Summary

18.1 Electromagnetic Waves

Electromagnetic waves are transverse waves. They are made up of changing electric and magnetic fields. The fields are produced by movements of electric charges. The fields are at right angles to each other. The fields are also at right angles to the direction of the wave. Electromagnetic waves do not need a medium. They can travel through a vacuum, or empty space. The transfer of energy by electromagnetic waves is called electromagnetic radiation.

All electromagnetic waves travel at the same speed in a vacuum: 3.00×10^8 meters per second. However, electromagnetic waves may have different frequencies and wavelengths. The higher the frequency of an electromagnetic wave, the shorter its wavelength is.

Around 1800, physicist Thomas Young showed that light travels as waves. About a century later, physicist Albert Einstein suggested that light is made up of packets of energy. Scientists now call these packets of energy photons. A photon model of light helps explain the photoelectric effect. The photoelectric effect occurs when light strikes the surface of a metal, and the metal gives off electrons. Today, scientists think that light and other types of electromagnetic radiation act like both waves and particles.

Photons can also explain why a light seems dimmer when you are farther from it. Photons travel outward from a light source in all directions. The photons become more and more spread out as they move away from the light. This causes the intensity of the light to decrease. Intensity is the rate at which energy flows through an area of a given size. It determines how bright light seems. Farther from the light source, there is less energy in a given area. Therefore, the light is less intense and not as bright.

18.2 The Electromagnetic Spectrum

All electromagnetic waves together make up the electromagnetic spectrum. In order of increasing frequency, the waves are radio waves, infrared rays, visible light, ultraviolet rays, X-rays, and gamma rays.

Radio waves have the lowest frequencies and longest wavelengths. They are used to transmit radio and television programs. At a radio station, sound waves are changed into electronic signals. The electronic signals are then coded onto radio waves. The station broadcasts the waves through the air. Your radio receives the coded radio waves. The radio decodes the radio waves and changes them back into sound waves. Radio waves also carry signals for television programs. In television, information for pictures as well as sound is coded onto the radio waves. Microwaves are the shortest-wavelength radio waves. They are used to cook and reheat food. They are also used to carry mobile phone calls.

You cannot see infrared rays. However, your skin can sense them as heat. A device called a thermograph can also sense infrared rays. A thermograph creates color-coded pictures showing which objects or organisms are warm and which are cool. The pictures are called thermograms. The pictures can be used to locate victims of disasters such as earthquakes. Infrared rays are also used in heat lamps. The lamps may be used to keep food or animals warm.

Visible light is the only part of the electromagnetic spectrum that we can see. We see each frequency of visible

light as a different color. From lowest to highest frequency, the colors of visible light are red, orange, yellow, green, blue, and violet. We use visible light to see, help keep us safe, and communicate with each other.

Ultraviolet rays help your skin produce vitamin D. However, too much ultraviolet radiation causes sunburn, wrinkles, and skin cancer. It also damages your eyes. Ultraviolet rays are used to kill germs and to help plants grow.

X-rays have high energy. They can pass through matter that visible light cannot pass through. X-rays are used to take pictures of bones and teeth. They are also used to see the contents of packages and suitcases.

Gamma rays have the highest frequency and shortest wavelength of all electromagnetic waves. They also have the most energy and the greatest ability to pass through matter. Too many gamma rays can be deadly to living things. Gamma rays are used to kill cancer cells. They are also used to make pictures of the brain and to find cracks in pipelines.

18.3 Behavior of Light

How light acts when it hits an object depends partly on the material the object is made of. Material can be transparent, translucent, or opaque.

- A transparent material allows light to pass through. You can see clearly through a transparent material. Water and clear glass are transparent.
- A translucent material allows light to pass through, but it scatters the light in all directions. You can see only the outlines of objects through a translucent material. Frosted glass and thin fabric are translucent.
- An opaque material absorbs or reflects all the light that hits it. You cannot see anything through an opaque material. Wood and metal are opaque.

When light reflects from a surface, it may form an image. An image is a copy of an object. Reflection can be regular or diffuse. Regular reflection occurs when light strikes a smooth surface and all the light reflects in the same direction. A regular image is sharp. Diffuse reflection occurs when light strikes a rough surface and the light reflects in many different directions. A diffuse image is blurry.

Light can refract, or bend. Refraction occurs when light passes at an angle from one medium into another and changes speed in the new medium. For example, refraction occurs when light passes at an angle from air into water because light travels slower in water than in air. If you place a straw in a clear glass of water, the straw appears to bend at the surface between the air and water.

Light can also be polarized by passing through a special filter called a polarizing filter. A polarizing filter reflects light waves that vibrate in certain directions. Polarizing filters are used in some sunglasses. They help reduce glare.

18.4 Color

When white light passes through a prism, it slows down. This causes the light to refract. How much the light slows down and refracts depends on its wavelength. Shorter wavelengths slow down and refract more than longer wavelengths. Violet light has the shortest wavelength and refracts the most. Red light has the longest wavelength and refracts the least. A prism separates each color of light from white light by refracting colors through different angles. This process is called *dispersion*.

Most objects reflect at least some of the light that strikes them. An object's color depends on the color of light that the object reflects. The color of light an object reflects depends, in turn, on the object's material and the color of light that strikes the object. For example, in sunlight, an apple reflects mostly red

wavelengths of light. Therefore, the apple appears red. However, in light containing only green wavelengths, the same apple absorbs all the light that hits it. No light is reflected. Therefore, in green light, the apple appears black.

Primary colors are three colors that can be combined in varying amounts to create all other possible colors. Secondary colors are colors created by combining two primary colors. The primary colors of light are red, green, and blue. All three primary colors together form white light. The secondary colors of light are cyan, yellow, and magenta.

A pigment is a material used to color paints, inks, and dyes. A pigment absorbs some colors of light and reflects other colors. The primary colors of pigments are cyan, yellow, and magenta. The secondary colors of pigments are red, green, and blue.

18.5 Sources of Light

Common light sources include incandescent, fluorescent, laser, neon, sodium-vapor, and tungsten-halogen lights. Each type of light source produces light in a different way.

- An incandescent light consists of a glass bulb containing a fine metal thread called a filament. When electrons flow through the filament, it heats up and glows.
- A fluorescent light consists of a glass tube coated on the inside with powder and filled with mercury vapor. When electrons flow through the vapor, it produces ultraviolet rays. The ultraviolet rays cause the coating of the tube to give off light.
- A laser light consists of a glass tube containing helium and neon gases. When electrons flow through the gases, atoms of the gases give off photons of light. Mirrors at both ends of the tube cause the photons to bounce back and forth. This excites other gas atoms to give off more photons. The result is a very intense light.
- A neon light consists of a glass tube containing neon or other gas. When electrons flow through the gas, it gives off colored light. Each gas produces light of a certain color.
- A sodium-vapor light consists of a glass bulb containing a small amount of sodium and a mixture of neon and argon gases. When electrons flow through the gases, they heat up. The heat causes the sodium to give off a very bright light.
- A tungsten-halogen light consists of a glass bulb containing a filament. The filament glows when electrons flow through it. The bulb also contains a halogen gas, such as bromine. The gas reduces wear on the filament. This makes the bulb lasts longer.