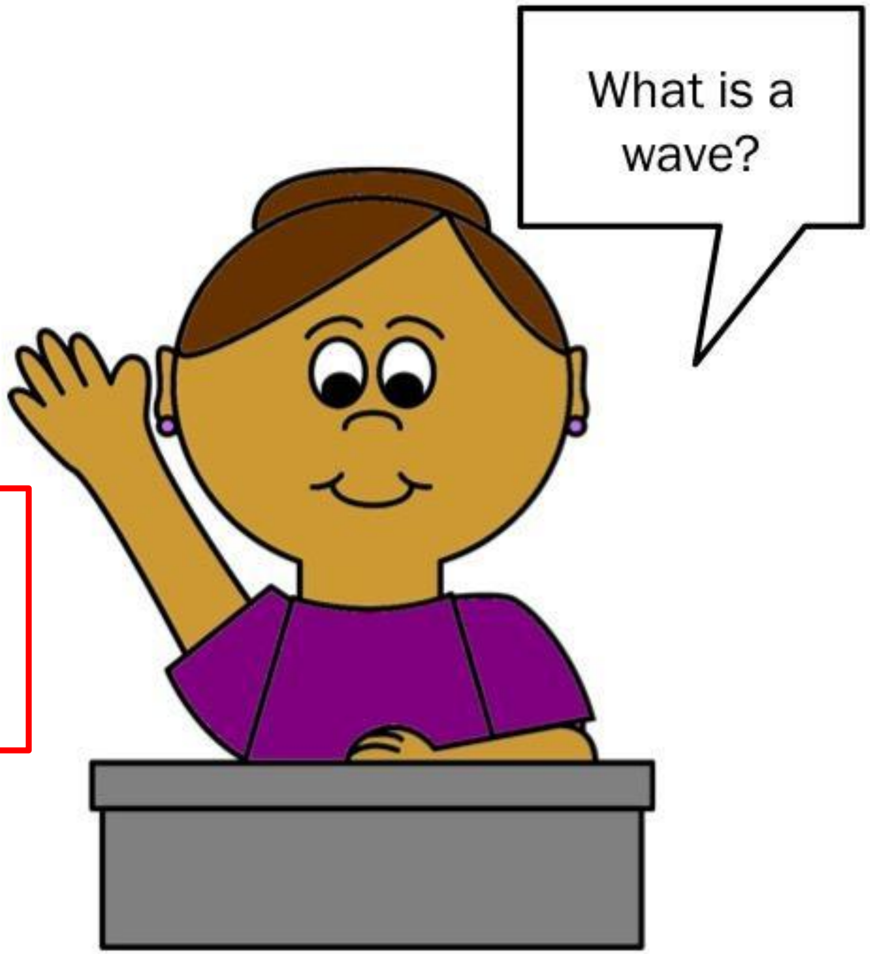
What is a wave?

- Waves are everywhere. In fact, you observe many different kinds of waves everyday.
- You *see* waves that move through matter, such as those that cause water to rise and sink in the ocean.
- You *feel* waves such as those that produce heat and *hear* waves such as those that produce sound.

What is a wave?

- A **wave** is a regular pattern of motion created by a vibratory disturbance.
- A wave can move through matter. Some waves can move through a vacuum (empty space).
- A wave transfers **energy** as it moves from one place to another.

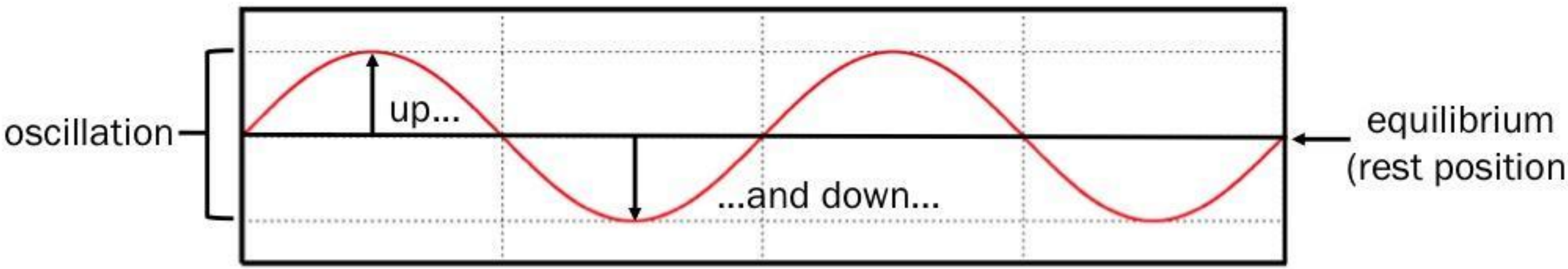


What is a wave?

- You can “see” energy carried by a wave traveling through matter. The movement of a wave is actually movement of energy through the matter.
- *In the picture, dipping a finger in water is a vibratory disturbance. This creates waves that travel through the water. The movement of the waves is actually movement of energy.*

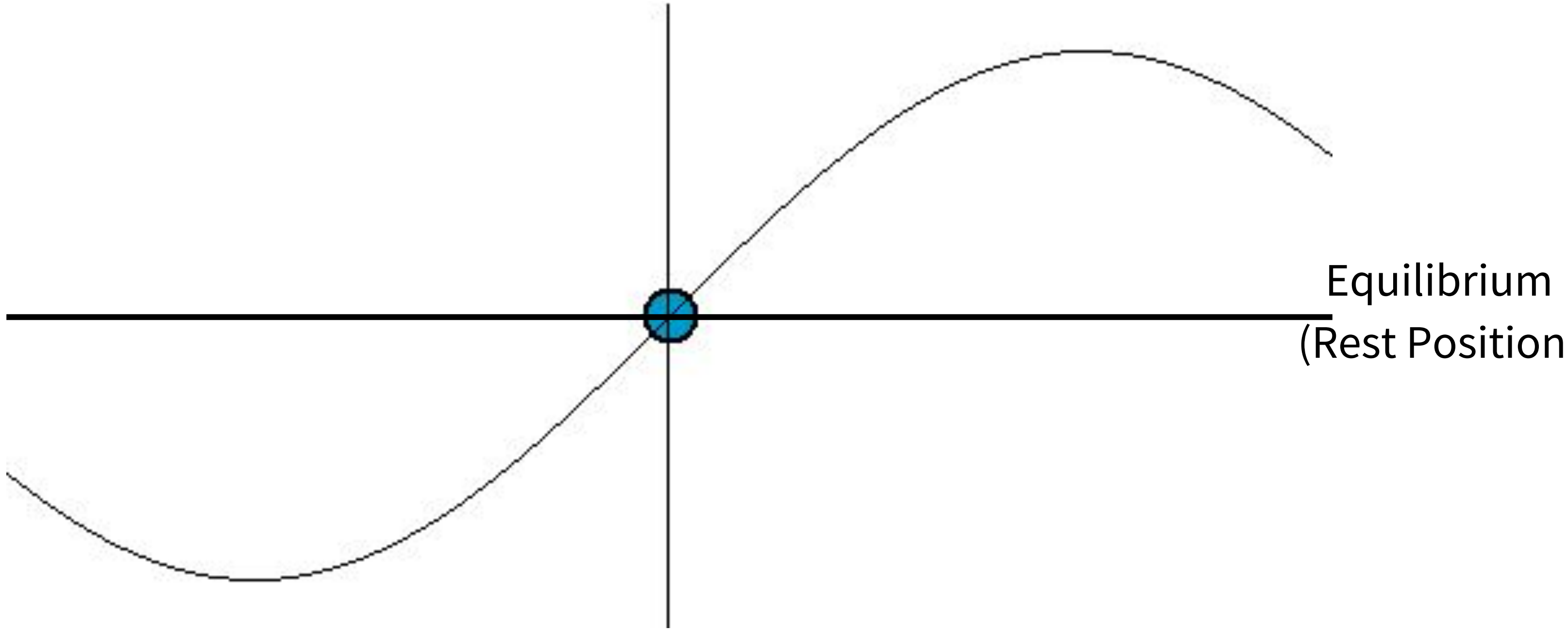
What is a wave?

- Most waves travel through a medium. A medium is a substance (gas, liquid or solid) through which a wave travels.
- When a wave travels through a medium, it causes particles in that substance to oscillate.
- An oscillation is a repeating and regular vibration. It is a “back and forth” motion across a point, called equilibrium. Equilibrium is also known as the rest position.



What is a wave?

- A wave does NOT transfer matter.
- The wave causes particles to move up and down or left and right. However, they always return to their original position once the wave has passed.



TYPES OF WAVES

There are 2 main categories of periodic waves:

1. Electromagnetic Waves
2. Mechanical Waves

ELECTROMAGNETIC WAVES

- These waves carry electromagnetic energy.
- Electromagnetic waves do not require a medium to travel through. Therefore, they can travel through a vacuum.
- Light is a type of electromagnetic wave.

MECHANICAL WAVES

- Mechanical waves are waves produced by a mechanical movement or vibrating object.
- Mechanical waves require a medium (solid, liquid or gas). They cannot travel through a vacuum. (empty space)
- Mechanical waves transfer energy through a series of collisions. Here how:
  1. An initial particle in the medium is disturbed.
  2. The particle collides into other particles in the medium.
  3. These particles then collide into other particles.
  4. The collisions continue so to transfer energy through the medium.
- Sound is a type of mechanical wave.

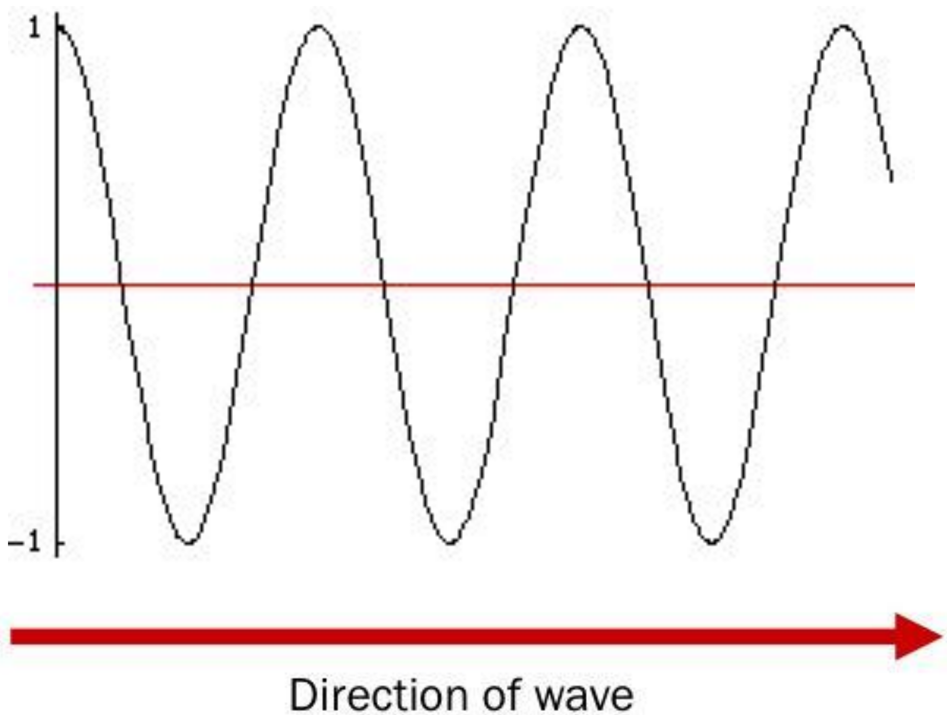
MECHANICAL WAVES

There are two kinds of Mechanical Waves you need to know:

1. Transverse waves
2. Longitudinal waves (Also mentioned in the reading and BrainPop video as Compressional Waves)

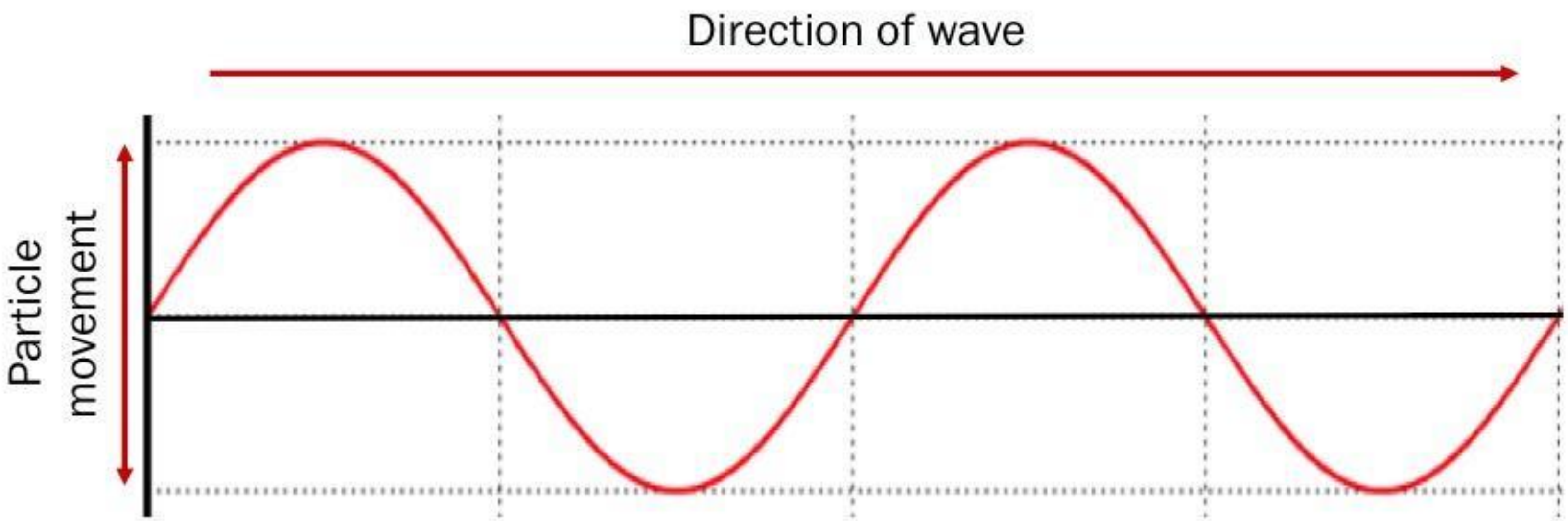
TRANSVERSE WAVES

- In a transverse wave, the particles of the medium move perpendicular to the direction of the movement of the wave.



