
Forces and Motion

Force and Motion

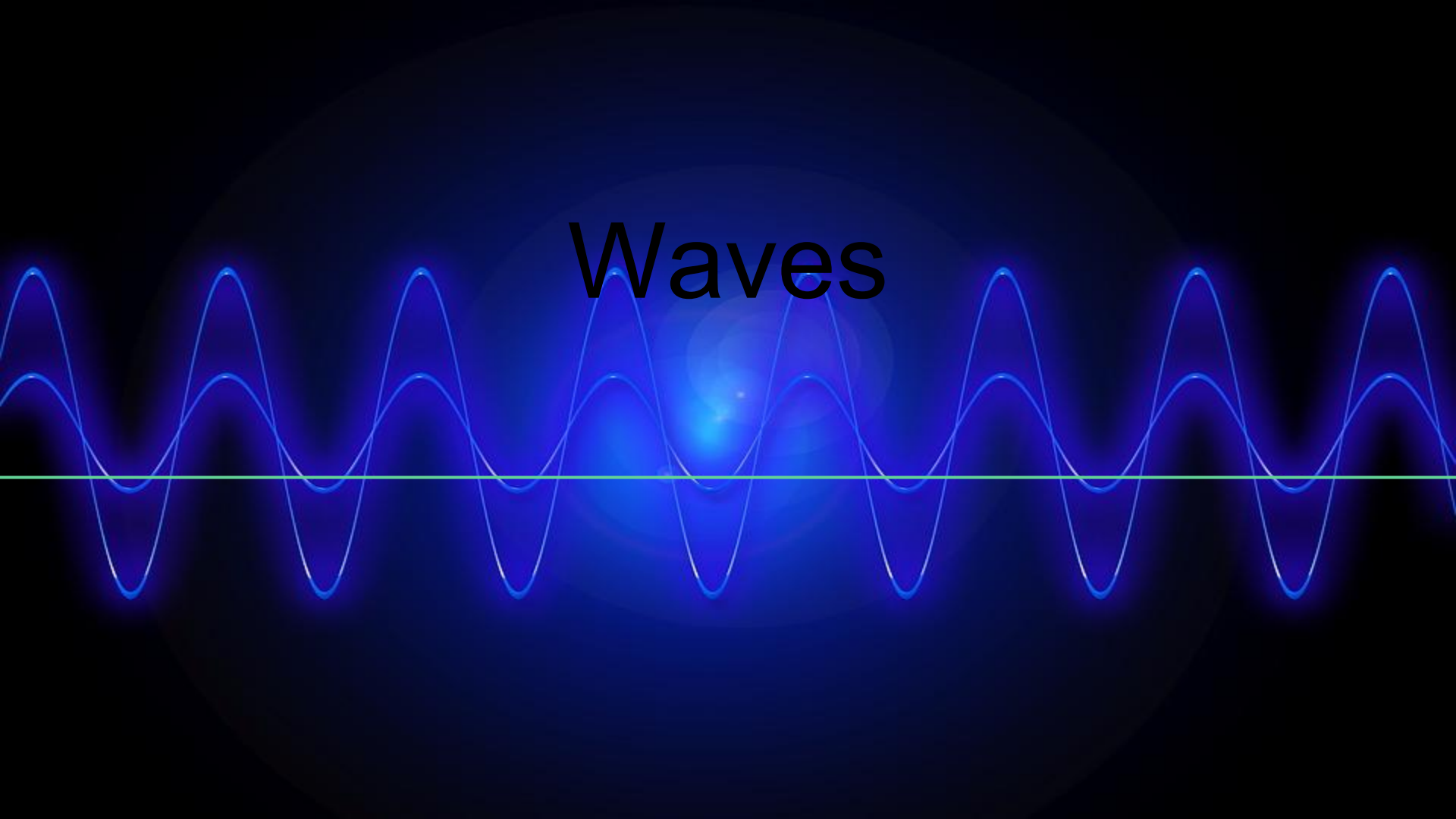
6.P.1 Understand the properties of waves and the wavelike property of energy in earthquakes, light and sound.

6.P.1.1 Compare the properties of waves to the wavelike property of energy in earthquakes, light and sound.

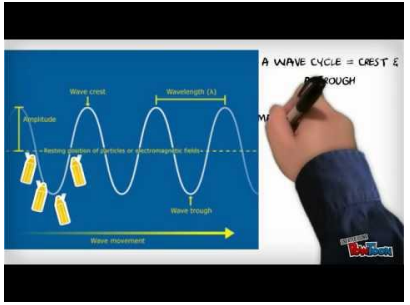
6.P.1.2 Explain the relationship among visible light, the electromagnetic spectrum, and sight.

6.P.1.3 Explain the relationship among the rate of vibration, the medium through which vibrations travel, sound and hearing.

Waves



Riding the Wave



What are waves?

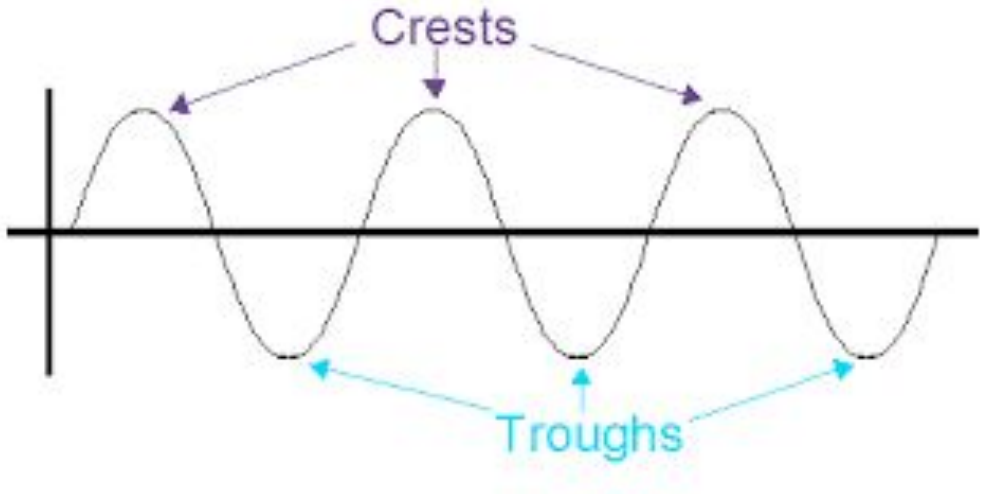
- **Waves** are disturbances that transfer energy from one place to another.

- Waves are caused by vibrations of a medium. A **medium** is the material through which a wave can travel.

- Water waves are just one of many kinds of waves. Sound and light are also waves.

What are waves?

- The points where a wave is highest are called crests. The points where a wave is lowest are called troughs.



What are waves?

- A wave is a disturbance that transfers energy.

- Some waves, such as ocean waves, transfer energy through a medium.

- Some waves, such as light waves, can transfer energy without a medium.

Different Ways to Transfer Energy

How does a wave transfer energy?

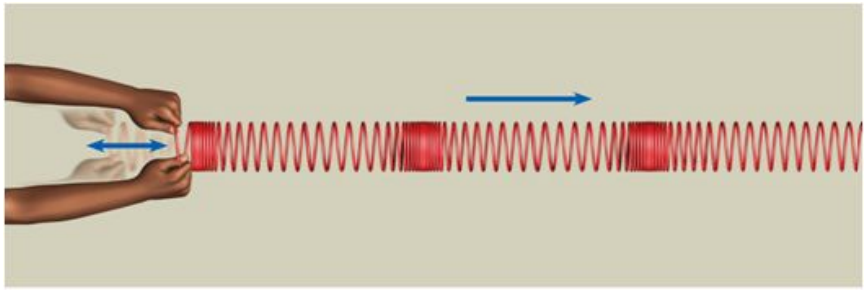
- Not all waves transfer energy the same way.

- Waves can be classified by comparing the direction that they cause particles in the medium to move with the direction in which the wave moves.

