18.3 Behavior of Light

Reading Focus

Key Concepts

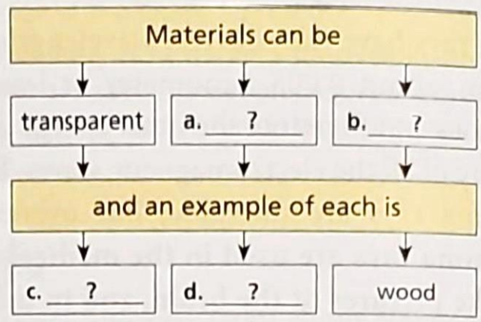
- What three types of materials affect the behavior of light?
- How does light behave when it enters a new medium?

Vocabulary

- transparent
- translucent
- opaque
- image
- regular reflection
- diffuse reflection
- mirage
- polarized light
- scattering

Reading Strategy

Monitoring Your Understanding Copy the flowchart below. As you read, complete it to show how different materials affect light.



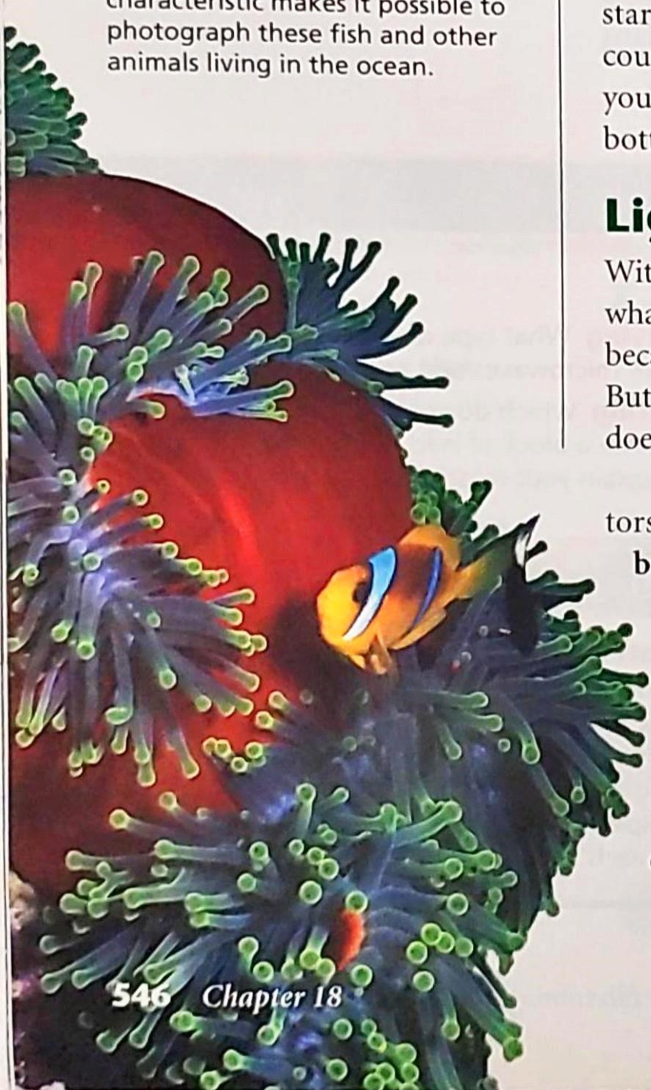


Figure 16 Water is transparent. You can see through it. That characteristic makes it possible to photograph these fish and other animals living in the ocean.

What would you see if you were snorkeling in warm ocean waters over a coral reef? You might see fish of bright colors, clown fish, sea stars, sponges, and clams. You might see sharks or turtles, and of course, coral. But why can you see these animals so clearly? Why can you see the reef through the water but not, for example, through the bottom of the boat that brought you to the reef?

Light and Materials

Without light, nothing is visible. When you look at the reef animals, what you are really seeing is light. You can see the reef through the water, because light passes through the water between the reef and your eyes. But you can't see the reef through the bottom of the boat because light doesn't pass through the boat.

How light behaves when it strikes an object depends on many factors, including the material the object is made of. **Materials can be transparent, translucent, or opaque.** Each type of material affects the behavior of light in different ways.

A material through which you can see clearly is transparent. A **transparent** material transmits light, which means it allows most of the light that strikes it to pass through it. For example, the water where the fish and coral in Figure 16 live is transparent. While riding on a bus, you can see buildings and trees outside because the bus windows are transparent.

If you can see through a material, but the objects you see through it do not look clear or distinct, then the material is translucent (trans LOO sunt). A **translucent** material scatters light. The soaps in Figure 17A are translucent. When you look into a room through a frosted glass door, you can make out shapes of people and objects, but the shapes are fuzzy and lack detail.

Most materials are opaque (oh PAYK). An **opaque** material either absorbs or reflects all of the light that strikes it. The fruit in Figure 17B is opaque. An opaque object does not allow any light to pass through it. You can't see through a wooden table or a metal desk. Wood and metal are examples of opaque materials.