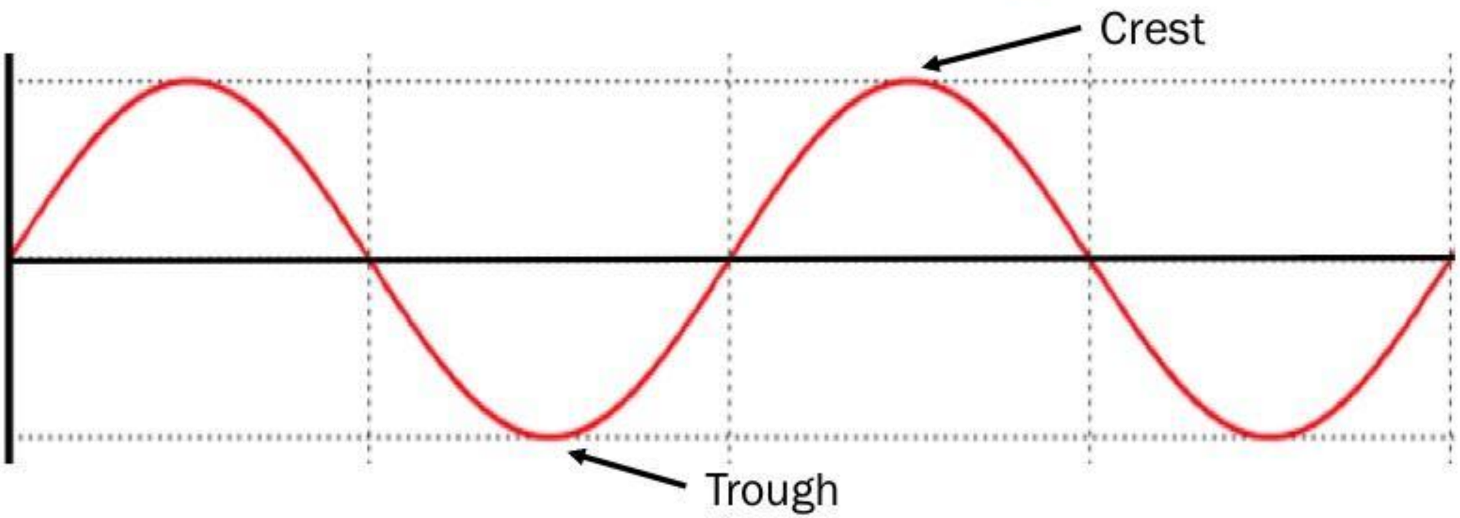
TRANSVERSE WAVES

- As a transverse wave moves across a medium, particles oscillate (moves) in a vertical direction. In other words, as a transverse wave moves forward the particles of the medium move side to side or up and down.



TRANSVERSE WAVES

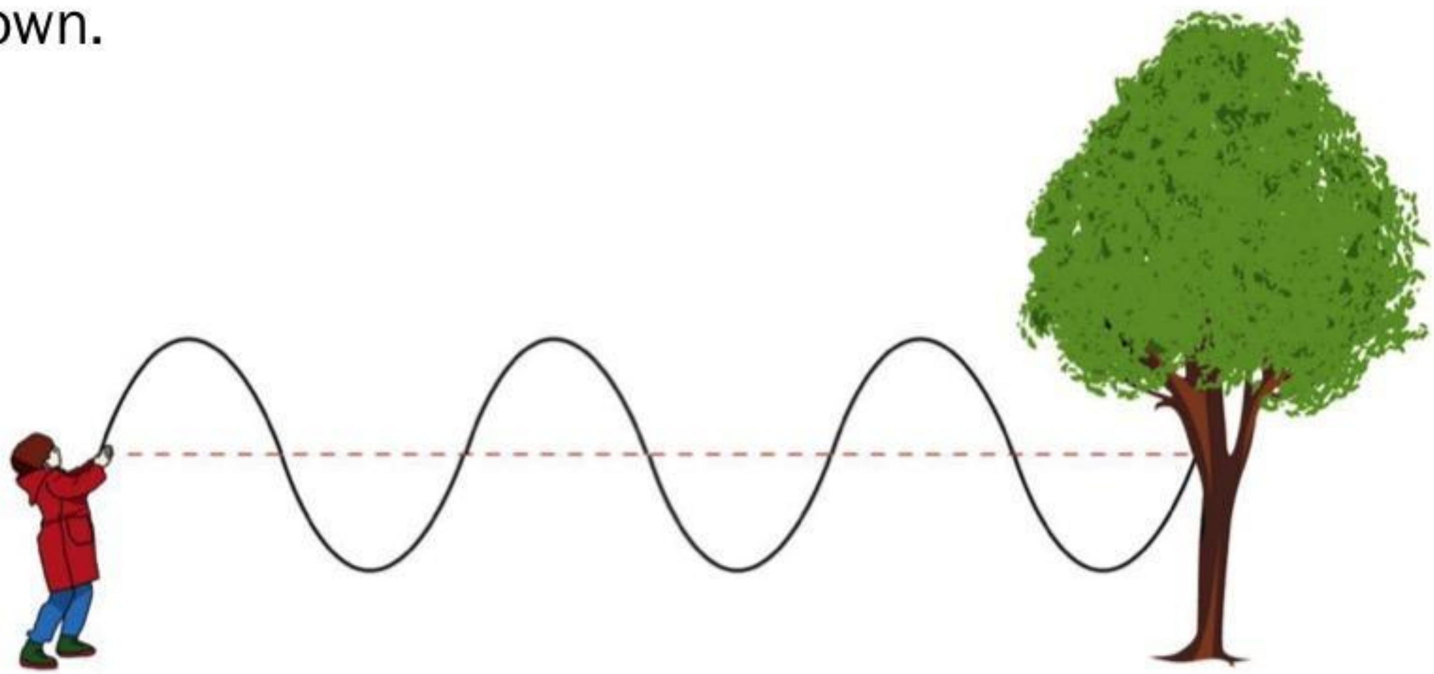
- As a wave moves towards an area in the medium, particles in the medium move upward from their rest position. The maximum upward displacement is called a crest.
- As the disturbance moves away from that area, the particles move downward, past the rest position. The maximum downward displacement is called a trough.



TRANSVERSE WAVES

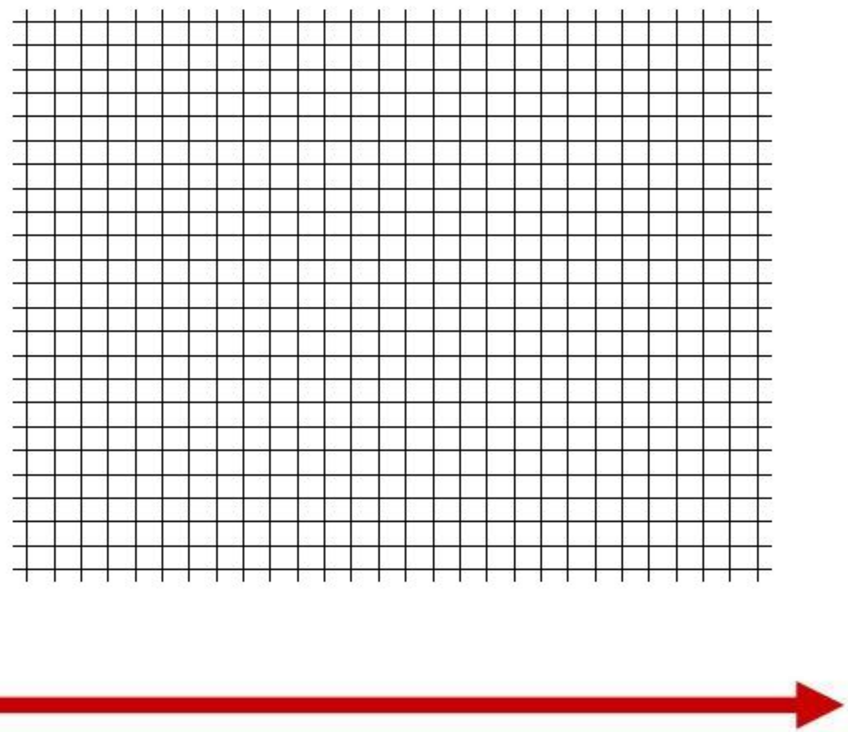
Example: Rope

- When a person disturbs (or shakes) a rope up and down, a transverse wave moves through the rope. The wave moves left or right while the "particles" of the wave move up and down.



LONGITUDINAL WAVES

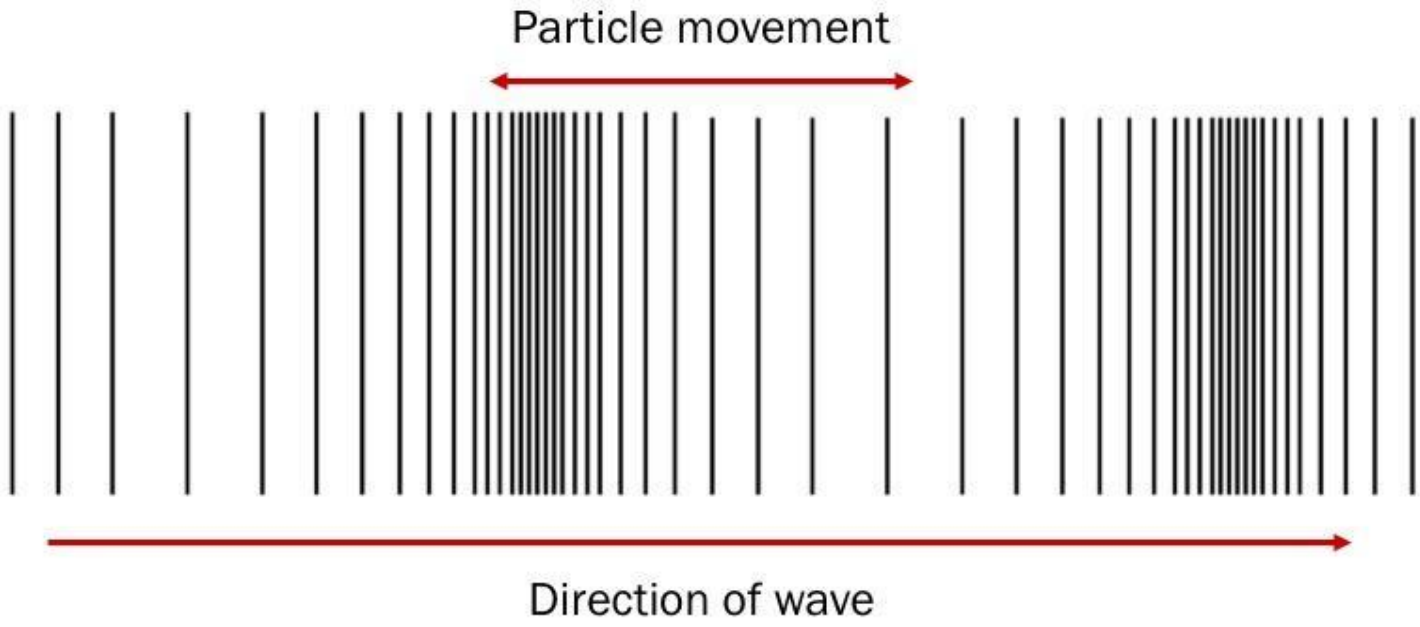
- In a longitudinal wave, the particles of the medium move in the same direction as the movement of the wave.