How do waves transfer energy?

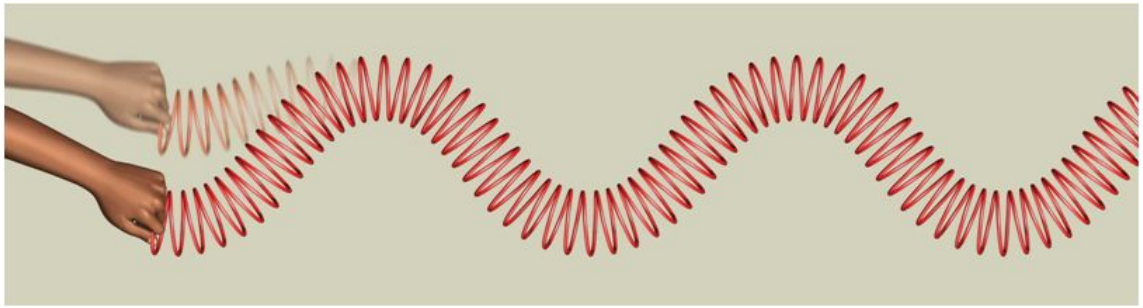
- Energy can be transferred from one object to another using *compressions*, when the coils are close together, and *rarefactions,* when the coils are far apart.

- This causes energy to travel in a **longitudinal wave**.
- Sound waves are longitudinal waves.



How do waves transfer energy?

- Energy can be transferred from one object to another using up and down motions. This causes energy to travel as a **transverse wave**.
- In a transverse wave, particles move perpendicularly to the direction the wave travels.



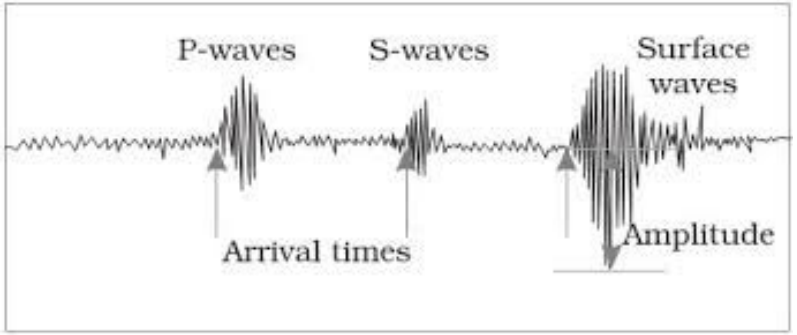
How do waves transfer energy?

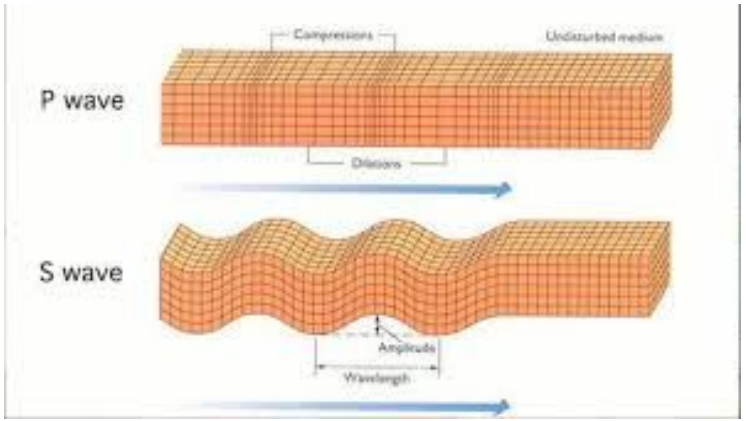
- Earthquakes send out both types of waves.

- Primary waves, called P waves, are longitudinal waves. They always arrive first.

- Secondary waves, called S waves, are transverse waves. They always arrive second.

- They can combine to form a surface wave, like ripples on a pond.





Making Waves

What are some types of waves?

- Waves can also be classified by what they are traveling through.

- Waves that require a medium, such as water waves, are called **mechanical waves**.

- Some mechanical waves can travel through more than one medium.

- For example, sound waves can move through air, water, and a solid wall.

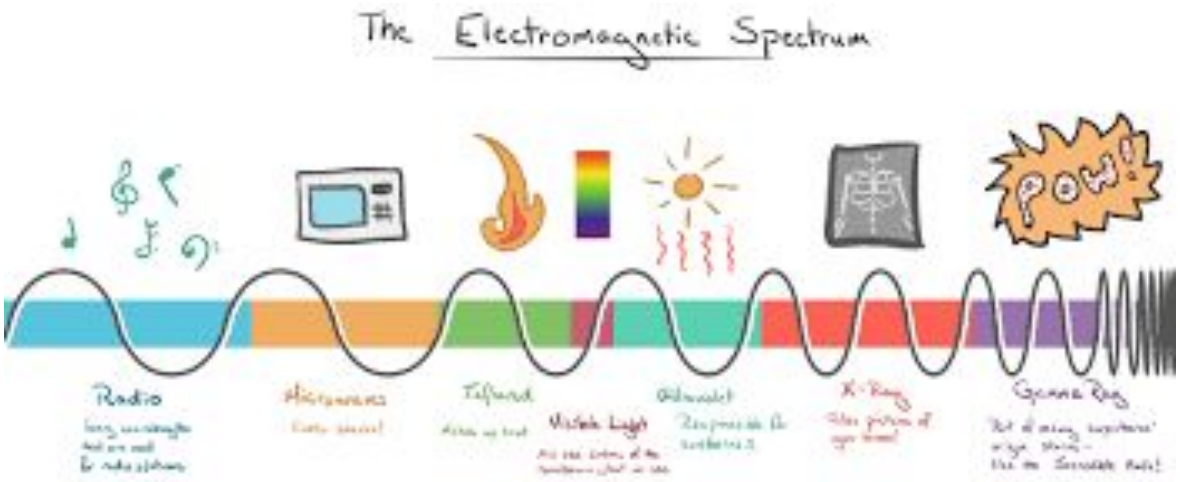
- Mechanical waves can’t travel without a medium.

What are some types of waves?

- Light and similar waves are called electromagnetic (EM) waves. An **electromagnetic wave** is a disturbance in electric and magnetic fields.

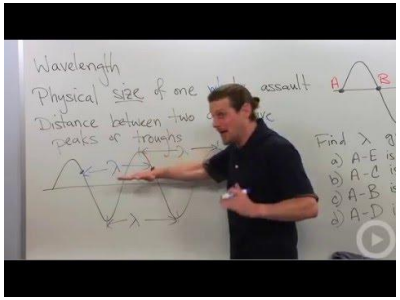
- Sunlight is an example of EM waves. Other examples include radio waves, microwaves, and X-rays.

- In empty space, all EM waves travel at the same speed, called the speed of light.



Properties of Waves

Amp It Up!

