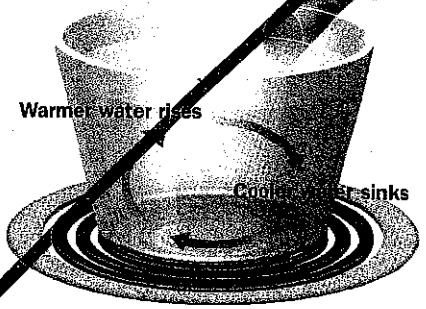
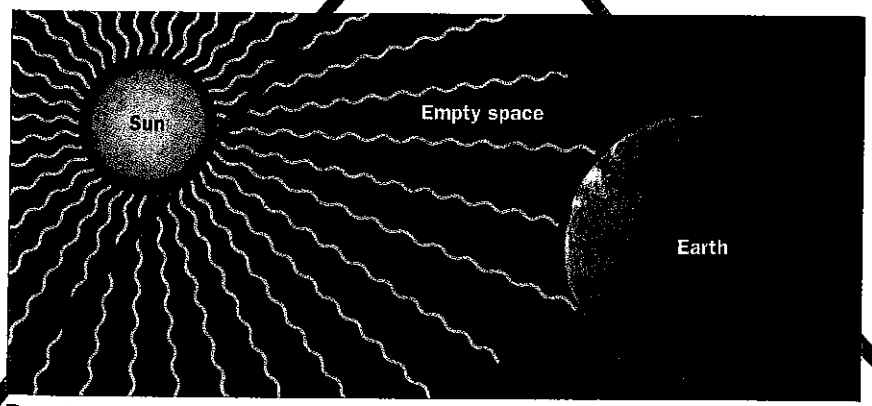
Convection is the transfer of heat in a fluid through currents. Suppose you place a pot of cold water on a hot stove. As the water at the bottom of the pot heats up, it becomes less dense (its particles spread out and become less compact). Because the warm water is less dense than the cold water above it, the warm water rises and displaces the cold water. The cold water, in turn, sinks. The movement of water that results is called a **convection current.** The convection current transfers thermal energy throughout the water in the pot.



Transfer of thermal energy by convection

Radiation is the transfer of energy as electromagnetic waves. Unlike conduction and convection, which involve the collision or movement of particles, radiation can occur through empty space. The sun heats Earth through the process of radiation.

SEE ALSO
309 Electromagnetic Spectrum
305 Waves



Transfer of energy by radiation

Waves Start here 305

One way that energy is transported is through waves. A **wave** is an oscillation (a back-and-forth or up-and-down motion) that travels from one place to another with a certain velocity (speed and direction.) Some waves, like sound waves and water waves, travel through matter. Waves that travel through matter are called **mechanical waves.** Other waves, like visible light, microwaves, X-rays, and radio waves, travel through empty space (as well as through matter). Waves that can travel through empty space are called **electromagnetic waves.**

SEE ALSO
308 Light
312 Sound
186 Earthquakes

306

Characteristics of a Wave

All waves have the following four characteristics:

The **amplitude** of a wave is the distance a wave oscillates from its resting position. The larger the amplitude, the more energy carried by the wave.

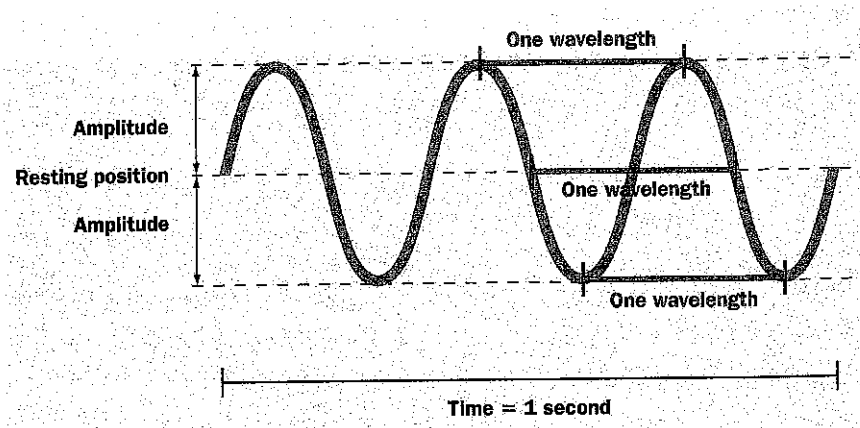
Wavelength is the distance from any point on one wave to a corresponding point on an adjacent wave.