Direction of wave

LONGITUDINAL WAVES

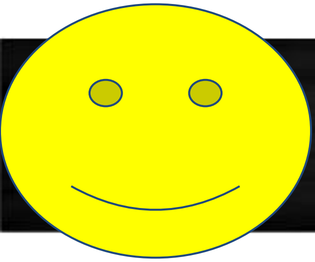
- As a longitudinal wave moves across a medium, particles oscillate parallel to the direction of the wave. This produces areas where particles are compressed or spread out.



LONGITUDINAL WAVES

Example: Slinky

- When a slinky is disturbed, a longitudinal wave moves through it. The wave moves to the left or right, causing areas of the slinky to be compressed and spread out.

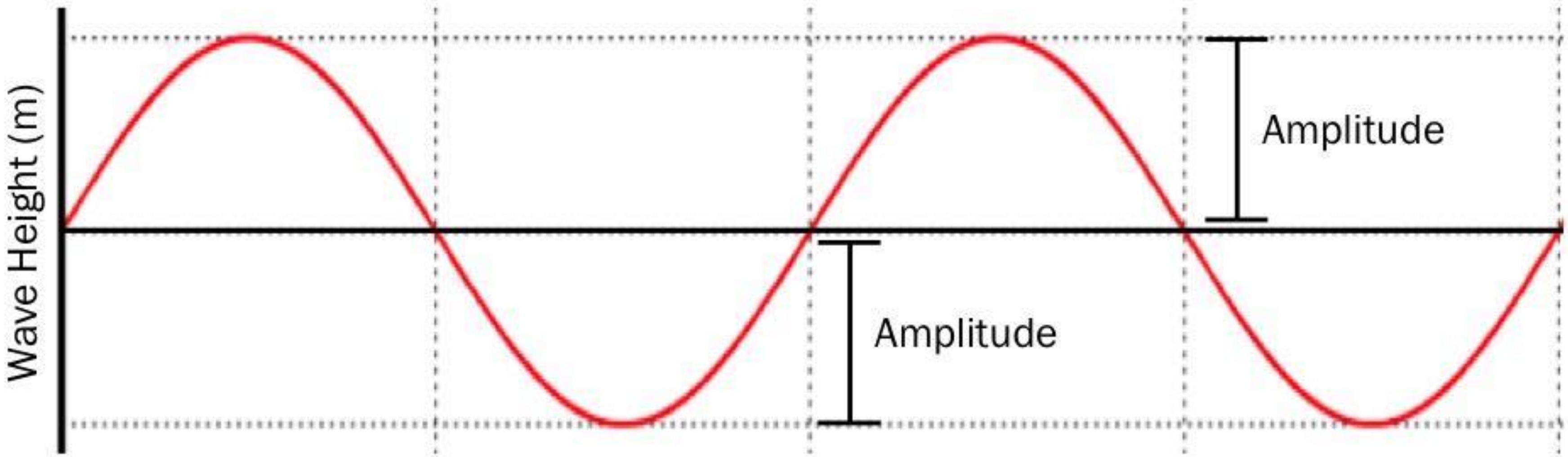


WAVE PROPERTIES

- Waves are characterized by their properties. Some of these properties are:
  - Amplitude
  - Wavelength
  - Frequency

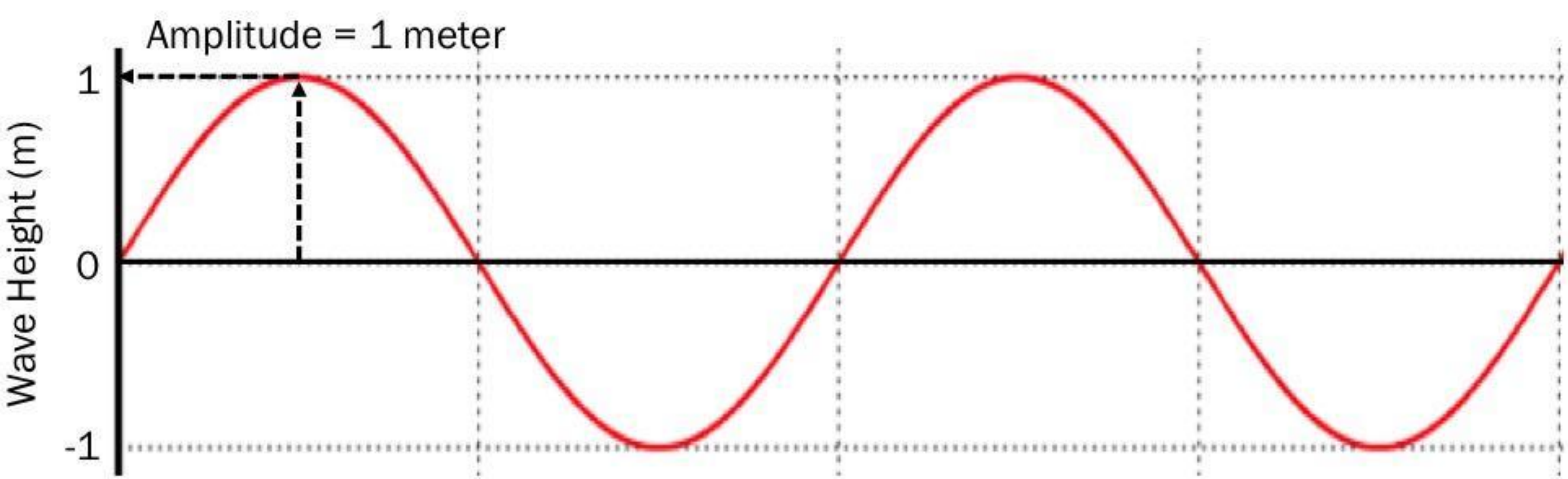
AMPLITUDE

- Amplitude is the height of the wave. It is the maximum displacement of a wave from its rest position or equilibrium.
- Amplitude is usually measured in meters (m).



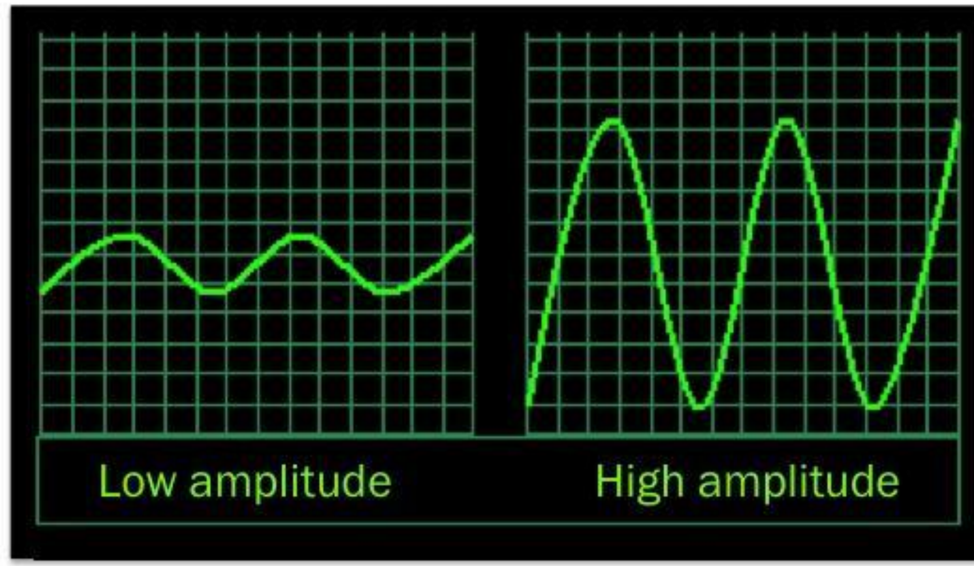
AMPLITUDE

- To determine the amplitude of a wave on a graph, measure the distance from equilibrium to the top of a crest or trough. Do NOT measure the distance from trough *to* crest.



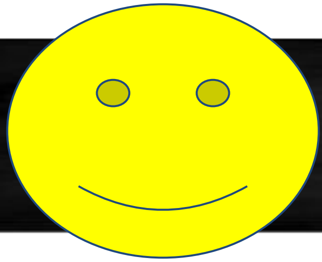
AMPLITUDE

- For mechanical waves, amplitude is related to the energy of the wave. Waves with a higher amplitude carry more energy.
- For sound waves, amplitude corresponds to loudness. The higher the amplitude of a sound wave, the more energy carried by the wave and the louder the noise.