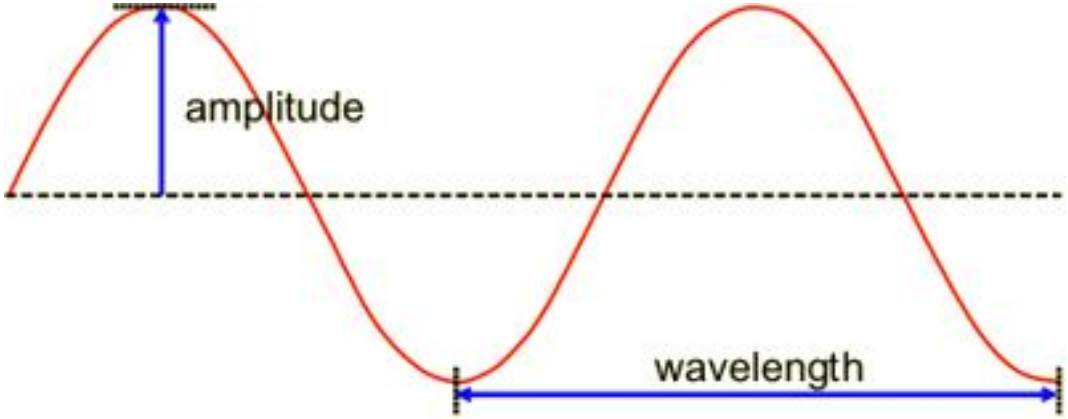


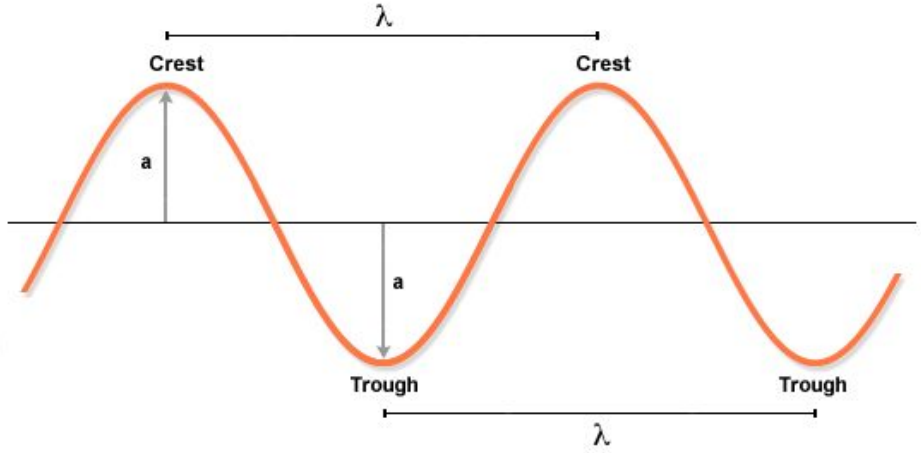
How can we describe a wave?

- A **wave** is disturbance that transfers energy from one place to another.

- A wave's **amplitude** is a measure of how far the particles in the medium move away from their normal rest position.

The **wavelength** is the distance from any point on a wave to an identical point on the next wave. This measures the length of one cycle, or repetition.


amplitude
wavelength


λ
Crest
Crest
a
a
Trough
Trough
λ

How can we describe a wave?

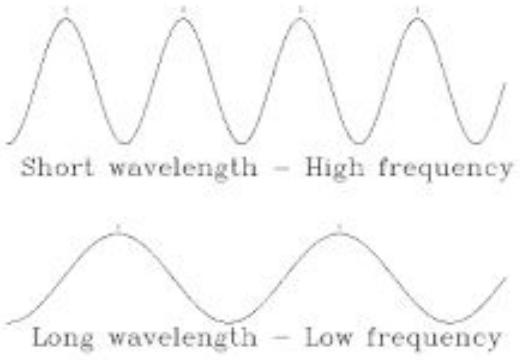
- Another property is **wave period**, the time required for one wavelength to pass a given point.

- Another way to express the time of a wave's cycle is frequency. The **frequency** of a wave tells how many cycles occur in an amount of time, usually 1 s.

How can we describe a wave?

- Frequency is measured in **hertz** (Hz). One hertz equals one wavelength per second.

- Frequency is the inverse of period.



Amp It Down

What affects the energy of a wave?

- Some waves carry more energy than others.

- For a mechanical wave, amplitude is related to the amount of energy the wave carries. For two similar waves, the wave with greater amplitude carries more energy.

- Greater frequency can also mean greater energy in a given amount of time. For most electromagnetic (EM) waves, energy is most strongly related to frequency.

What affects the energy of a wave?

- As a wave moves through a medium, particles may move in different directions or come to rest in different places.

- As the wave travels through more of the medium, more energy is lost to the medium.

- Often, higher-frequency waves lose energy more readily than lower-frequency waves lose energy. For example, when you stand far from a concert, you might hear only the low-frequency (bass) sounds.

A Happy Medium

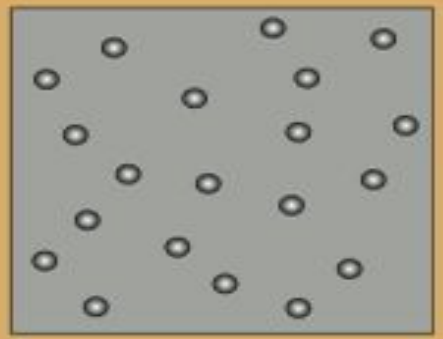
What determines the speed of a wave?

- **Wave speed**, or the speed at which waves travel, depends on the properties of the medium.

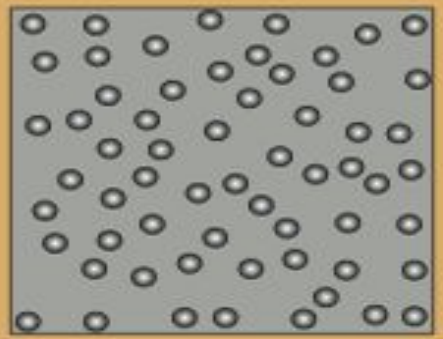
- Waves tend to travel more slowly in a denser medium.

How Sound Travels

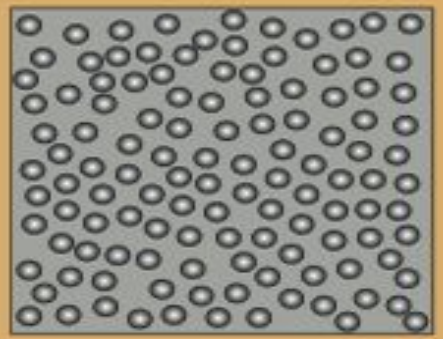
The speed at which **sound** travels from one place to another depends upon the **medium** and how closely packed the molecules are in the *matter*. A medium is a substance that allows sound waves to travel through it. Where there is no medium, no sound can be transmitted. Of the three mediums (solid, liquid, and gas), sound waves travel the slowest through gases, faster through liquids, and fastest through solids.



GAS
FAST



LIQUID
FASTER



SOLID
FASTEST!

What determines the speed of a wave?

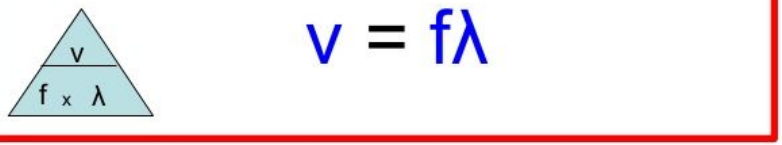
- In gases, wave speed is higher at higher temperatures.
- All electromagnetic waves travel at the same speed in empty space, but they travel more slowly through a denser medium.
- Wave speed can be calculated from frequency and wavelength.
- Speed is distance divided by time.

The Wave Equation

V = speed of wave (m/s)

f = frequency of wave (Hz)

λ = wavelength (m)

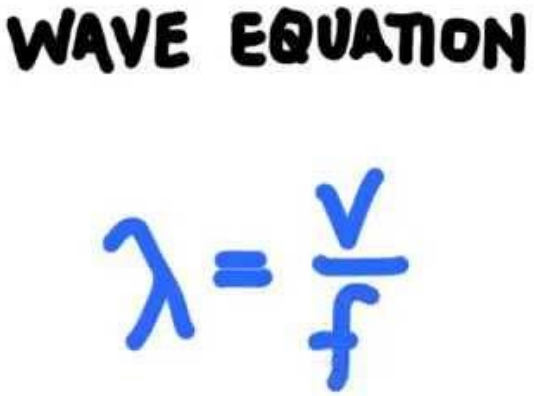


What determines the speed of a wave?

- The speed of a wave equals its wavelength divided by its period.

- This relationship can be combined with the relationship between wavelength and frequency.

- Wavelength is equal to wave speed divided by frequency.



Light Waves

The Electromagnetic Spectrum and Sight

Electromagnetic Light Show

What is the nature of light?

