Summary

THE BIG IDEA **Light is the ONLY thing you see! All visible objects either emit or reflect light.**

27.1 Early Concepts of Light

Scientists now agree that light has a dual nature, part particle and part wave.

- Until Einstein, some scientists believed light consisted of particles. Other scientists argued that light was a wave.
- Einstein published a theory to explain the *photoelectric effect.* His theory stated that light consists of particles called photons. **Photons** are massless bundles of concentrated electromagnetic energy.

27.2 The Speed of Light

Michelson's experimental value for the speed of light was 299,920 km/s, which is usually rounded to 300,000 km/s.

- The first demonstration that light travels at a finite speed was supplied by Olaus Roemer when he measured discrepancies in the periods of Jupiter's moons. Christian Huygens was able to explain the discrepancies.
- Albert Michelson used a mirror arrangement to measure the speed of light.
- The distance light travels in one year is called a **light-year.**

27.3 Electromagnetic Waves

The electromagnetic spectrum consists of radio waves, microwaves, infrared, light, ultraviolet rays, X-rays, and gamma rays.

- Light is energy that is emitted by accelerating electric charges. This energy travels as an **electromagnetic wave** that is partly electric and partly magnetic.
- The range of electromagnetic waves is the **electromagnetic spectrum.**
- Electromagnetic waves of frequencies lower than the red of visible light are called **infrared** waves, and those with frequencies higher than violet are called **ultraviolet** waves.

27.4 Light and Transparent Materials

Light passes through materials whose atoms absorb the energy and immediately reemit it as light.

- When light strikes matter, electrons in the matter are forced into vibration that depends on the frequency of the light and the natural frequency of electrons in the material.

- Materials that transmit light are **transparent.** Glass and water are transparent.
- Electrons in glass have a natural frequency in the ultraviolet range. Ultraviolet light increases the amplitude of the atoms' vibrations. This energy is in the form of heat.
- When electromagnetic waves with lower frequency than ultraviolet shine on glass, the atoms are forced into vibration with smaller amplitudes. The atoms then hold the energy for only a short time before reemitting it as transmitted light.
- Infrared waves vibrate not only the electrons, but the entire structure of glass. This vibration increases the internal energy of the glass and makes it warmer.

27.5 Opaque Materials

In opaque materials, any coordinated vibrations given by light to the atoms and molecules are turned into random kinetic energy—that is, into internal energy.

- Materials that absorb light without reemission and thus allow no light through them are **opaque.** Opaque materials become slightly warmer as light strikes them.
- Light that shines on metal sets free electrons into vibration, and this energy is reemitted as visible light in the form of a reflection. That's why metals are shiny.
- Our atmosphere is transparent to visible light and some infrared, but fortunately, almost opaque to high-frequency ultraviolet waves.

27.6 Shadows

When light shines on an object, some of the rays may be stopped while others pass on in a straight-line path.

- A thin beam of light is often called a **ray.** Any beam of light can be thought of as made of a bundle of rays.
- A **shadow** forms where light rays cannot reach. Shadows usually have a dark part on the inside and a lighter part around the edges. A total shadow is called an **umbra.** A partial shadow is called a **penumbra**. A penumbra appears where some of the light is blocked but where other light fills in.
- Both an umbra and a penumbra form during a solar eclipse, when the moon's shadow falls on Earth, and during a lunar eclipse, when Earth's shadow falls on the moon.
- Shadows also occur when light is bent in passing through a transparent material such as water.

27.7 Polarization

Light that reflects at glancing angles from nonmetallic surfaces, such as glass, water, or roads, vibrates mainly in the plane of the reflecting surface.

- **Polarization** is the alignment of vibrations in a transverse wave, usually by filtering out waves traveling in other directions.
- If you shake the end of a rope up and down, the vibrations are back and forth in the vertical direction. So, the wave is vertically polarized. If you shake the rope from side to side, a horizontally polarized wave is produced.
- A single vibrating electron emits an electromagnetic wave that is polarized. Common light sources, such as light bulbs or the sun, emit light that is not polarized.
- A special filter can polarize light. Such filters eliminate glare from a horizontal surface.

27.8 Polarized Light and 3-D Viewing

A pair of photographs or movie frames, taken a short distance apart (about average eye spacing), can be seen in 3-D when the left eye sees only the left view and the right eye sees only the right view.

- Vision in three dimensions depends on the fact that both eyes give impressions simultaneously (or nearly so), with each eye viewing a scene from a slightly different angle.
- A 3-D slide show or movie has one horizontally polarized view and another vertically polarized view. The viewer wears polarizing eyeglasses with the lens axes also at right angles. The views merge in the brain to produce an image with depth—a 3-D image.