SEE ALSO

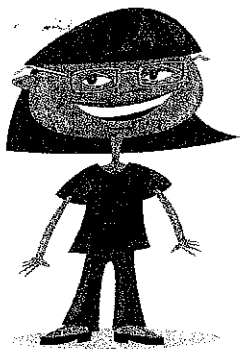
313 Properties of Sound

Frequency is the number of oscillations produced in a certain amount of time. The greater the number of oscillations per second, the higher the frequency. The higher the frequency, the more energy carried by the wave. Frequency is measured in **hertz (Hz).** One hertz is equal to one wave per second.

Wave speed is the distance a wave travels in a given amount of time. Waves move faster through some mediums than through others.



Frequency = 3 waves per second, or 3 Hz (hertz)



Create your own waves by tying one end of a rope to a doorknob and moving the other end up and down.

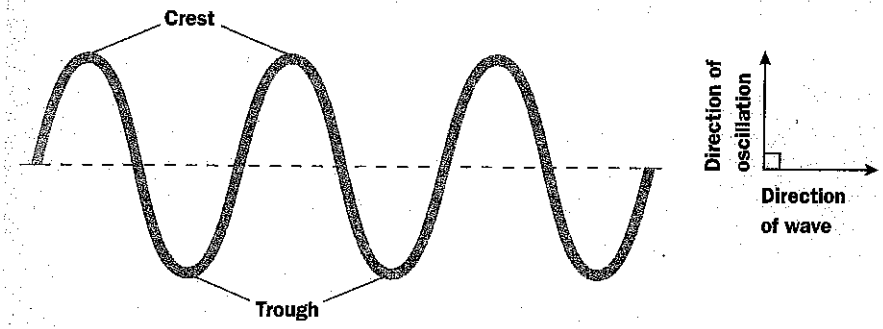
Kinds of Waves

When the oscillation (back-and-forth or up-and-down motion) of a wave is perpendicular to the direction in which the wave travels, the wave is called a **transverse wave.**

Look at the figure of the transverse wave. The peak, or highest point, of a transverse wave is the **crest.** The valley, or lowest point, between two crests is the **trough.** Some examples of transverse waves include electromagnetic (light) waves and a type of seismic wave (a wave that occurs during earthquakes) called a secondary wave (S-wave).

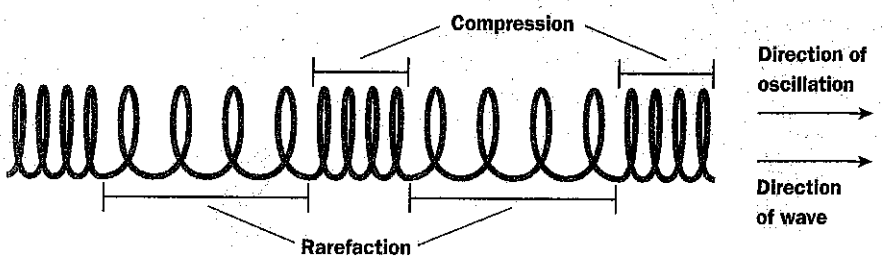
SEE ALSO
186 Earthquakes

Transverse Wave



A **longitudinal wave** is a wave whose oscillation is parallel to the direction in which the wave travels. For example, if you set a spring on your desk and push the end of the spring over and over, you create regions where the coils are closer together (called **compressions**) and regions where the coils are farther apart (called **rarefactions**). The compressions and rarefactions move in the same direction in which the wave travels. Examples of longitudinal waves are sound waves and a type of seismic wave called a primary wave (P-wave).

Longitudinal Wave



Light

308

Look around you. What do you see? You might say books, pencils, desks, and chairs. But what you really see is light bouncing off books, pencils, desks, and chairs. You can see objects only if they reflect light or produce it themselves. **Light** is a type of energy produced by the vibration of electrically charged particles.

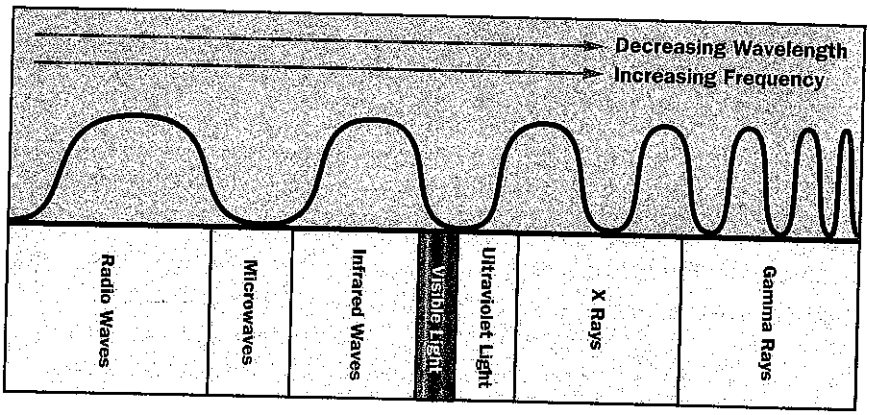
309

Electromagnetic Spectrum

Light travels in the form of electromagnetic waves. There are many different types of electromagnetic waves, most of which cannot be detected by the human eye.