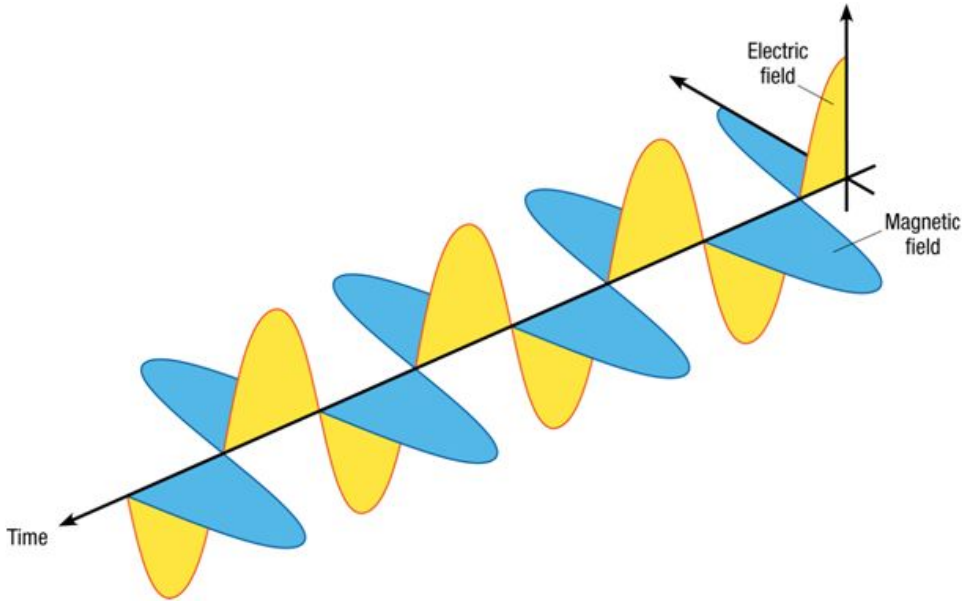
- Light waves are different from other kinds of waves.

- When an electrically charged particle vibrates, its fields also vibrate, producing an electromagnetic (EM) wave.

- Light waves are vibrating electric and magnetic fields that transfer energy through space.

What is the nature of light?

- EM waves travel perpendicular to both electric and magnetic fields.



What is the nature of light?

- **Radiation** is energy that has been transmitted by waves or particles. This transfer of energy is called EM radiation.

- All EM waves move at the same speed in a vacuum: the speed of light.

- EM waves can travel through many materials.

What determines the color of light?

- Different wavelengths of light are perceived by our eyes as different colors.

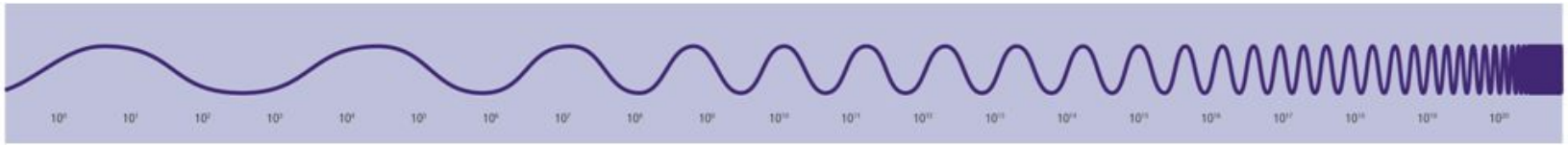
- White light is what we perceive when we see all the wavelengths of light at once, in equal proportions.

- Our eyes only register three colors of light: red, green, and blue. All other colors we see are a mixture of these three colors.

Invisible Colors

What are the parts of the EM spectrum?

The range of frequencies that EM waves can have is called the **electromagnetic (EM) spectrum**



What are the parts of the EM spectrum?

- **Infrared** light has slightly longer wavelengths than red light has. **Ultraviolet** (UV) light has slightly shorter wavelengths than violet light has.

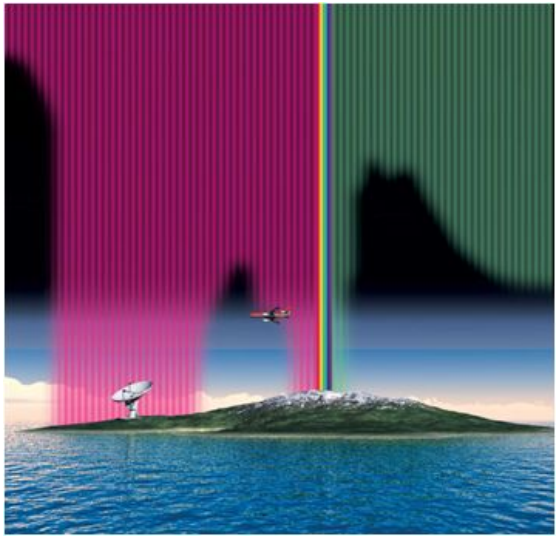
Star Light, Star Bright

How much of the sun's energy reaches us?

- Most of the sun's energy is in the narrow visible light range, but the sun gives off some radiation in every part of the spectrum.

How much of the sun’s energy reaches us?

- Not all wavelengths of light penetrate the atmosphere equally. Radio waves penetrate the atmosphere easily.



How much of the sun’s energy reaches us?

- Some EM radiation can be dangerous to humans, so we take extra steps to protect ourselves.

- UV light can be harmful. It can penetrate clouds.

- In space, the dangers from EM radiation are very high because there is no atmosphere to filter the radiation.

Frequency Asked Questions

How much energy does EM radiation have?

- Different frequencies of EM waves carry different amounts of energy.

- High-frequency EM waves have more energy than low-frequency EM waves have.

- Because low-frequency waves, such as radio waves, carry less energy, they are safer. Walkie-talkies and baby monitors use radio waves.

- High-frequency waves, such as UV light, carry more energy and can be harmful. UV light causes sunburns, and X-rays require precautions.


Interactions of Light

Shedding Light on the Matter

How can matter interact with light?

- Three forms of matter-light interactions play an important role in how people see light.

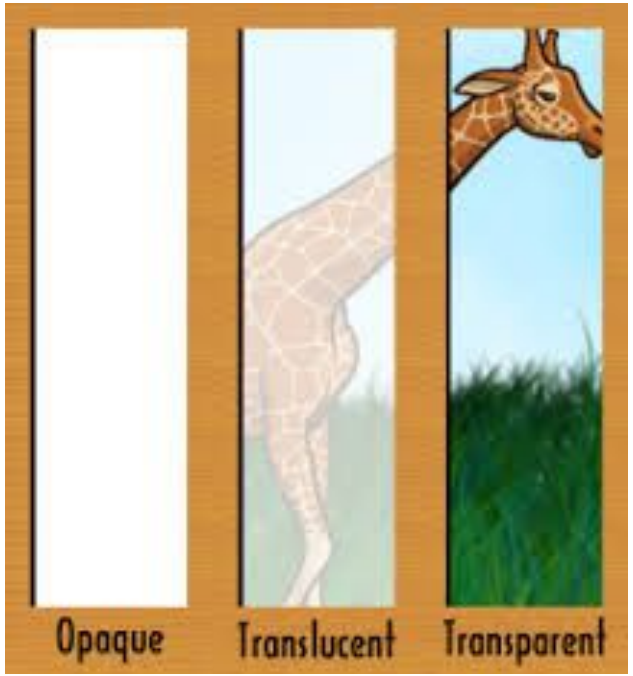
- When light enters a medium, the medium lets all, some, or no light pass through.

How can matter interact with light?

- Matter that transmits light is **transparent**.

- Matter that transmits light but scatters it in all directions is **translucent**.