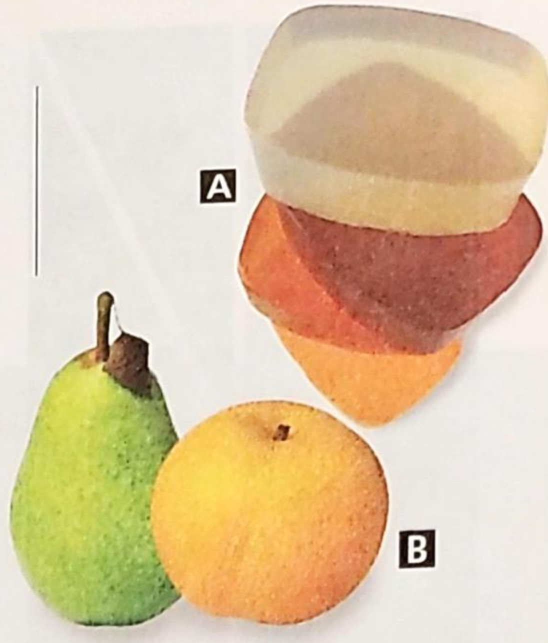


Figure 17 When light strikes a new medium, it can be reflected, absorbed, refracted, polarized, or scattered. **A** The translucent bars of soap scatter light, making the soaps and what you can see through them appear fuzzy. **B** You cannot see through the fruit because opaque materials do not transmit any light.

Interactions of Light

When light encounters matter, some or all of the energy in the light can be transferred to the matter. And just as light can affect matter, matter can affect light. **When light strikes a new medium, the light can be reflected, absorbed, or transmitted. When light is transmitted, it can be refracted, polarized, or scattered.**

Reflection When you look in a mirror, you see a clear image of yourself. An **image** is a copy of an object formed by reflected (or refracted) waves of light. Similarly, when you look at a still lake, you can see a sharp reflected image of the far shore. But what happens to the reflected image in the lake if the wind suddenly gusts, causing ripples in the surface of the water? The image is blurred, or fuzzy-looking. When light reflects from a smooth surface, you see a clear, sharp image. When light reflects from a rough surface, you see a blurred reflected image or no image at all.

Regular reflection occurs when parallel light waves strike a surface and reflect all in the same direction. Regular reflection happens when light hits a smooth, polished surface, like a mirror or the surface of a still body of water such as in Figure 18.

Diffuse reflection occurs when parallel light waves strike a rough, uneven surface, and reflect in many different directions. If you could look at this page of your book through a microscope, you would see that the paper has a rough surface. The rough surface causes diffuse reflection of the light that shines on it.

Figure 18 Almost all objects reflect light. **A** In regular reflection, a smooth surface reflects a clear image because parallel light waves reflect all in the same direction. **B** In diffuse reflection, parallel light waves reflect in many directions.

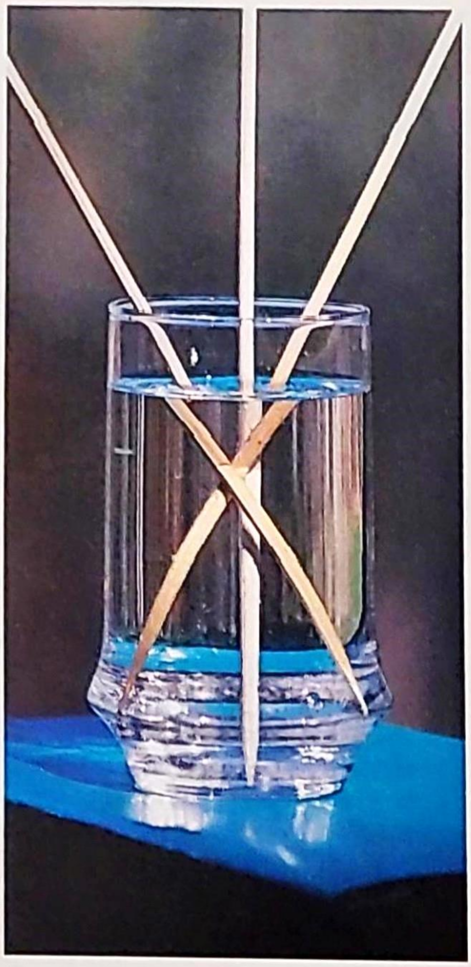


Figure 19 Light refracts, or bends, when it moves from one medium to another. Because the light bends, the image you see appears to be bent as well.
Relating Cause and Effect ***Why do the underwater parts of the skewers appear to be closer to you than the parts above water?***

Refraction A light wave can refract, or bend, when it passes at an angle from one medium into another. You can easily observe two common effects of refraction when light travels from air into water. Refraction makes underwater objects appear closer and larger than they really are. Refraction can also make an object, such as a skewer, appear to break at the surface of the water, as shown in Figure 19.

Refraction can also sometimes cause a mirage. A **mirage** is a false or distorted image. Mirages occur because light travels faster in hot air than in cooler, denser air. On a sunny day, air tends to be hotter just above the surface of a road than higher up. Normally, light travels from the sun all the way to the ground before being reflected. But on a hot day, light is gradually refracted as it moves into layers of hotter and hotter air. This gradual refraction causes some of the light to follow a curved path, rather than a straight path to the ground. Light that reaches your eyes after traveling in this manner can look as if it was reflected from a layer of water. Mirages also form this way above the hot sand in deserts.