SEE ALSO
306 Characteristics of a Wave

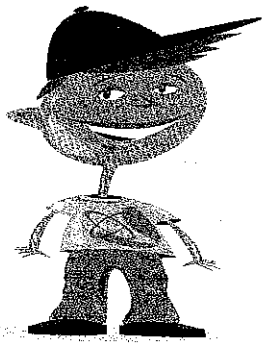
Electromagnetic waves are classified by their wavelength. If you look at the figure below, you will see that gamma rays have the shortest wavelength and radio waves have the longest. Light falls somewhere in the middle of the spectrum. The full range of electromagnetic waves is called the **electromagnetic spectrum.**



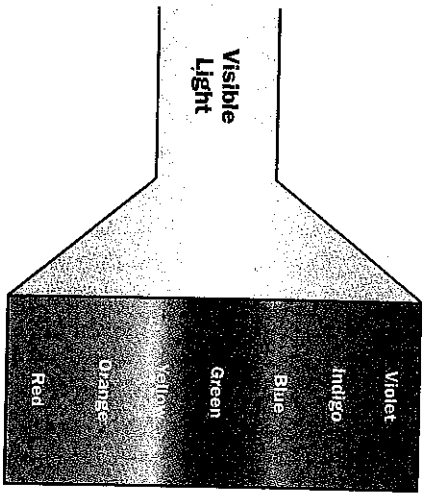
The shorter the wavelength, the higher the frequency of the wave. The higher the frequency, the greater the energy of the wave. So gamma rays have the most energy, while radio waves have the least.

The only part of the electromagnetic spectrum that you can see with your eyes is visible light. Visible light includes all the colors of the rainbow: red, orange, yellow, green, blue, indigo, and violet. Red light has the longest wavelength; violet light has the shortest. When all the different colors of light are combined, you see them as white light.

SEE ALSO
306 Characteristics of a Wave



You can remember the order of the colors in the visible light spectrum with the help of my good friend, Roy G. Biv.

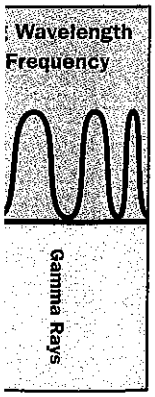


Properties of Light

How would you describe the properties of light? One way is to describe how light travels.

- **Light spreads out in all directions from its source.**
- **Light travels in straight lines called rays.**
- **Light travels "at the speed of light"** (about 186,282 miles per second, or 299,792 kilometers per second).
- **Light can travel in a vacuum.** A vacuum is empty space. Like all electromagnetic waves, light can travel through empty space as well as through matter.

These same properties apply to all types of electromagnetic waves, not just light.



311

Light at a Surface

Three things can happen to light when it hits the surface of matter. The light can be reflected by the matter, it can pass through the matter, or it can be absorbed by the matter.

Reflection of Light

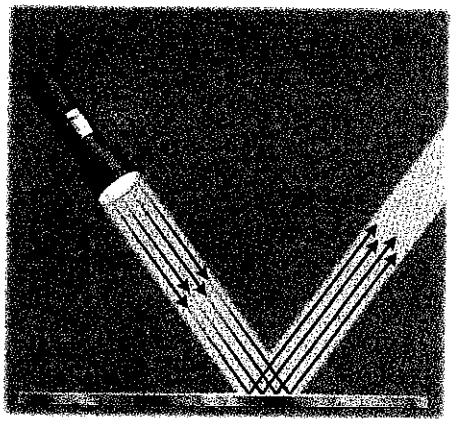
If you shine light on a surface, some of that light will bounce off, or be reflected by, the surface. This process is called **reflection.** Light will always be reflected by a surface at the same angle at which it hits the surface. This is called the **law of reflection.**

The **angle of incidence** is the angle at which light hits a surface. The **angle of reflection** is the angle at which light is reflected by a surface. The angle of incidence always equals the angle of reflection.