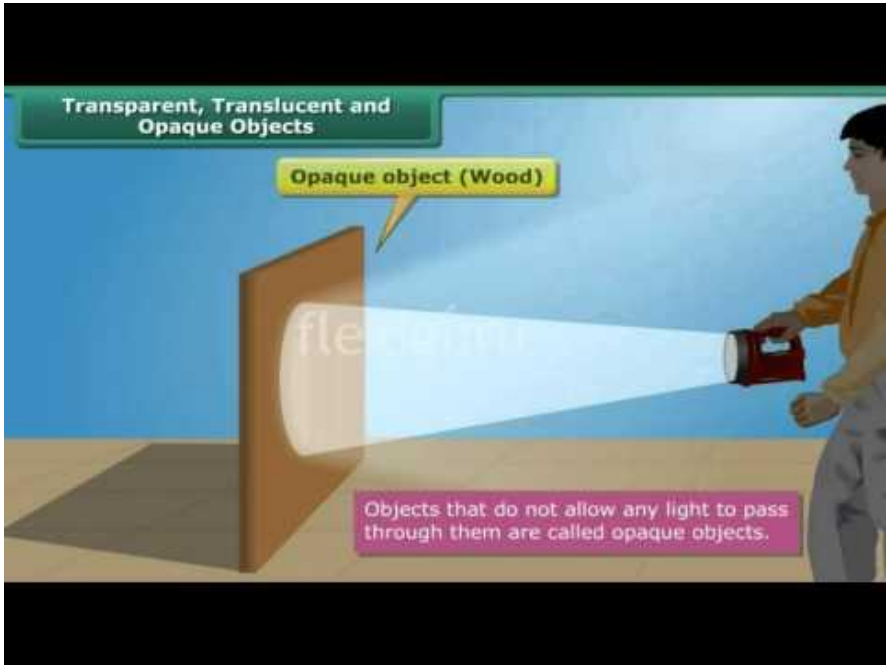
- Matter can absorb light. When light enters a material but does not leave it, the light is absorbed.



How can matter interact with light?

- **Absorption** is the transfer of light energy to matter.

- **Opaque** materials do not let any light pass through them because they reflect light, absorb light, or both.



How can matter interact with light?

- Matter can reflect light. **Reflection** is the bouncing of light off a surface.

- When light strikes a smooth surface, the light bounces off at an angle equal to the angle at which it hit the surface, producing a clear image.

- When light strikes an uneven surface, the light is reflected in many directions. You see the object but do not see a reflected image of yourself.

- Nearly everything we can see, we see because light is reflected off a surface.

Color Me Impressed!

What determines the color of objects we see?

- When white light strikes an object, the color of the object depends on how the object transmits, reflects, or absorbs the colors of light.

- An object that reflects a certain color of light appears to be that color.

- A frog appears green because its skin absorbs all colors but green.

- An object that reflects every color appears white.

- An object that absorbs every color appears black.

What determines the color of objects we see?

- When light is transmitted through an object, the object can absorb some colors and allow other colors to pass through.

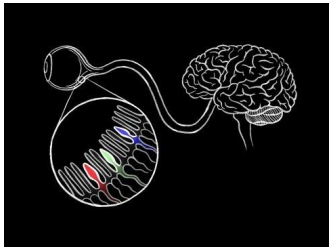
- The color that passes through a transparent or translucent object determines the color of that object.

- Some matter absorbs certain types of electromagnetic waves and allows other types of electromagnetic waves to pass through.

- Sometimes the color of an object depends on what light shines on it.

- If a red filter is placed between a green frog and white light, the filter will absorb all colors of light except red, orange, and yellow.

- The frog reflects no light, and you perceive the frog's color as gray or black.



What happens when light waves interact with matter?

- Light bends when it passes at an angle from one medium to another.

- The bending of a wave as it passes from one medium to another is called **refraction**.

- Refraction occurs because light changes speed as it enters a medium at an angle.

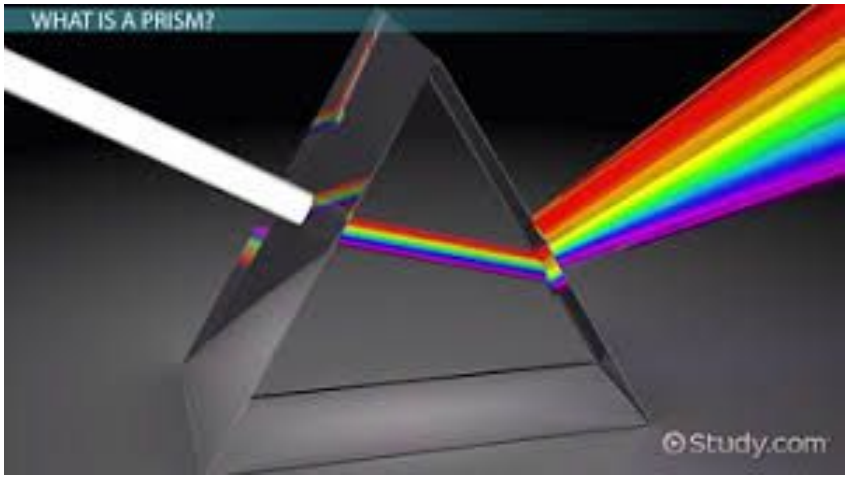
- When light slows in a medium, it bends inward, creating a smaller angle.

- Light waves with shorter wavelengths bend more.

What happens when light waves interact with matter?

- The waves that make up white light have different wavelengths.

- As white light passes through a prism, the wavelengths refract at different angles and you see a spectrum of colors.



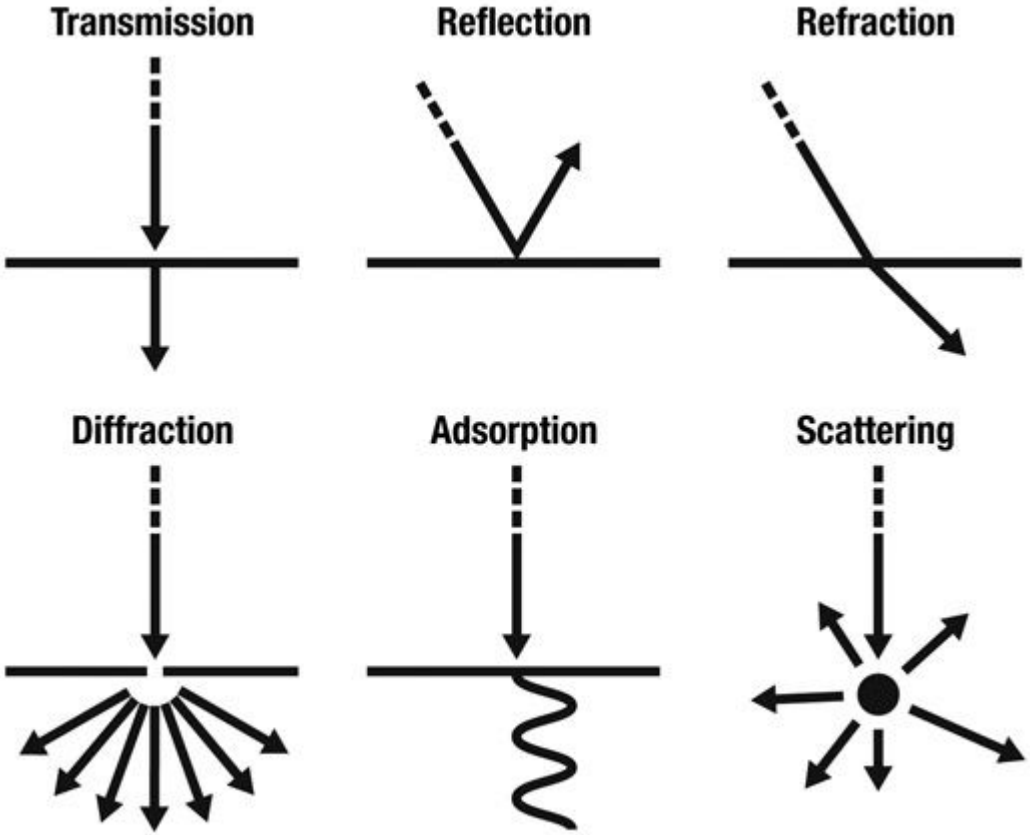
What happens when light waves interact with matter?