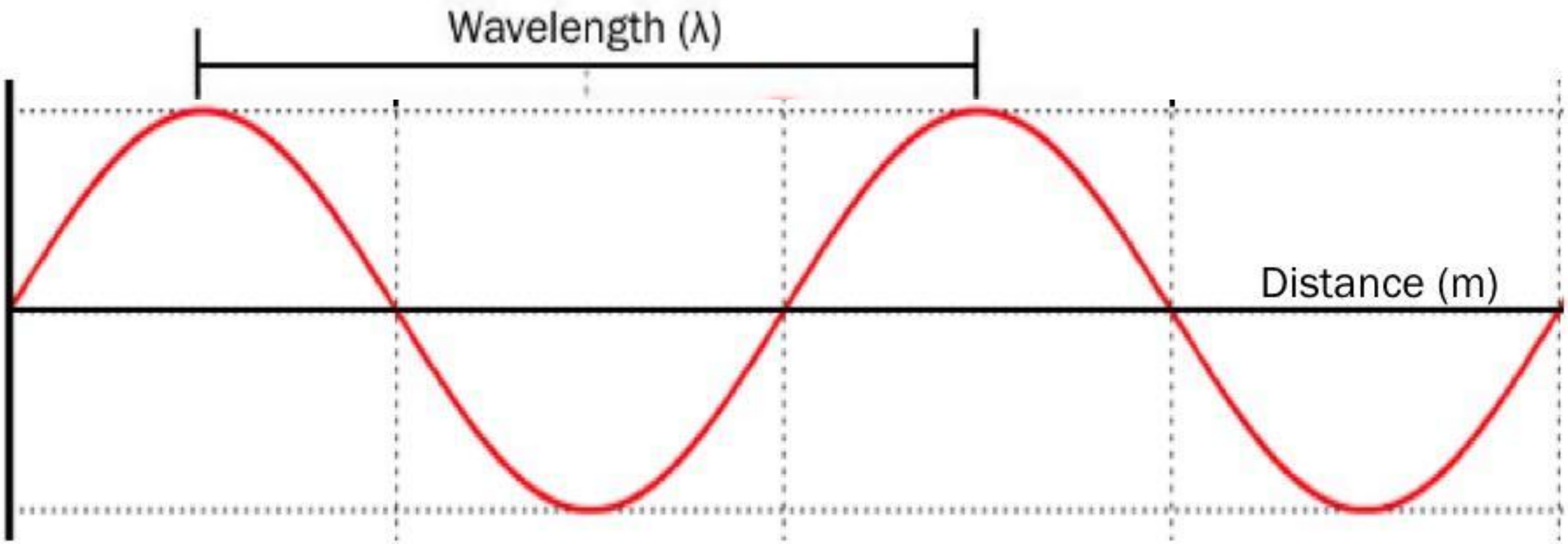
LOW energy

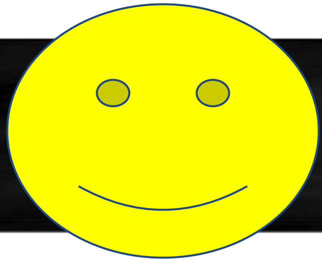
HIGH energy



WAVELENGTH

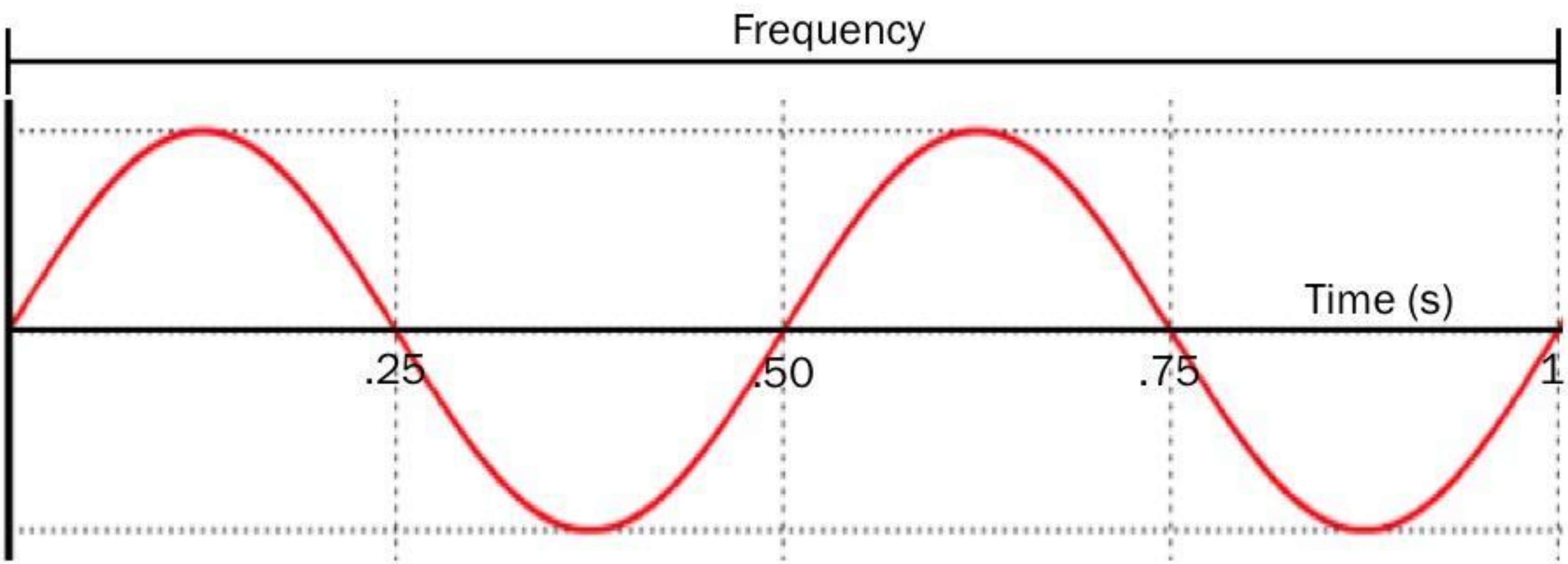
- Wavelength is the length of one complete wave.





FREQUENCY

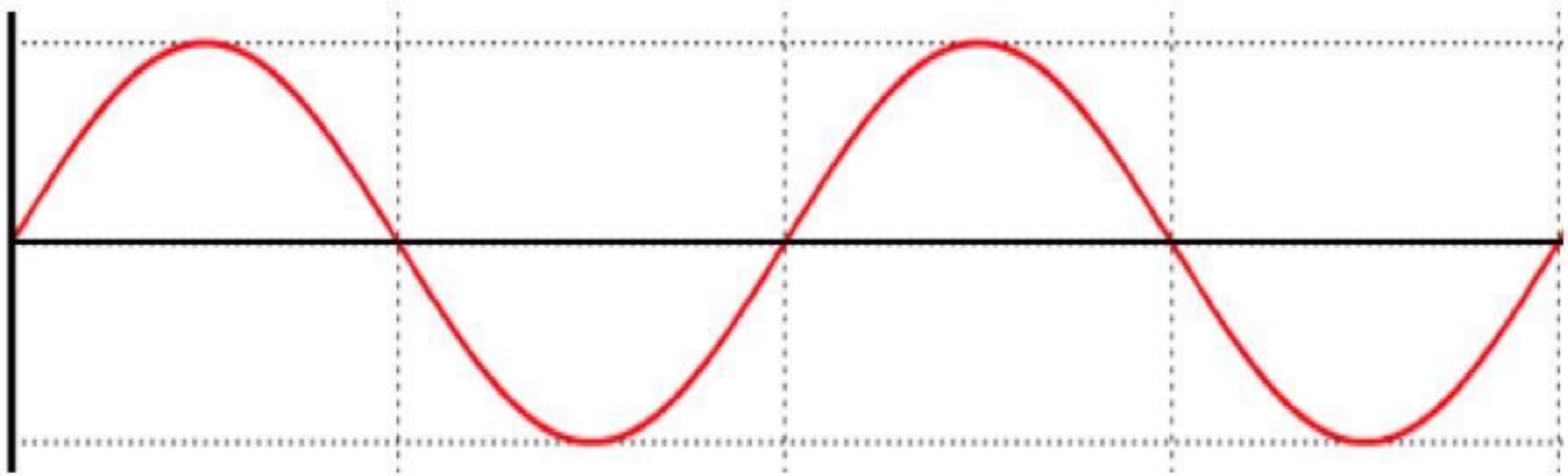
- The frequency of a wave is the number of times a wave cycles in one second.
- Frequency is measured in Hertz (Hz).



GRAPHING WAVES

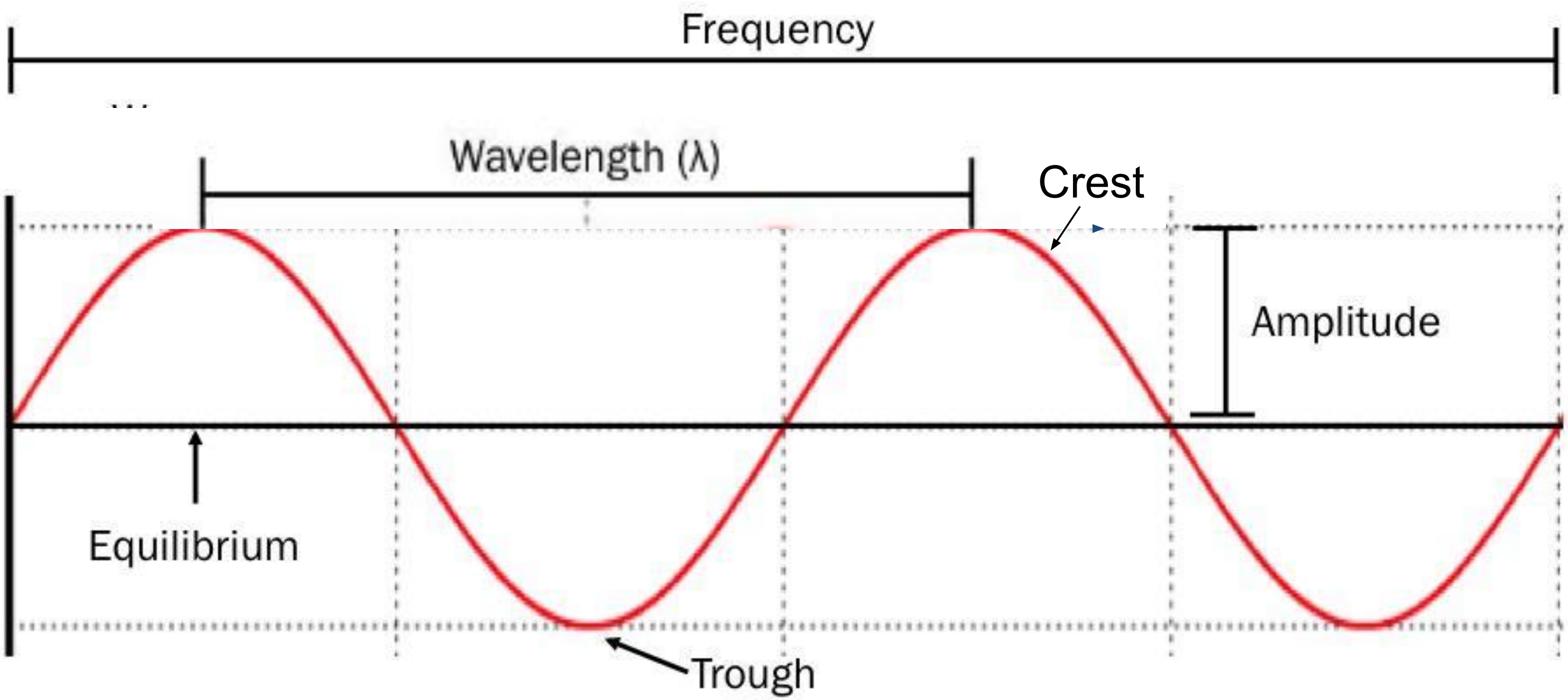
Review: Try to label the following on a graph:

- Crest
- Trough
- Wavelength
- Amplitude
- Equilibrium (rest position)



GRAPHING WAVES

- Label crest, trough, equilibrium, amplitude, frequency, wavelength and period on the graph of the wave below.



SOUND

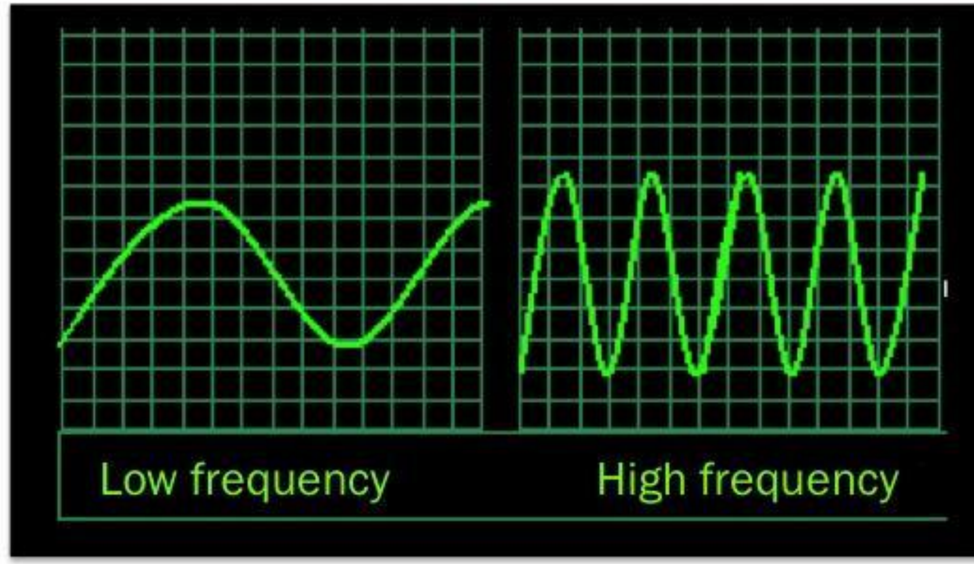
- Sound waves are the most studied mechanical wave. They are produced by mechanical movement.
- Mechanical movement can cause an object to vibrate. A vibrating object causes particles around it, including particles in the air, to vibrate. Vibrating air particles create sound waves that can be heard by humans.
- For example, plucking the strings of a guitar causes the strings to vibrate. This vibration spreads to particles in air, which can be heard by people.

PITCH

- The frequency of a sound wave determines the pitch of the noise.
- Pitch describes the “highness” or “lowness” of sound.
- In music, pitch corresponds to the vertical position of a note on on a musical scale.
- Pitch, like frequency, is measured in Hertz.
- *When studying sound, the term frequency and pitch can be used interchangeably.*

PITCH

- Sound waves with a low frequency oscillate slowly. These waves produce sound with a lower pitch.
- Sound waves with a high frequency oscillate fast. These waves produce sound with a higher pitch.



LOW pitch

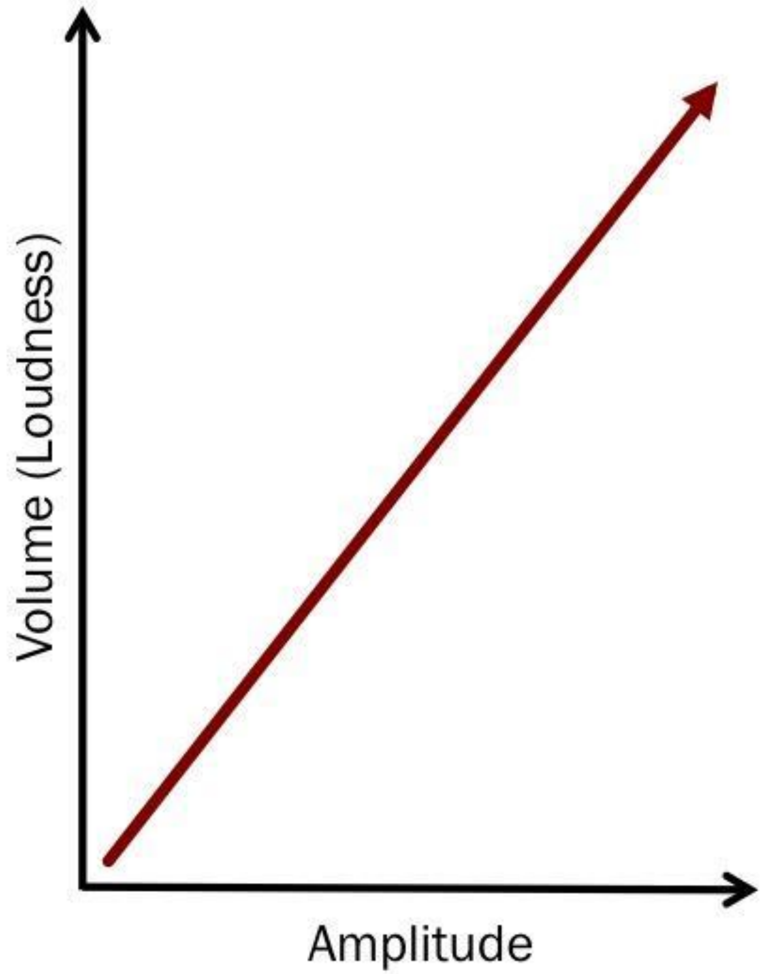
HIGH pitch

PITCH

- A healthy, young person can hear sound with a pitch (or frequency) of 20 to 20,000 Hertz.
- People lose the ability to hear sound with higher pitch as they get older. The highest pitch a middle age adult can hear is 12,000 to 14,000 Hertz.