The law of reflection is evident when you look into a smooth, shiny surface like a mirror. You see yourself in a mirror because all the light rays are reflected at the same angle. Reflection from a smooth surface is called **specular reflection.**

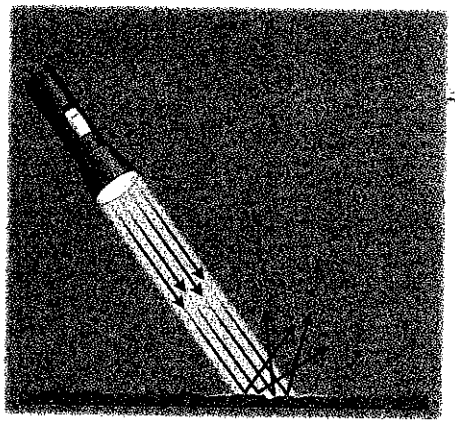
But the law of reflection is at work even on rough surfaces. Think of a rough surface as being made of many small smooth surfaces positioned at different angles. So, when light shines on a rough surface, such as a brick wall, the light rays get reflected at many different angles. You cannot use such a surface as a mirror. Reflection of light from a rough surface is called **diffuse reflection.**

Specular Reflection



Mirror

Diffuse Reflection



Rough Surface

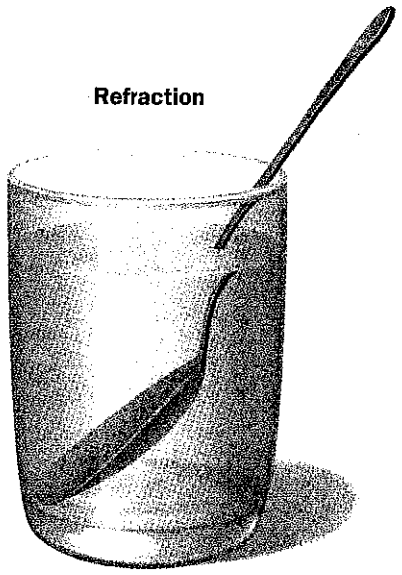
Transmission of Light

Sometimes light passes through matter. This is called **transmission.** Light passes through some materials more easily than others. For example, light passes through water, air, and glass very easily. These materials are said to be **transparent.** You can see through transparent matter because light passes through it.

Translucent matter transmits some but not all of the light that hits it. An example of translucent matter is a sheet of waxed paper. **Opaque** matter does not transmit any light. You cannot see through it because light does not pass through it. Your desk is an example of opaque matter. So is this book.

Light always travels in straight lines. But when it passes from one medium to another (from air to water, for example), light changes direction slightly. This is called **refraction.** You can see this phenomenon when you put a spoon in a glass of water. Refraction occurs because light travels at different speeds through different materials. In the case of the spoon and glass of water, the light rays bend as they pass from the water to the air because light travels faster through air than through water.

Refraction



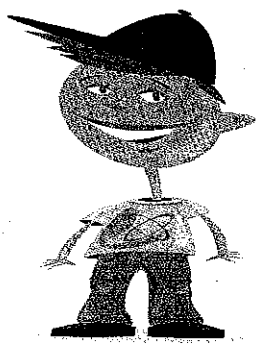
SEE ALSO
306 Characteristics of a Wave

Absorption of Light

The atoms in matter can also absorb light. Absorbed light energy is converted into some other form, such as thermal energy.

SEE ALSO
301 Thermal Energy

Objects get their color from selective absorption. For example, an apple looks red because it absorbs all the colors of light except red. Red light gets reflected to your eyes. A white object looks white because it reflects all colors of light and absorbs none. A black object looks black because it absorbs all colors of light and reflects none.



Remember that all the colors of light seen together appear to us as white light.

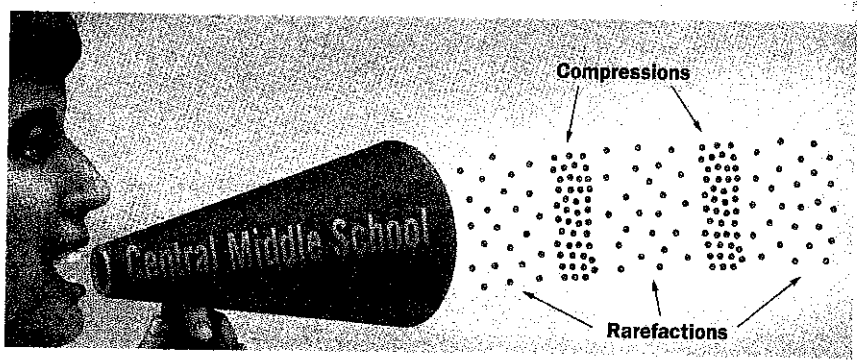
312

Sound

Did you hear that? Sound is all around you: clocks ticking, horns blowing, feet shuffling, babies crying.

Sound is produced when an object vibrates. The vibrating object pushes the particles of matter next to it and causes them to compress (squeeze together). That compressed matter, in turn, compresses the matter next to it. The compression travels through the matter as a wave of energy. Sound waves travel in all directions away from their source. Sound waves are longitudinal waves.