- When light strikes matter, the light can change direction. This is called **scattering**.

- Light scattering allows us to see objects that are not in the direct path of the light source.

- Another result of scattered light is the color of the sky. Blue light is scattered more than other colors, so the sky appears blue.

- When the sun strikes Earth at an angle, light waves pass through more of the atmosphere. Only the long-wavelength red light reaches Earth.


Transmission
Reflection
Refraction
Diffraction
Adsorption
Scattering

Let’s Focus

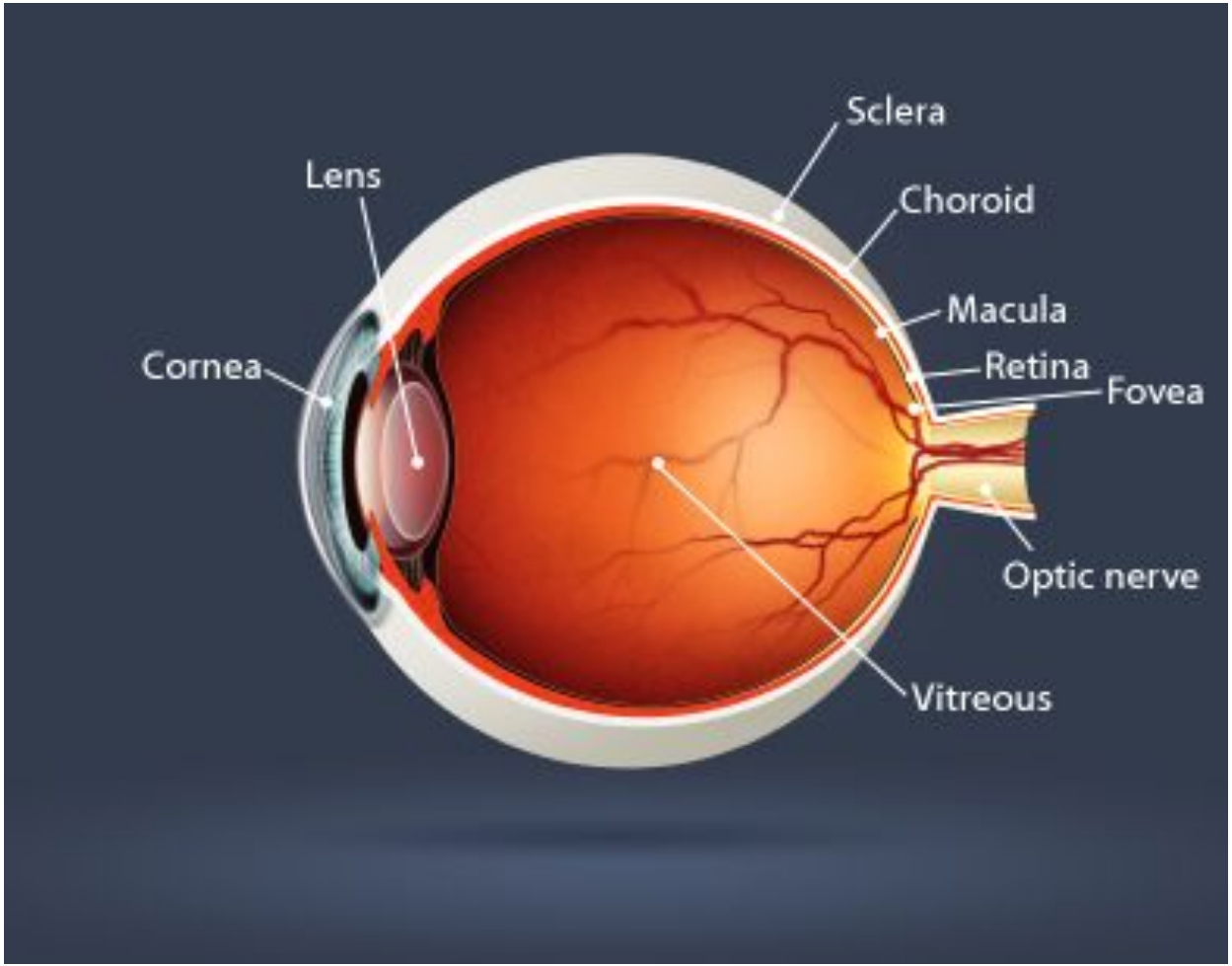
- You see an object when your eyes detect light and send signals to your brain.

- Some objects produce their own light, while other objects reflect light.

- Light waves enter the eye through the **cornea**, which is the transparent membrane that forms the front part of the eye.

- The cornea refracts, or bends, the light so that it passes through the pupil at the center of the iris.

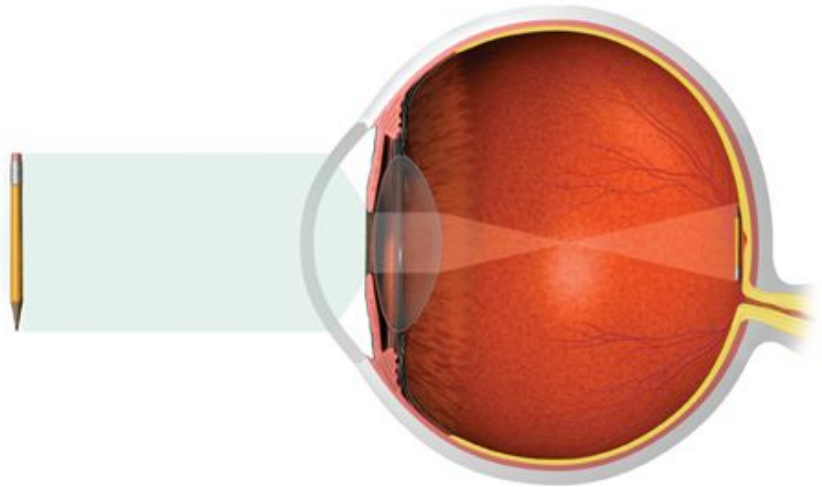
- The iris changes the size of the pupil to control the amount of light that is let in.


Sclera
Lens
Choroid
Macula
Cornea
Retina
Fovea
Optic nerve
Vitreous

How do people detect and interpret light waves?

- The light refracts again as it enter the lens.

- Muscles around the lens change its thickness so that objects at different distances can be seen in focus.

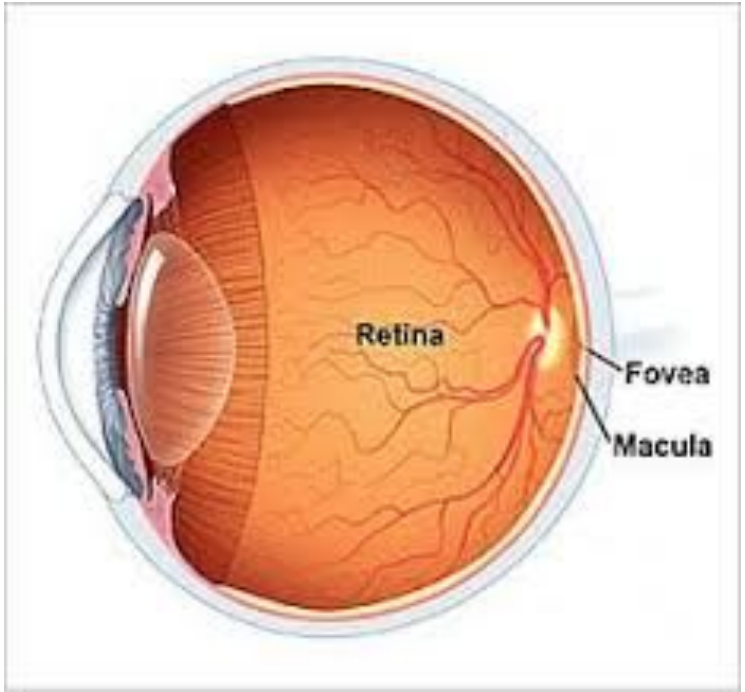


How do people detect and interpret light waves?