VOLUME

- The amplitude of a sound wave is directly related to volume.
- As amplitude increases, volume increases. The higher the volume, the louder the sound.

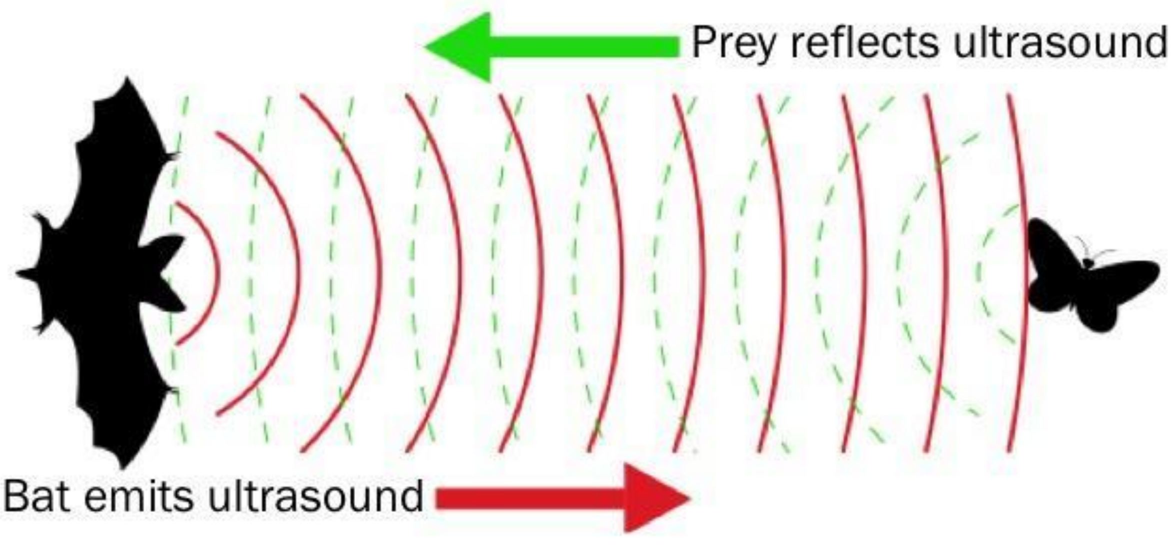


ULTRASOUND

- Sound with a frequency higher than 20,000 Hz is called ultrasound.
- Although humans cannot hear ultrasound, many animals, including bats, toothed whales and dolphins, can hear it.
- Bats use ultrasound to hunt and navigate. This is important to bats because they are nocturnal and cannot rely on vision in the darkness of night.
- Whales and dolphins use ultrasound to hunt and navigate as well. This is important to these marine animals because the ocean is large and it's hard to see in the water.

ULTRASOUND

- The use of ultrasound to navigate or capture food is called echolocation. Here's how echolocation works with bats:
  - A bat emits ultrasound waves.
  - The ultrasound reflects off prey and "echoes" back to the bat.
  - The time it takes for the waves to get back to the bat and the orientation of the waves helps the bat locate the prey.



ULTRASOUND

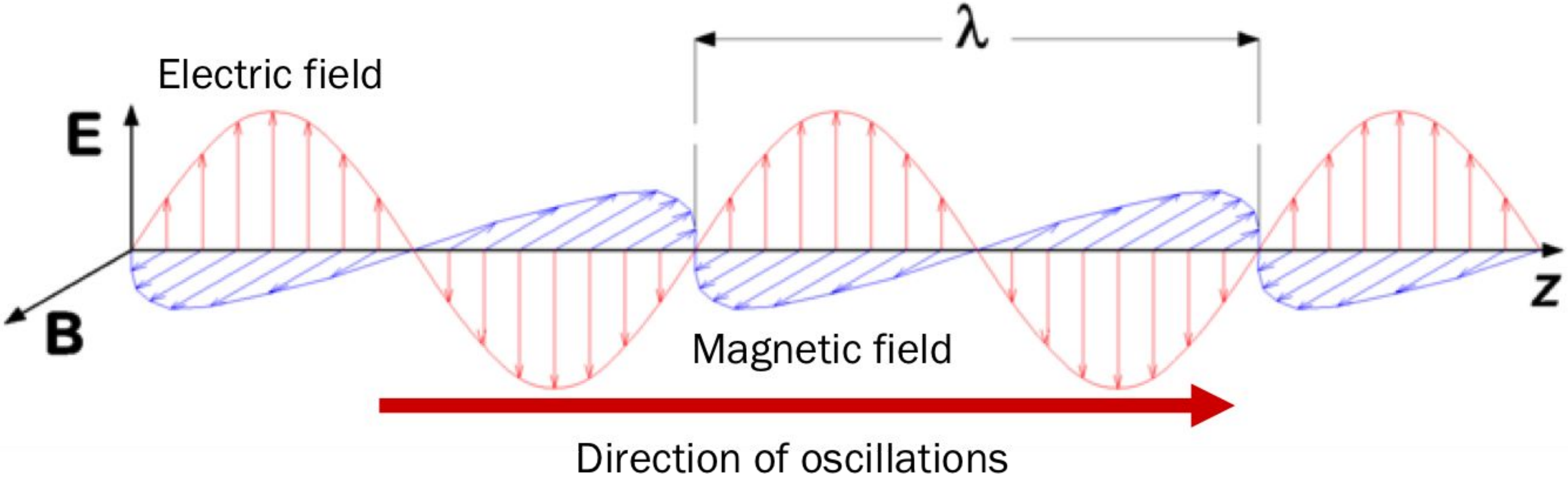
- Humans use ultrasound to produce images of structures inside the body. This is called sonography. Here's how it works:
  - A probe is pressed against the skin. This probe emits ultrasound waves into the body.
  - The ultrasound reflects off different types of tissue in the body.
  - The reflected waves are picked up by the probe. The probe relays information on how the waves reflect to a machine, which produces an image of the structures in the body.

ULTRASOUND

- Sonography is the safest way to produce images of structures inside the body. It does not rely on x-rays or other forms of high-energy radiation.
- For this reason, sonography is the technique most often used to produce images of a baby during pregnancy

WHAT IS LIGHT?

- Light is electromagnetic energy. Electromagnetic energy is carried by electromagnetic waves.
- Electromagnetic (EM) waves are oscillations of electric and magnetic fields. These fields oscillate perpendicular to each other but travel in the same direction.
- Electromagnetic waves are also called light waves.

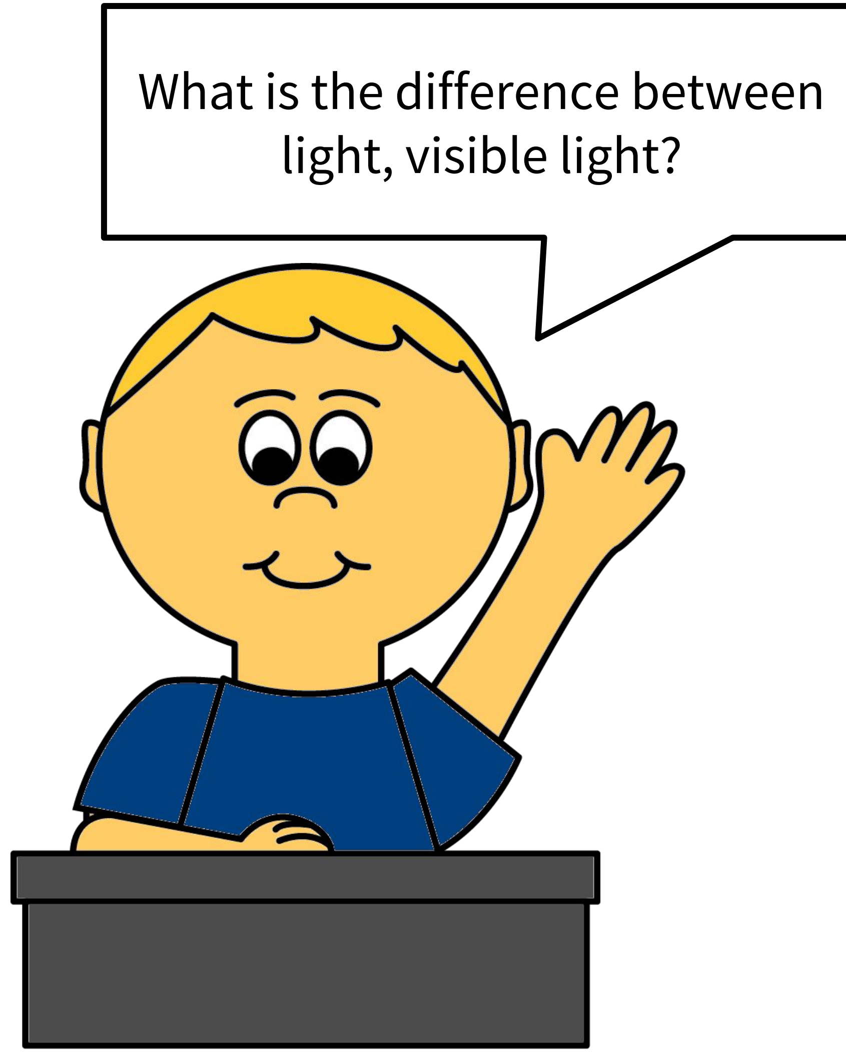


WHAT IS LIGHT?

- An Electromagnetic wave (or light wave) is a transverse wave. It travels at a constant speed and oscillates regularly.
- An EM wave has similar properties to a mechanical wave:
  - amplitude
  - Wavelength
  - frequency

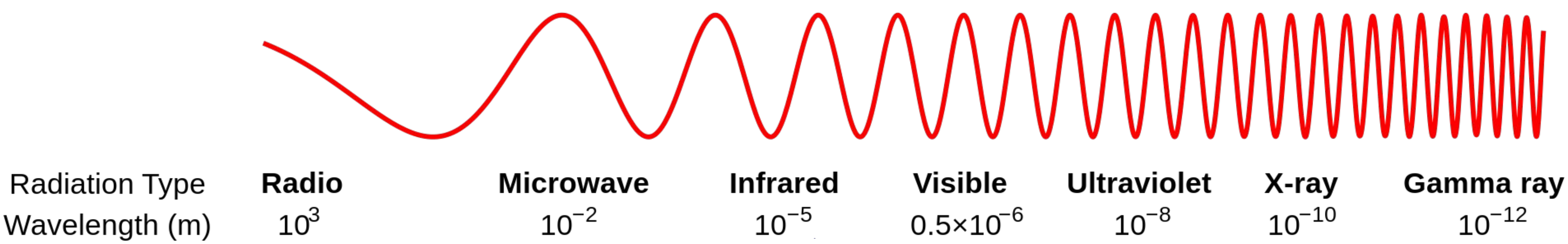
WHAT IS LIGHT?

- What we call light is actually visible light. Visible light is a type of electromagnetic radiation we can see.
- There are *different types* of light. Visible light is the only form of light that we can see.