SEE ALSO
307 Kinds of Waves



SEE ALSO
310 Properties of Light

Unlike light, sound waves need a medium (matter) to travel through. Sound cannot exist in a vacuum. Like light, sound travels at different speeds through different materials. In general, sound travels faster through solids than through liquids, and faster through liquids than through gases. Sound waves also travel faster through a warmer medium than through a cooler medium.

Material	Speed of Sound (m/s)
Steel	5200
Glass	4540
Oak wood	3850
Silver	3650
Water	1520
Cork	500
Air	330

Sound travels much more slowly than light. That's why you often see a flash of lightning before you hear the rumble of thunder. The thunder is produced by the lightning, but it takes sound much longer to reach your ears than it takes light to reach your eyes.

Properties of Sound

313

How would you describe a sound? Is it loud or soft? High or low? Soothing or jarring? The properties of sound depend in large part on the amplitude and frequency of the sound waves.

Amplitude and Loudness

Amplitude is the distance a wave oscillates from its resting position. The greater the amplitude of the sound wave, the louder the sound. Loudness is measured in units called **decibels (dB).** The softest sound that can be heard by the human ear is assigned a decibel level of 0. The average human can hear sounds between 0 and 120 decibels. Beyond that, the energy of the sound waves is so great that it can injure your ears.

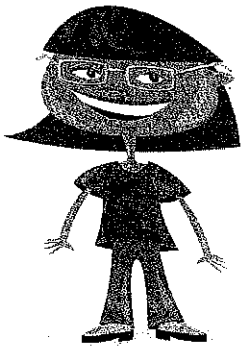
SEE ALSO
306 Characteristics of a Wave

Sound	Decibel (dB) Level
Rustling leaves	10
Whisper	30
Normal conversation	65
Vacuum cleaner	75
Lawn mower	100
Rock concert	120
Jet engine at takeoff	150

Frequency and Pitch

Frequency is the number of waves produced in a given time. The frequency of a sound wave determines its pitch, or how high or low the sound is. The higher the frequency of a sound wave, the higher the pitch. Most humans can perceive sound waves within a frequency range of 20 to 20,000 Hz, or waves per second.

Loudness and pitch are not related. A high-pitched sound can be soft and a low-pitched sound can be loud.



SEE ALSO
306 Characteristics of a Wave

CHAPTER 12

SOUND AND ELECTROMAGNETIC ENERGY

- ***THE PHYSICAL SETTING: KEY IDEA 4***
  Energy exists in many forms and when these forms change energy is conserved

Waves

Waves are disturbances that transfer energy from place to place. If you throw a stone into a pond, circular waves move along the surface. When the stone hits the pond, it has kinetic energy. Some of the kinetic energy of the moving stone is transferred to the water, causing the water to move.

The substance through which some waves travel is a **medium**. This can be a solid, liquid, or gas. Air is usually the medium for sound waves. Light does not need a medium to travel through, it can travel through empty space (**vacuum**).

There are two types of waves. Transverse waves are waves in which the particles move up and down at right angles to the direction of the wave motion. Compressional waves are waves in which the particles move back and forth, in the direction of wave motion.

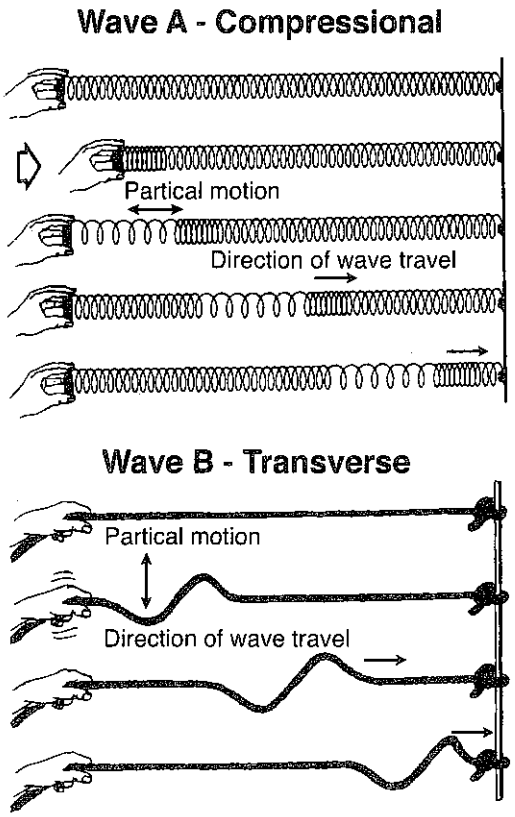


FIGURE 1. TRANSVERSE & COMPRESSIONAL WAVES

Transverse waves have a number of features. These include the crest, trough, and wavelength. The crest is the top of the wave. The trough is the bottom of the wave. The distance between two adjacent crests or troughs is known as the **wavelength**. The number of waves that pass a specific location in one second is the frequency.