- Images are received by the **retina**, the light sensitive tissue that lines the inside of the eye.

- Rod cells and cone cells in the retina detect light.

- Rods are very sensitive even in dim light. Cones detect brighter light and colors.

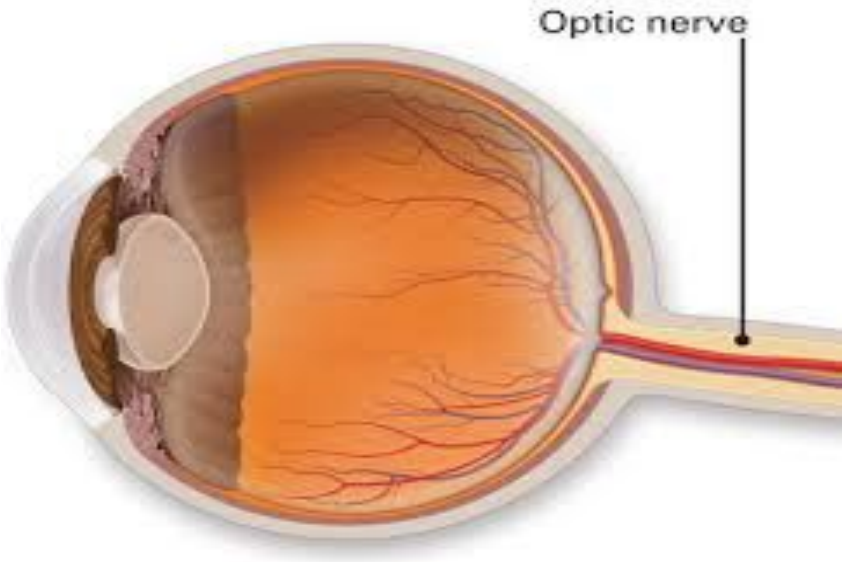


How do people detect and interpret light waves?

- The retina is the part of the eye that detects light and sends signals to the brain.

- The image is actually focused upside down onto the retina.

- Rods and cones convert the input into electrical signals that travel to the brain through the *optic nerve.*



How do people detect and interpret light waves?

- Different parts of the brain take in signals and interpret the color, shape, movement, and location of an image.

- Although the image is upside down, the brain understands the image as being right-side up.

- The brain combines slightly different information from the left and right eyes to produce a sense of distance and depth.

Out of Sight

What are some common vision problems?

- Nearsightedness happens when a person's eye is too long, or the cornea is curved steeply.

- Nearsighted eyes produce an image in front of the retina, rather than on the retina.

- A nearsighted person can see something clearly only if it is nearby.

What are some common vision problems?

- Farsightedness happens when a person’s eye is too short, or the cornea is not curved enough.

- A farsighted person can see something clearly when it is a distant object; nearby things are blurry.

- People can be born farsighted. Some people grow out of farsightedness.

What are some common vision problems?

- About 5% to 8% of men and 0.5% of women in the world have a color deficiency.

- This condition is often called color blindness, but most people with color blindness can see some colors.

- Color vision deficiency happens when the cones in the retina do not work properly.

- These people see certain colors, such as red and green, as a different color, such as yellow.

Sound Waves

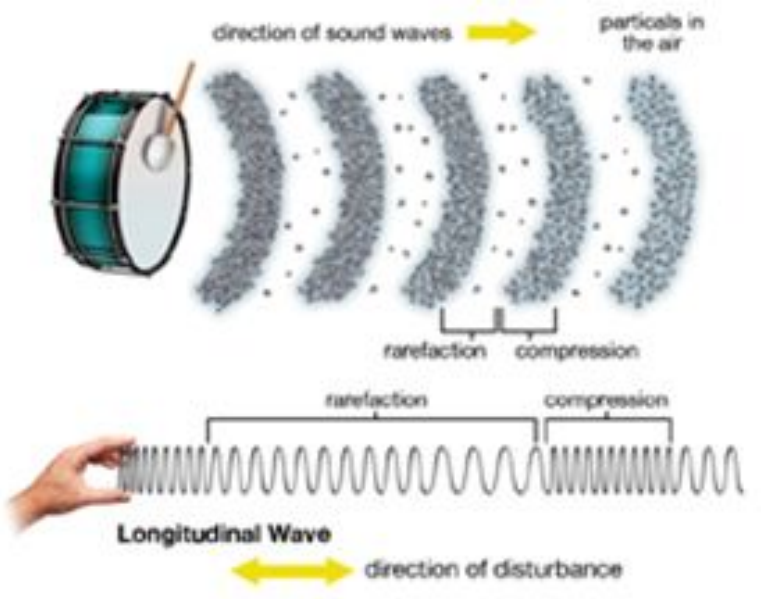
Sound and Hearing

Listen Up!

What is sound?

- A *vibration* is the complete back and forth motion of an object.

- Beating a drum causes the drum skin to vibrate, which causes the air around it to vibrate.



What are sound waves?

- A **sound wave** is a longitudinal wave that is caused by vibrations and that travels through a medium.

- In a **longitudinal wave**, the particles of a medium vibrate in the same direction that the wave travels.

- As the wave passes through a medium, its particles compress together and then spread out.

What are sound waves?

- Longitudinal waves are also called *compression waves*. They are made up of compressions and rarefactions.

- A *compression* is the part of a longitudinal wave where particles are close together.

- A *rarefaction* is the part of a longitudinal wave where particles are spread apart.

How do sound waves travel?

- Sound waves travel in all directions away from their source.

- They can only travel through a medium.

- All matter—solids, liquids, and gases—is composed of particles. The particles in matter make up the medium through which waves can travel.

How do sound waves travel?

- The particles of a medium only vibrate back and forth along the path of the sound waves.

- Most sounds travel through air, but some travel through other materials, such as water, glass, and metal.

- In a vacuum there are no particles to vibrate, so no sound can be made.

- Sound must travel through a medium to be detected.