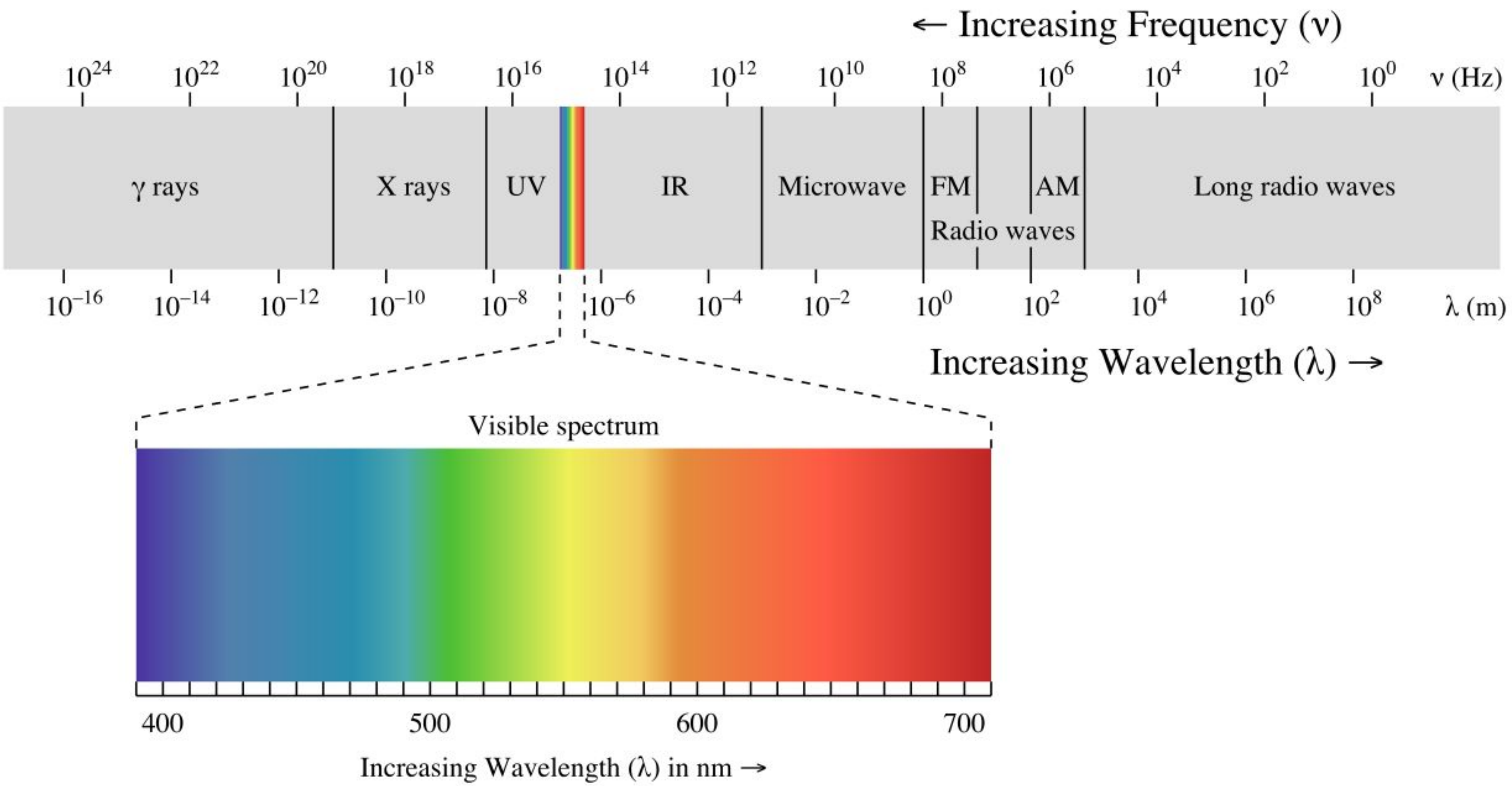
PHOTONS

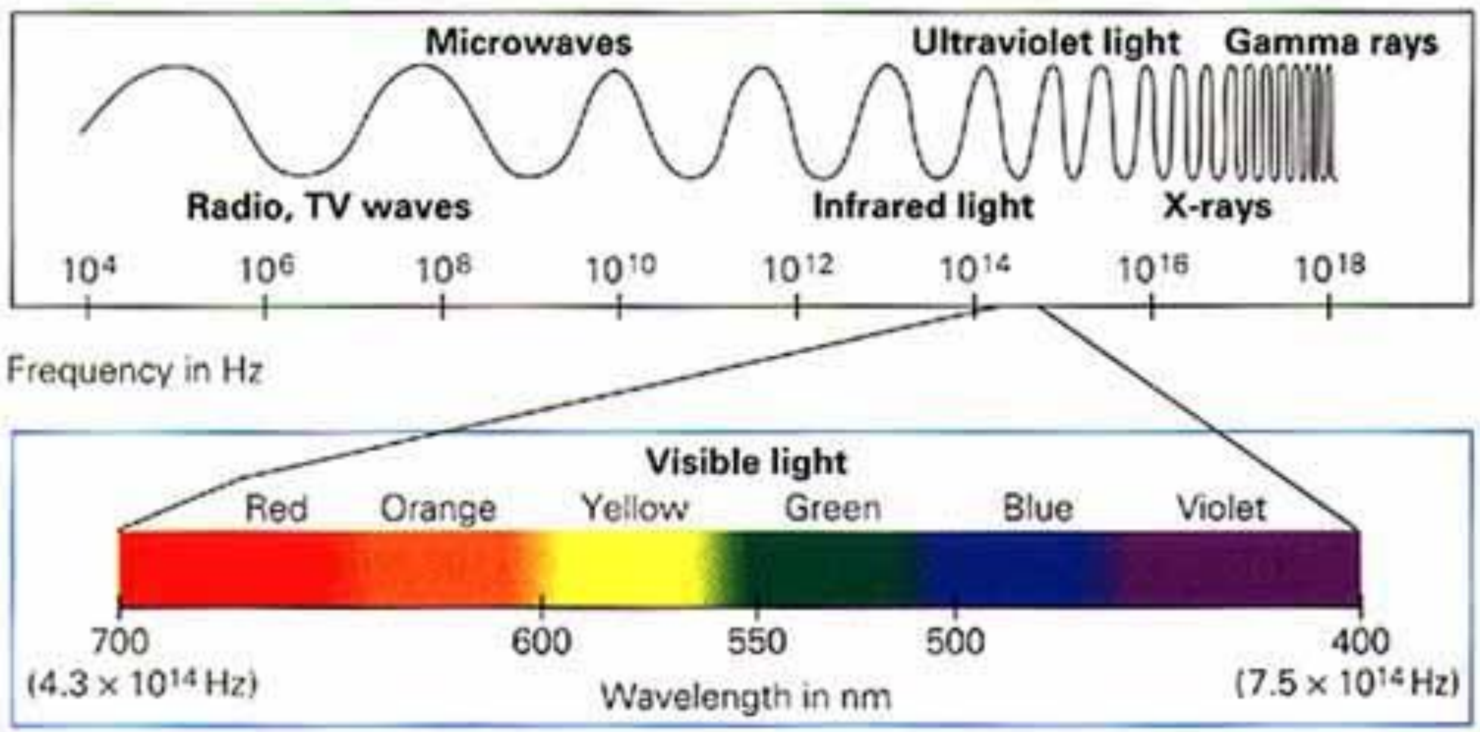
- Photons oscillate at different rates to produce different types of electromagnetic waves.
- The rate at which the photons oscillate determines the frequency and wavelength of each type of EM wave.



EM WAVES

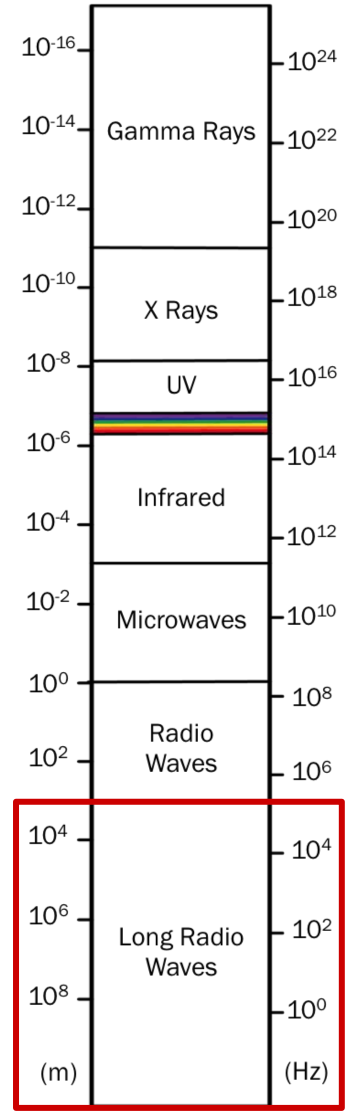
- The different types of electromagnetic waves make up the electromagnetic spectrum.




Microwaves
Ultraviolet light
Gamma rays
Radio, TV waves
Infrared light
X-rays
10^4
10^6
10^8
10^{10}
10^{12}
10^{14}
10^{16}
10^{18}
Frequency in Hz
Visible light
Red
Orange
Yellow
Green
Blue
Violet
700
(4.3×10^{14} Hz)
600
550
500
400
(7.5×10^{14} Hz)
Wavelength in nm

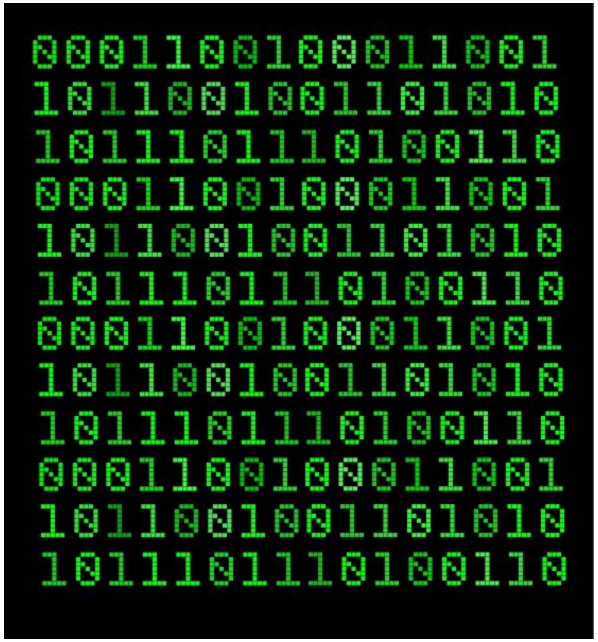
LONG RADIO WAVES

- Long radio waves are EM waves with the longest wavelength and lowest frequency. In fact, the wavelength of the longest long radio waves are nearly three football fields long (1,000 m).
- Long radio waves are also called longwaves.
- Long radio waves are important to marine and aeronautical navigation.



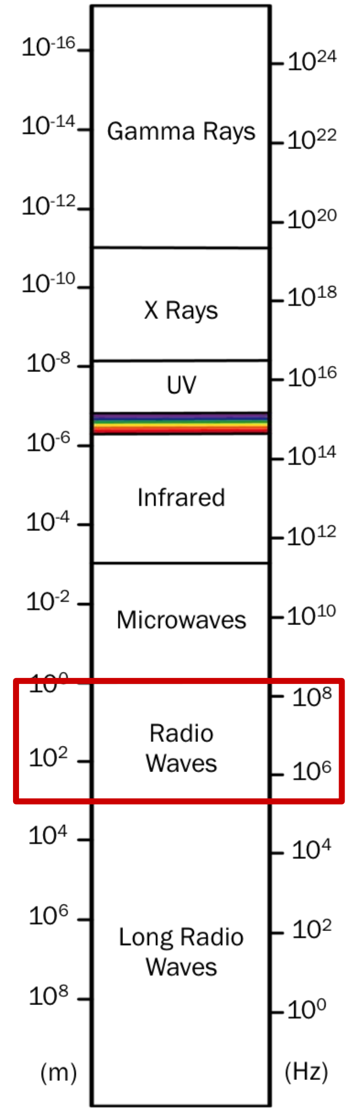
LONG RADIO WAVES

- Today, communication relies most on the transmission of digital information.
- Text, visual and voice information can be digitalized or coded into numbers. We call this number-coded information digital information.
- Digital information is coded into patterns of 1s and 0s instead of dots and dashes. This information can be stored or transmitted, received and decoded.
- Digital information can be transmitted wirelessly via radio waves, microwaves or infrared.