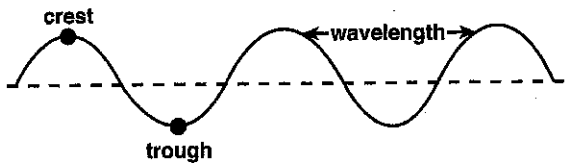


FIGURE 2. PARTS OF A TRANSVERSE WAVE

Waves can be reflected, refracted, or diffracted. **Reflection** is the bouncing back of a wave after striking a barrier or surface. Light waves are reflected off a mirror, so we see our image. An echo is reflected sound waves.

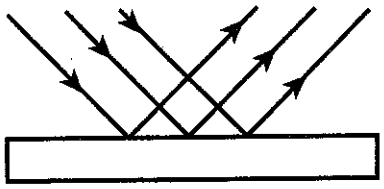


FIGURE 3. REFLECTION

Refraction is the bending of waves as they move from one medium to another. Light is refracted when it goes through a prism. When light moves from the air to the glass , the light wave will bend.

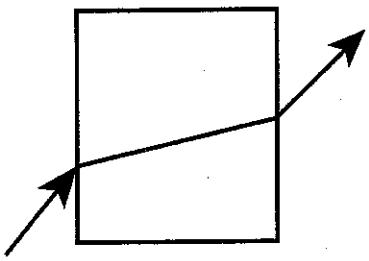


FIGURE 4. REFRACTION

Diffraction is the bending of waves around a barrier. This is why you can hear noise from around a corner.

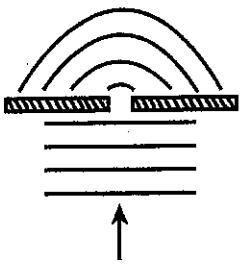
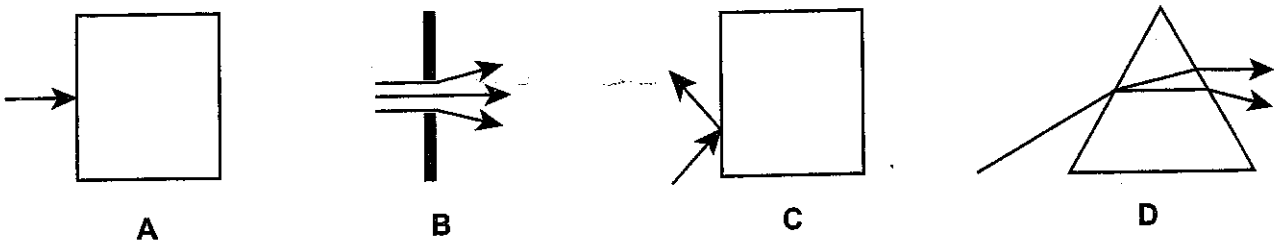


FIGURE 5. DIFFRACTION

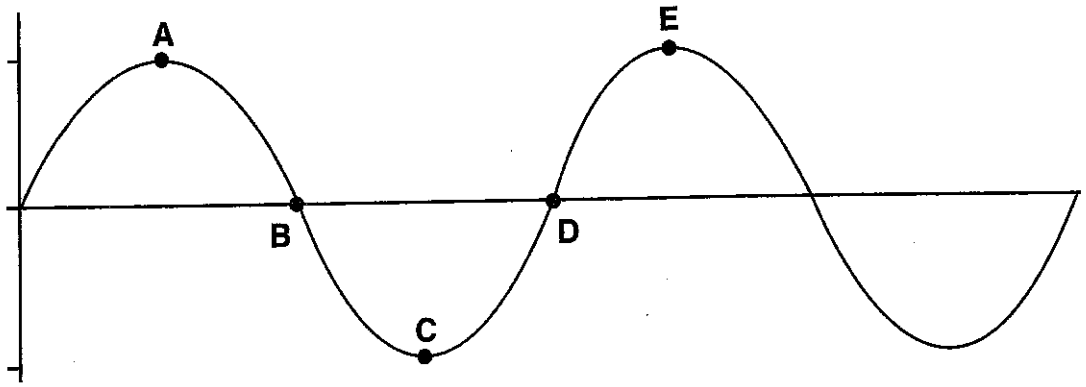
Review Questions

1. Waves are disturbances that transfer _____.
2. The material that a wave travels through is called a _____.
3. Light can travel through a _____.
4. The distance from a crest to the next crest is the _____.
5. Select the diagram that illustrates:



a. reflection _____ **b.** refraction _____ **c.** diffraction _____

6. In the diagram below, the wavelength is between letters _____ and _____.



Sound

Sound is a form of energy that travels as a compressional wave. Sound cannot travel through a vacuum, it needs a medium (substance) to travel through. **Sound** travels through the medium by vibrating the particles of that substance. When sound travels through air it vibrates the air molecules. As sound travels into your ear, it vibrates the bones and tissues of your inner ear.

