to the ground is hotter and less dense than air higher up. As a result, light from the sky directed at the ground is bent upward as it enters the less dense air. The "pools of water" were actually images of the sky refracted by warm air near the ground (see Figure 5.13).

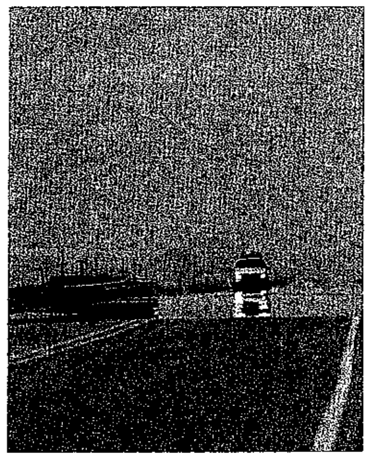


Figure 5.13 Refracted light can create a mirage.

Suggested Activities

Find Out Activity 5-3 on page 177
Find Out Activity 5-4 on page 177

Explore More

A numerical way to measure the ability of a transparent material to refract light is called the index of refraction. Empty space has an index of 1.0, and water has an index of about 1.3. Diamond is extremely refractive and has an index of 2.4. There is a very interesting connection between the speed of light in a material and its refractive index. Find out about this relationship. Go to **www.bcscience8.ca.**

Reading Check

1. Why does a white page not reflect like a mirror?
2. What is the difference between the incident ray and the reflected ray?
3. What point does the normal intersect?
4. What does the angle of incidence always equal?
5. What happens when light rays travel from water into air?
6. Why do objects underwater seem closer to the surface than they are?
7. Why does the highway ahead of you look wet when it is dry?