Reading Checkpoint *What is a mirage?*

Polarization Light with waves that vibrate in only one plane is **polarized light.** Polarizing filters transmit light waves that vibrate in this way. Look at Figure 20. Unpolarized light vibrates in all directions. A vertical polarizing filter stops waves vibrating on a horizontal plane. Waves vibrating on a vertical plane pass through. A horizontal polarizing filter then blocks the waves vibrating on a vertical plane. To understand how a polarizing filter works, think of a light wave as being like a postcard that you push through a mail slot in a door. If you hold the postcard so that it lines up with the mail slot, then you can easily push it through. But if the postcard is at an angle to the mail slot, it has trouble passing through. In the same way, a polarizing filter blocks waves with electric fields vibrating in one direction.

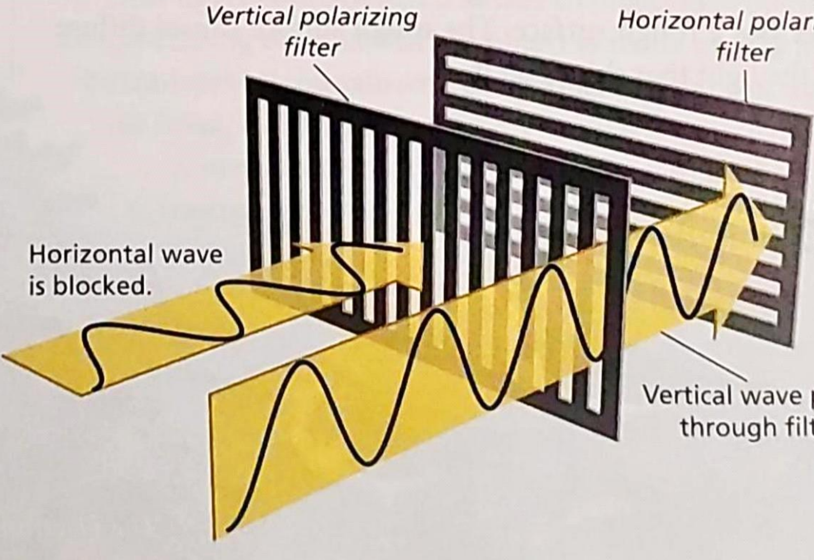


Figure 20 This simplified model shows how polarizing filters behave. A vertical polarizing filter blocks light that is horizontally polarized.
Applying Concepts ***What would happen if you looked at light through a horizontally polarizing filter and a vertically polarizing filter at the same time?***

Light reflecting from a nonmetallic flat surface, such as a window or the surface of a lake, can become polarized. When sunlight reflects from a horizontal surface, horizontally polarized light reflects more strongly than the rest of the sunlight. This reflection produces glare. To block the glare, polarized sunglasses have vertically polarized filters, which block the horizontally polarized light.

Scattering Earth's atmosphere contains many molecules and other tiny particles. These particles can scatter sunlight. **Scattering** means that light is redirected as it passes through a medium. Look at Figure 21. A scattering effect reddens the sun at sunset and sunrise. Most of the particles in the atmosphere are very small. Small particles scatter shorter-wavelength blue light more than light of longer wavelengths. The sunlight encounters more of the molecules and tiny particles that scatter the shorter-wavelength colors. By the time the sunlight reaches your eyes, most of the blue and even some of the green and yellow have been scattered. Most of what remains for your eyes to detect are the longer wavelengths of light, orange and red.

When the sun is high in the sky, its light travels a shorter distance through Earth's atmosphere. It scatters blue light in all directions much more than other colors of light. Scattering explains why the sky appears blue on a sunny day, even though air itself is colorless.

Figure 21 The lower the sun is on the horizon, the more of the atmosphere the light travels through before it reaches Earth's surface. In certain weather conditions, the blue, green, and yellow wavelengths of sunlight are heavily scattered. What's left to enjoy are the beautiful reds and oranges of sunrise and sunset.

Section 18.3 Assessment

Reviewing Concepts

1. Explain the differences among opaque, transparent, and translucent materials. Name two objects made from each type of material.
2. List and explain three things that can happen to a light wave when it enters a new medium.
3. What is the difference between diffuse reflection and regular reflection?
4. What happens to light that passes through a horizontal polarizing filter?

Critical Thinking

5. **Predicting** A black car reflects much less light than a white car. Which car's surface will be warmer after 1 hour of sunshine? Explain.
6. **Formulating Hypotheses** A mountain climber finds that her sunglasses are not blocking glare from a vertical rock wall. What can you hypothesize about the polarizing filters in her sunglasses?
7. **Applying Concepts** On a foggy night, you can see a car's headlight beams but you may not be able to see the car itself. Explain why.

Connecting Concepts

Mechanical Waves Review the behaviors of mechanical waves discussed in Section 17.2, such as reflection and refraction. Compare them with the behaviors of light.