Sound travels much slower than light. This is why you see lightning before you hear thunder. Sound travels at different speeds through different mediums. It travels slowest through gases and fastest through solids. The speed of sound also depends on the temperature. As temperature increases, molecules move faster and there are more collisions, so sound travels faster. On a cold winter day sound will travel slower.

The intensity of sound is the amount of energy it has. Sound is measured in decibels (dB). A whisper is 10 dB but a jet plane is 170 dB. Continuous exposure to loud sounds can cause health problems such as increase in blood pressure and a loss of hearing.

Review Questions

7. Sound cannot travel though a _____.
8. Sound is caused by the _____ of particles.
9. The speed of light is _____ than the speed of sound.
10. Sound travels fastest through _____ materials.
11. Sound travels faster when the temperature is _____.
12. Constant exposure to sounds of more than 90 dB can cause _____ loss.

Electromagnetic Energy

Electromagnetic energies can travel through a medium (material) or through a vacuum (empty space). All electromagnetic energies travel at the speed of light which is more than a million times faster than sound. Electromagnetic energy includes microwave, infrared (heat), visible light, ultraviolet, x-rays, and gamma rays. These energies travel as transverse waves. Each type has a different wavelength. The shorter the wavelength, the more dangerous the electromagnetic energy.

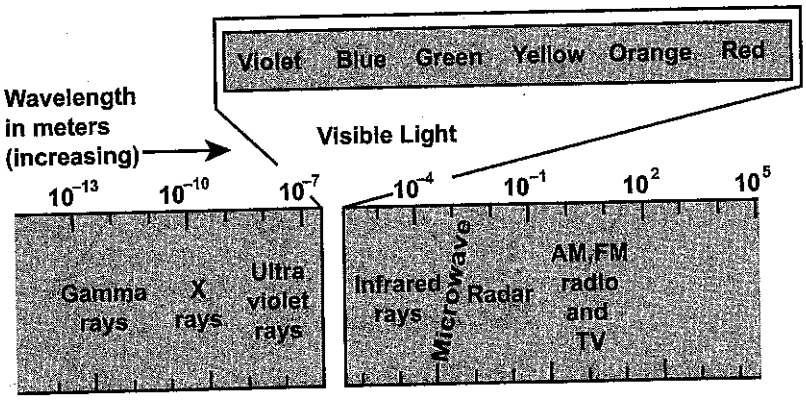


FIGURE 6. ELECTROMAGNETIC SPECTRUM

Gamma rays have the shortest wavelength. They are very dangerous and are used to destroy cancer cells. They are given off by radioactive elements and nuclear explosions. X-rays have great penetrating power and are used to examine bones, teeth, and luggage.

Ultraviolet radiation (UV) is found in light from the Sun. It causes sunburn and skin cancers. Ultraviolet radiation can damage the immune system, cause damage and cataracts in the eye, and stunt plant growth. Ozone in the stratosphere blocks out most of the UV radiation from the Sun.

Visible light is the only electromagnetic energy we can see. Each color we see has a different wavelength. Red is the longest, and blue the shortest wavelength.

Infrared radiation produces heat energy. Earth receives infrared radiation from the Sun. All objects give off heat or infrared radiation. Earth radiates heat to space, our bodies radiate heat to a room.

Microwave radiation is used in communications, cell phones, satellites, and in cooking. It is absorbed by food, which causes the food to heat up.

Radio waves have the longest wavelength. They are used to transmit radio and TV signals. Reflected radio waves can give us ground images in the dark or through clouds.

Review Questions

13. Electromagnetic waves can travel through a medium or through a _____.

14. Each type of electromagnetic energy has a different _____.

15. Cancer cells are destroyed by _____.

16. The only electromagnetic energy that we can see is _____.

17. Ozone blocks out _____ rays.

18. Heat is _____ radiation.

19. Name the type of energy used or given off.

a. a warm kitten _____

b. image of a broken arm _____

c. sunburn _____

d. a television antenna _____

e. cooks food quickly _____

f. the colors we see _____

Light Energy

Light waves travel as transverse waves. Light does not need a medium or a material to travel through, it can travel through a vacuum. The speed of light is 300,000 km/sec.