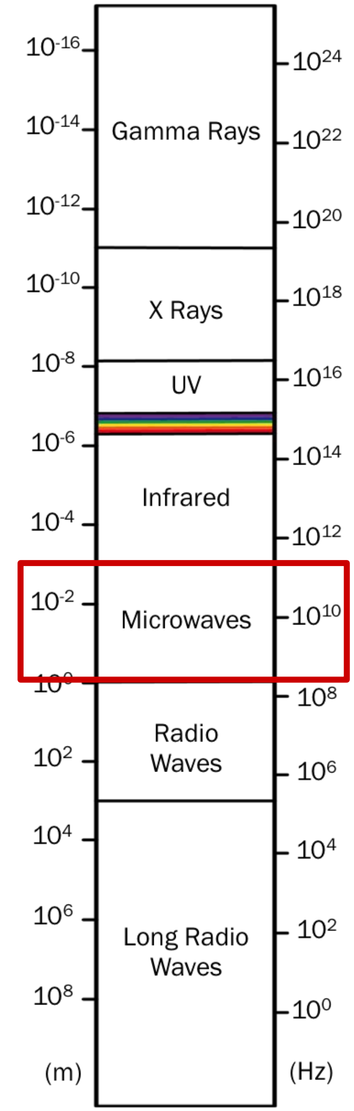
RADIO WAVES

- Radio waves are EM waves with the second longest wavelength and lowest frequency.
- Radio waves are naturally made by lightning and stars.
- Radio waves are artificially made and used for radio communication, TV broadcasting and radar.
- When listening to the radio, the numerical AM or FM radio station corresponds to the frequency of a specific radio waves.



MICROWAVES

- Microwaves are used for communication. Specifically, they are important to Bluetooth, WiFi and cellphone (mobile) networks.
- Microwaves are also used for navigation and radar. Specifically, they are important to GPS, air traffic control, weather forecasting and speed limit enforcement.

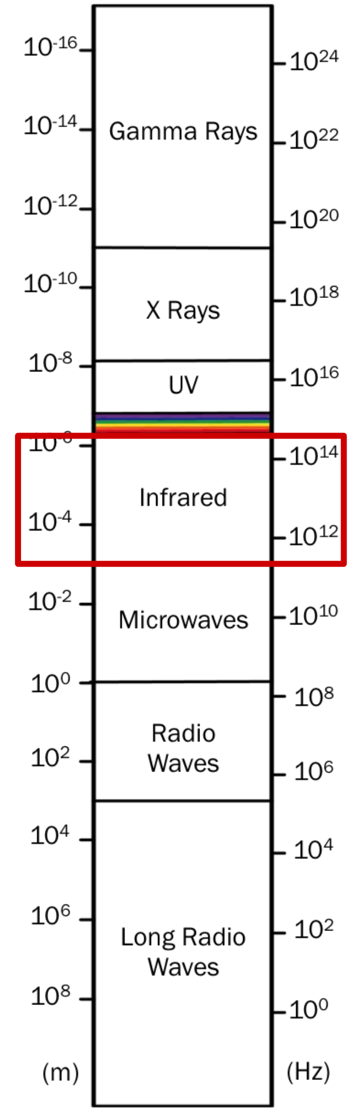


MICROWAVES

- Microwaves are also used for heating food.
- A microwave oven is an appliance that generates intense microwaves. These waves carry energy. The energy of the microwaves is absorbed by the food. When the food absorbs energy, its temperature rises and the food is cooked.
- A microwave oven is constructed of metal and thick glass to keep the microwaves inside the microwave oven.

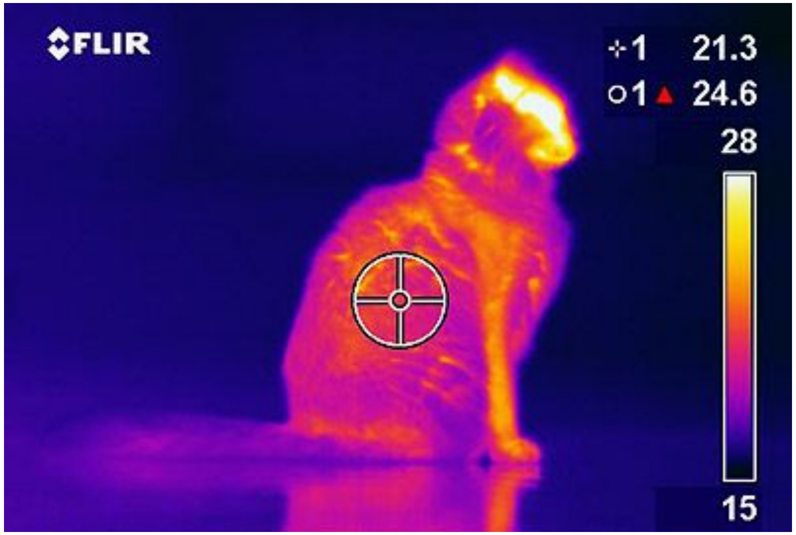
INFRARED

- Infrared is associated with thermal energy. Objects that emit thermal energy (heat) are giving off infrared radiation.
- Although you cannot see or hear infrared, *you can feel it.*



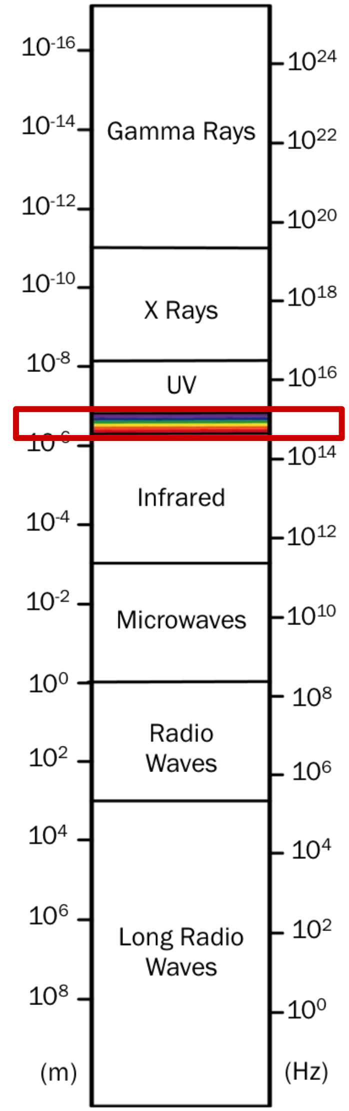
INFRARED

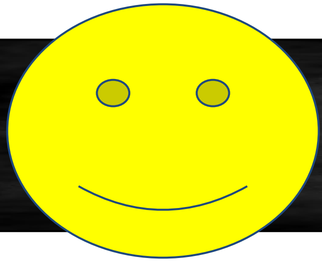
- There are special devices that can visualize infrared. These devices are called infrared cameras.
- Infrared cameras produce images based on the amount of infrared emitted by an object. These cameras are especially helpful in producing images of living things. Living things emit thermal energy and thus, infrared.



VISIBLE LIGHT

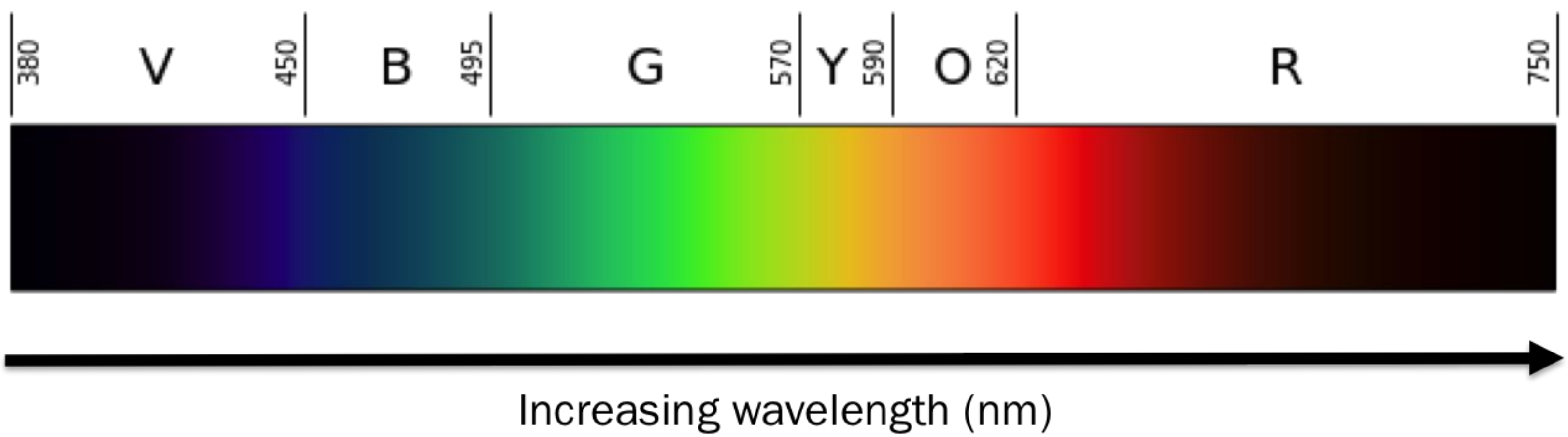
- Visible light is electromagnetic radiation that we can see.



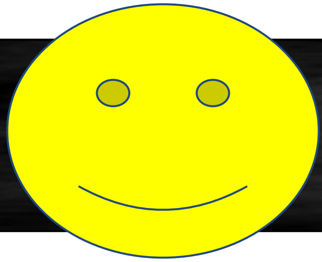


VISIBLE LIGHT

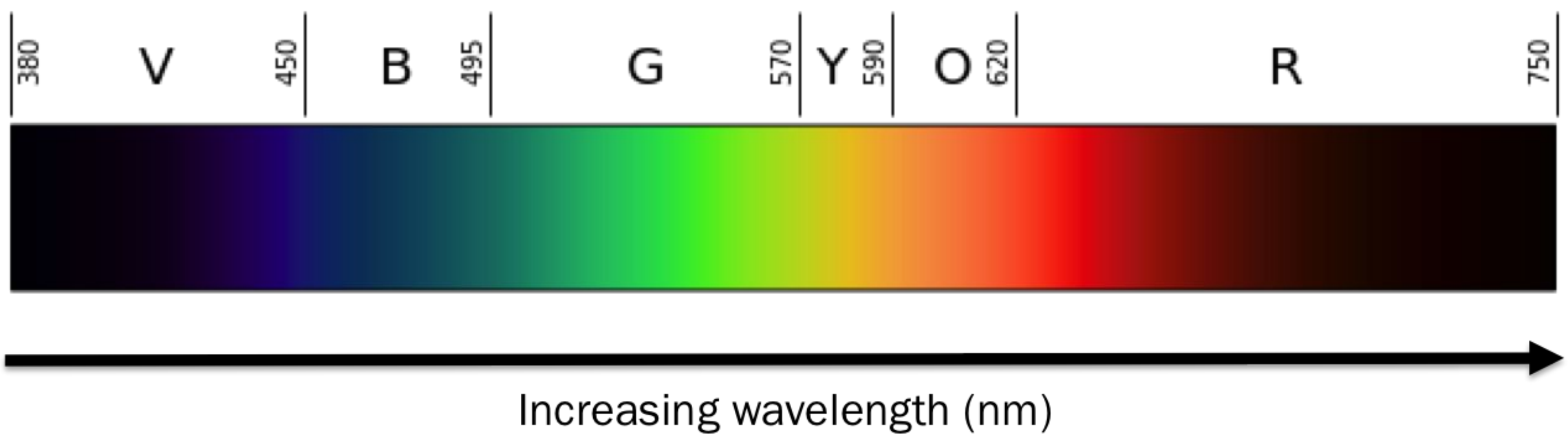
- White light is a combination of all the colors of visible light.
- There are 7 colors of visible light. These colors are red, orange, yellow, green, blue, indigo and violet.
- Each color of light has a specific wavelength and frequency. Red has the longest wavelength/lowest frequency. Violet has the shortest wavelength/highest frequency.



VISIBLE LIGHT

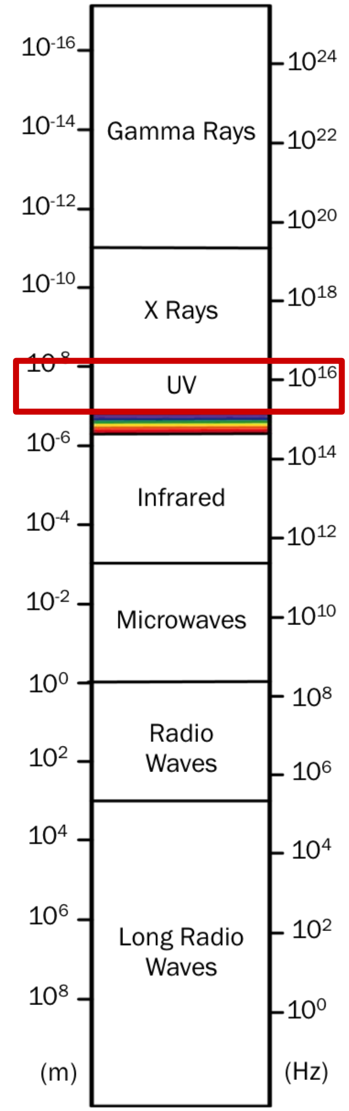


- White light is a combination of all the colors of visible light.
- A light wave's amplitude effects its brightness.
- ex. you are increasing the amplitude of the light waves when you turn the brightness up and decreasing its amplitude when you dim your screen.