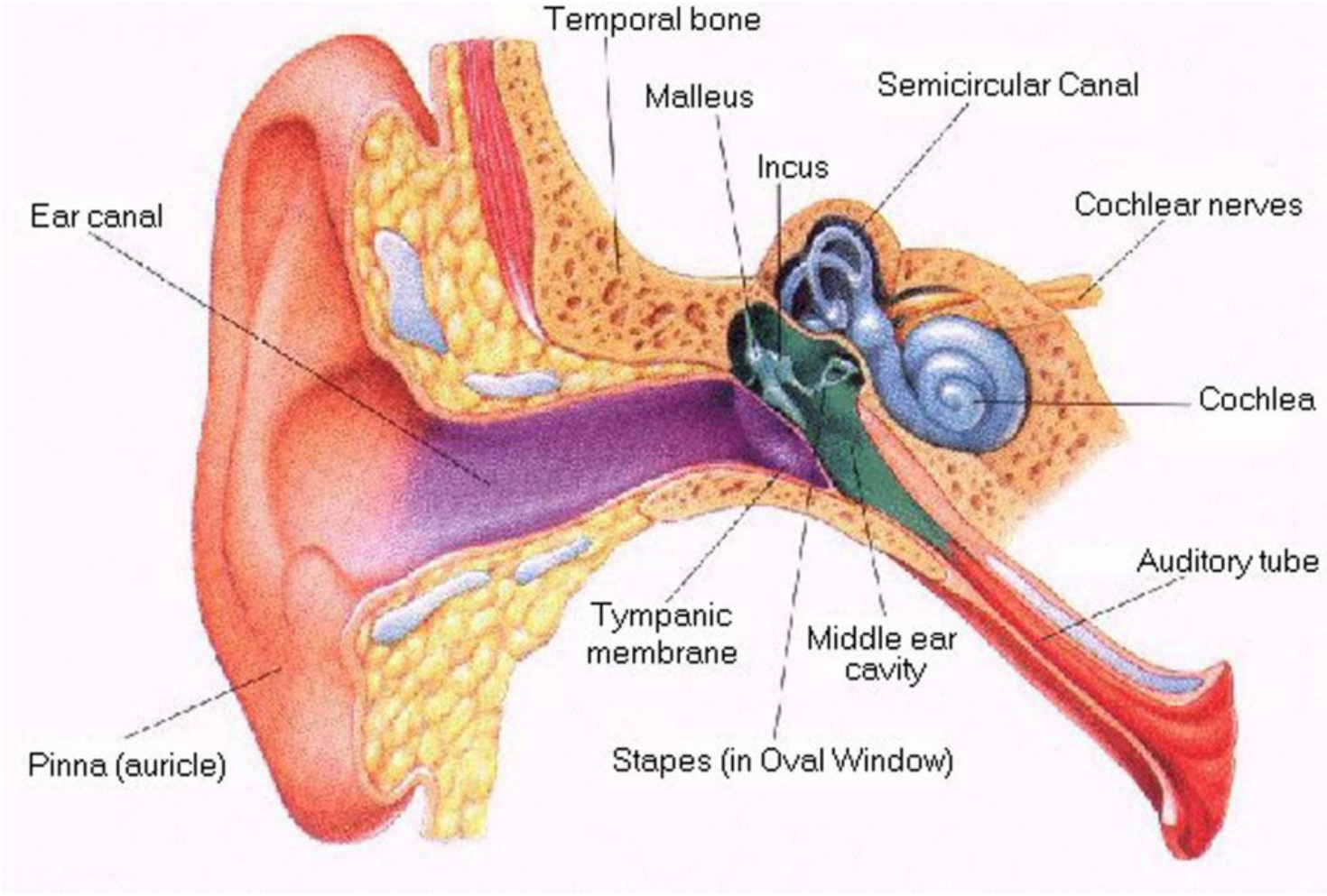
Do You Hear That?

How do humans hear sound?

- Humans detect sounds with their ears, which act like funnels for sound waves.

- The ear directs sound vibrations from the environment to the three tiny bones in the middle ear.

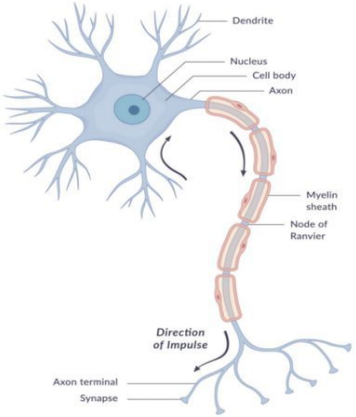
- These bones carry vibrations from the eardrum to the oval window, which leads to the inner ear.

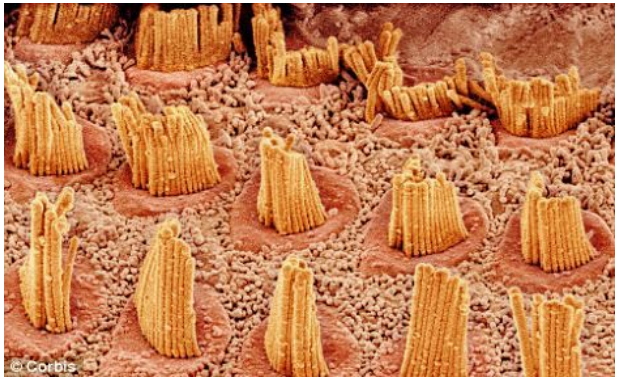

Temporal bone
Malleus
Semicircular Canal
Incus
Ear canal
Cochlear nerves
Cochlea
Auditory tube
Tympanic membrane
Middle ear cavity
Pinna (auricle)
Stapes (in Oval Window)

How do humans hear sound?

- Vibrations travel through fluid to the cochlea, which has thousands of nerve cells.

- Each nerve cell has tiny surface hairs that bend with the vibrations to send electrical signals to the brain, which interprets the signals as sound.





Can You Hear Me Now?

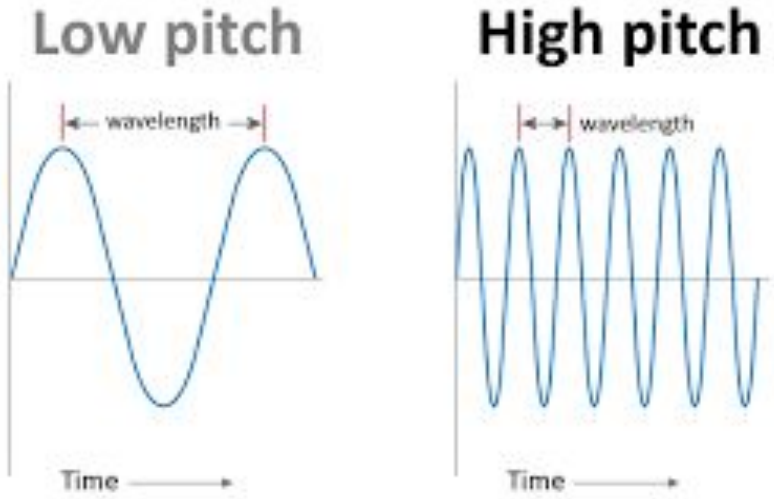
What determines pitch?

- **Pitch** is how high or low you think is a sound is.

- The pitch heard depends on the ear's sensitivity to pitches over a wide range.

- Frequency is expressed in hertz (Hz).

- One hertz is one complete wavelength, or cycle, per second.



What determines pitch?

- In a given medium, the higher the frequency of a wave, the shorter its wavelength and the higher its pitch.

- High-frequency waves have shorter wavelengths and produce high-pitched sounds.

- Low-frequency waves have longer wavelengths and produce low-pitched sounds.

What makes a sound loud?

- **Loudness** is a measure of how well a sound can be heard.

- The measure of how much energy a sound wave carries is the wave's intensity, or amplitude.

- The *amplitude* of a sound wave is the maximum distance that the particles of a wave vibrate from their rest position.

What makes a sound loud?

- The greater the amplitude, the louder the sound.

- The smaller the amplitude, the softer the sound.

- Amplifiers can increase loudness by receiving sound signals and increasing the wave’s amplitude.

Turn That Down!

How is loudness measured?

- Loudness is a characteristic of sound that can be calculated from the intensity of a sound wave.

- The most common unit used to express loudness is the **decibel** (dB).

- One decibel is one tenth of a *bel,* the base unit.

- The bel is named after Alexander Graham Bell, who invented the telephone.

How is loudness measured?

- The softest sounds most humans can hear are at a level of 0 dB.

- Sounds that are 120 dB or higher can be painful.

- Rock concerts usually measure about 115 dB.

How loud is too loud?

- Short exposures to sounds that are loud enough to be painful can cause hearing loss.

- Even loud sounds that are not painful can damage your hearing if exposed to them for long periods of time.

- Loud sounds can damage the hairs on the nerve cells in the cochlea. Once damaged, these hairs do not grow back.

How loud is too loud?

- Using earplugs to block loud sounds, lowering the volume when using earbuds, and moving away from a loud speaker are all ways to protect yourself from hearing loss.

- Doubling the distance between yourself and a loud sound can reduce the sound’s intensity by as much as one-fourth of what it was.

Hello? Hello? Hello?

How do sound and matter interact?

- Sound waves do not travel easily through all matter.

- Sound may bounce away from some surfaces. Sound may be absorbed by other sources or transmitted through a barrier

- Reflection is the bouncing back of a wave when it hits a barrier. Sound waves reflect best off smooth, hard surfaces.

- Some matter absorbs sound waves better than other matter.

- A rough wall will absorb sound better than a smooth wall will.

- Soft materials, such as rugs and drapes, will absorb sound better than hard surfaces will.

Steven Tyler's Vocal Cords