Light is the only energy we can see. Some objects are luminous and give off light such as the Sun or a lamp. Other objects reflect light. We see the Moon and each other because of reflected light.

Light can be reflected, or bounced back unchanged. Reflection is best off a smooth, light-colored surface. Light can be absorbed, or taken into an object and then changed to heat energy. Dark, rough objects absorb light energy the best and therefore become warm very quickly.

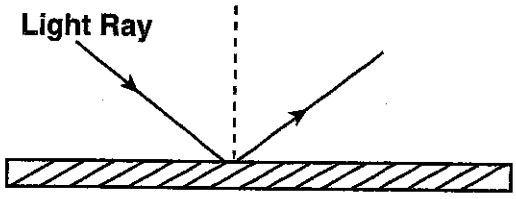


FIGURE 7. REFLECTION OF LIGHT

Refraction occurs when light enters a new medium causing its speed and direction to change. Refraction results in the bending of light rays. We see rainbows because of the refraction of sunlight as it passes through ice crystals and water droplets in the atmosphere. Objects appear bent when they are viewed in water. A pencil in a cup will appear to bend at the point that the water and air meet.

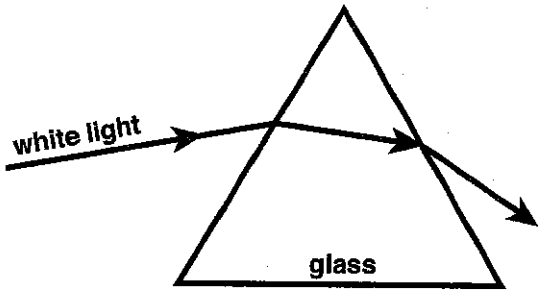


FIGURE 8. REFRACTION OF LIGHT

Light can be transmitted or passed through a material. Window glass allows light to be transmitted.

Review Questions

20. Light can travel through a medium like glass or through a _____.

21. We see objects because the objects _____ light.

22. The bending of light is _____.

23. A light colored, smooth surface will _____ light more than a dark, rough surface.

24. A black shirt will tend to _____ light energy.

25. Clear glass will _____ light.

CHAPTER REVIEW

1. An echo is an example of
   (1) reflection (2) refraction (3) diffraction (4) absorption

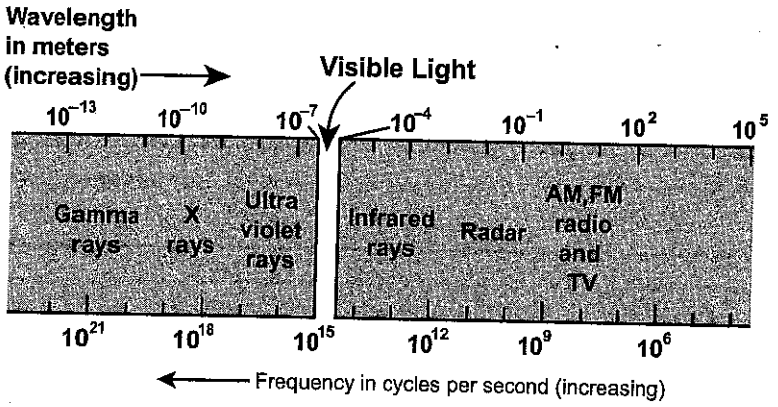
2. When you sit in a room you can hear noises in the hallway because sound is
   (1) reflected (2) refracted (3) diffracted (4) absorbed

3. Sound is produced when particles of matter
   (1) vibrate (2) change phase (3) evaporate (4) chemically react

4. Through which material will sound travel the fastest?
   (1) cold solid (2) hot solid (3) hot gas (4) cold gas

5. Which of the following is true about sound?
   (1) Sound will travel slower in a vacuum.
   (2) Sound will travel faster in a vacuum.
   (3) Sound will not travel through a vacuum.

Base your answers to **questions 6-9** on the diagram below which shows the types of electromagnetic energies.



6. Based on the diagram which statement is true?
   (1) X-rays have a shorter wavelength than visible light.
   (2) Visible light has a shorter wavelength than gamma rays.
   (3) Infrared radiation has a shorter wavelength than gamma rays.
   (4) Radio waves have a shorter wavelength than infrared radiation.

7. What is the difference between ultraviolet, visible, and infrared radiation?
   (1) temperature (2) wavelength (3) speed of travel (4) density

8. Which energy is not classified as electromagnetic?
   (1) radar (2) sound (3) television (4) heat

9. The electromagnetic energy that allows us to see objects is
   (1) gamma rays
   (2) x-ray radiation
   (3) ultraviolet radiation
   (4) visible light