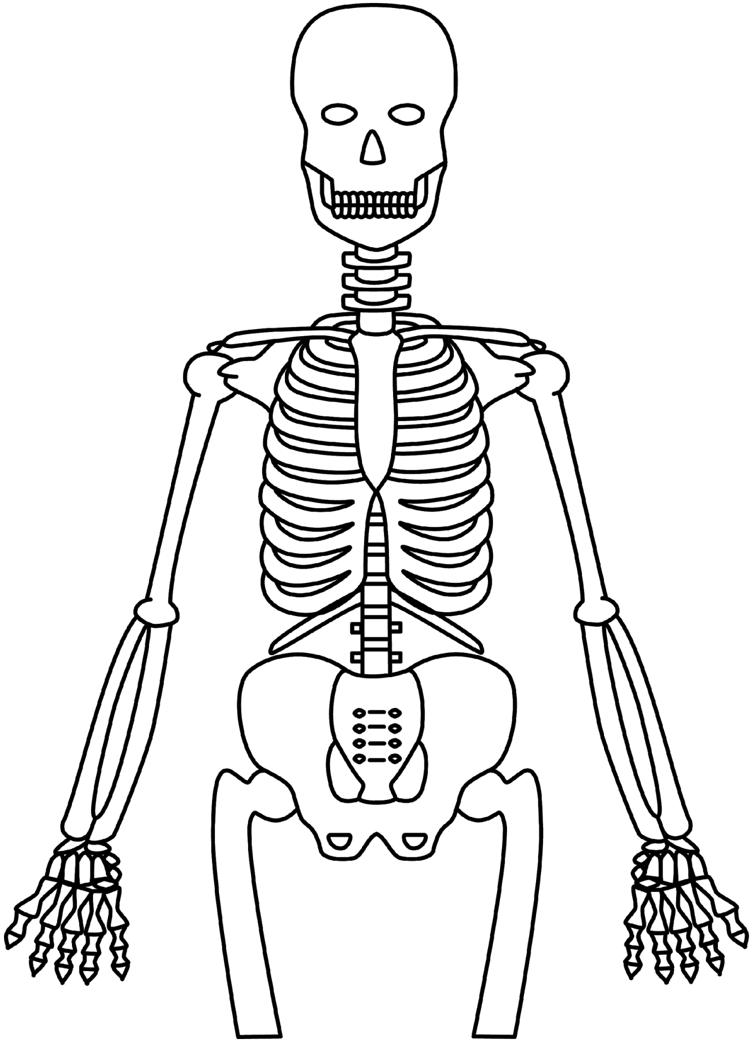
ULTRAVIOLET

- UV light is invisible to humans, but can be seen by some insects and birds.
- UV light has both beneficial and harmful effects on living things.



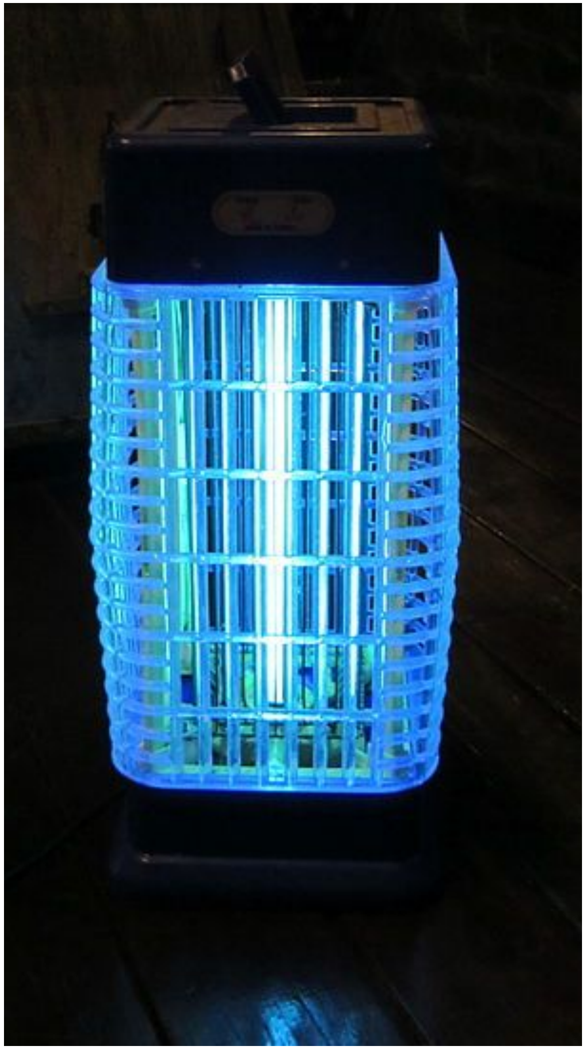
ULTRAVIOLET

- Ultraviolet light is beneficial to living things, including humans.
- Exposure to UV light promotes production of Vitamin D in your skin. Vitamin D helps your body absorb other vitamins and minerals, including calcium and iron. Calcium is important to your bones and iron is important to your blood.



ULTRAVIOLET

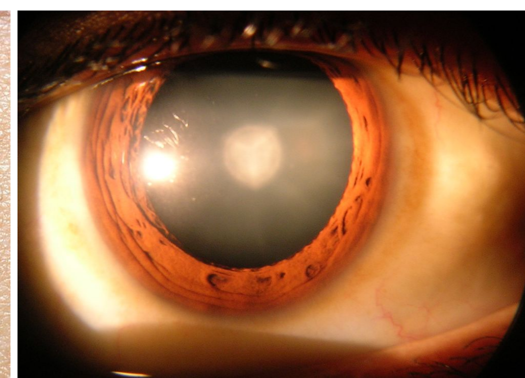
- Insects use UV light to help navigate. They use UV light emitted by the sun to help orient themselves.
- Bug Zappers manipulate an insects attraction to UV light.
- A Bug Zapper contains a black light. A black light is a lamp that emits ultraviolet light. Insects are attracted to ultraviolet light of the lamp and then electrocuted by the device.



ULTRAVIOLET

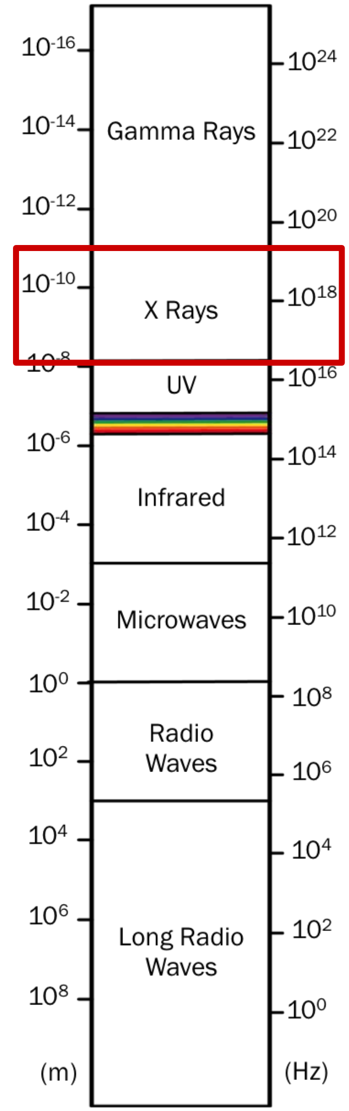
- Ultraviolet also has detrimental effects as well.
- Overexposure to UV light damages skin. It causes sunburns, premature aging and increases the risk of skin cancer.
- UV light also damages the eyes. Too much exposure to UV light can cause cataracts. A cataract is clouding of an eye lens.





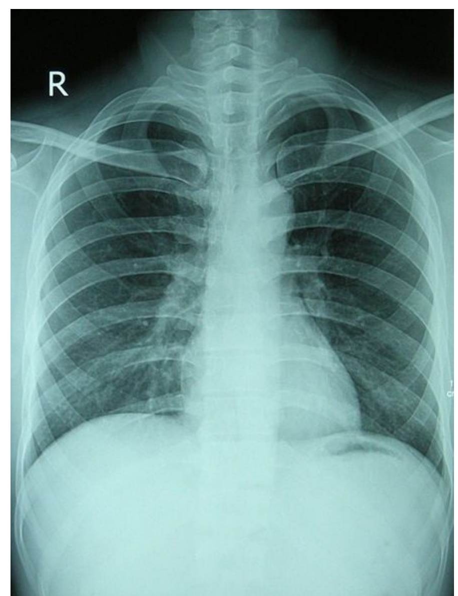
X-RAYS

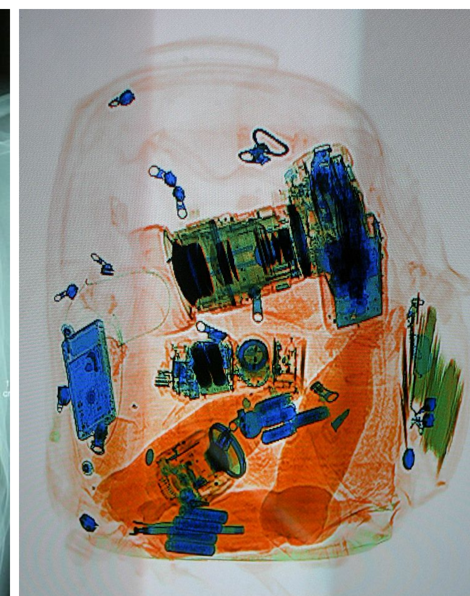
- X-Rays are high-energy electromagnetic waves. These waves have the second highest frequency of all EM waves.



X-RAYS

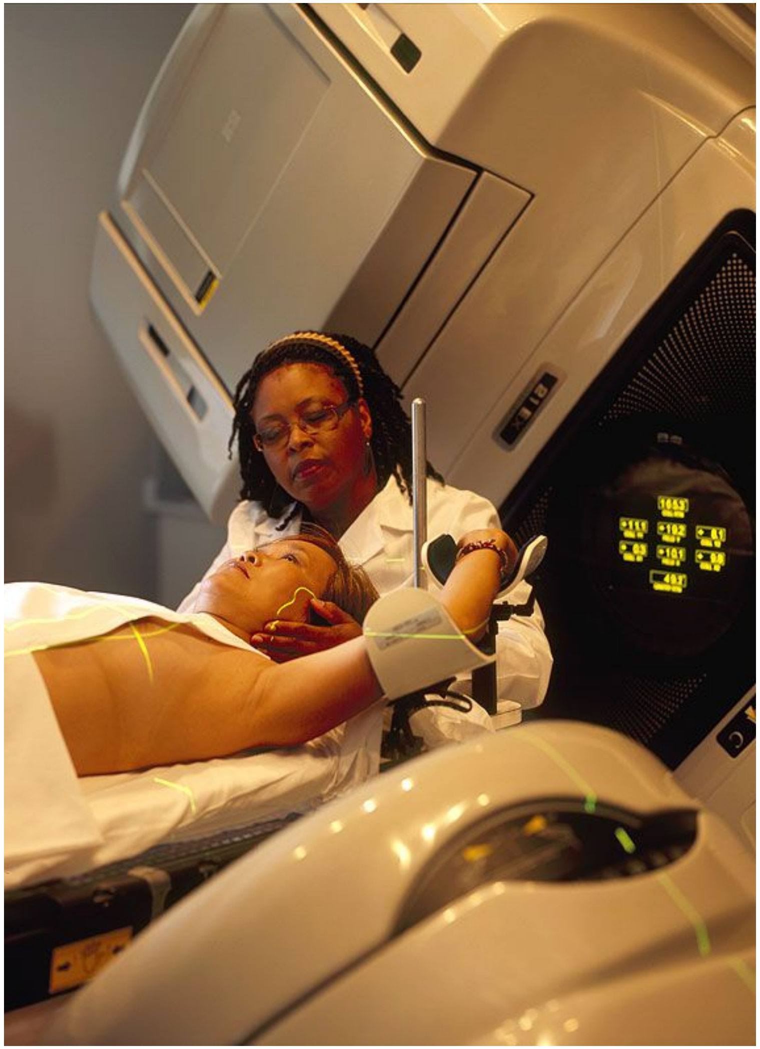
- X-Rays are used to produce images that show what is inside an object or living thing.
- X-Rays are used in medical imaging (radiology) to see the internal structures of a person. This helps doctors diagnose diseases and anatomy abnormalities.
- X-Rays are also used in airport security. They help security agents observe what is inside luggage.





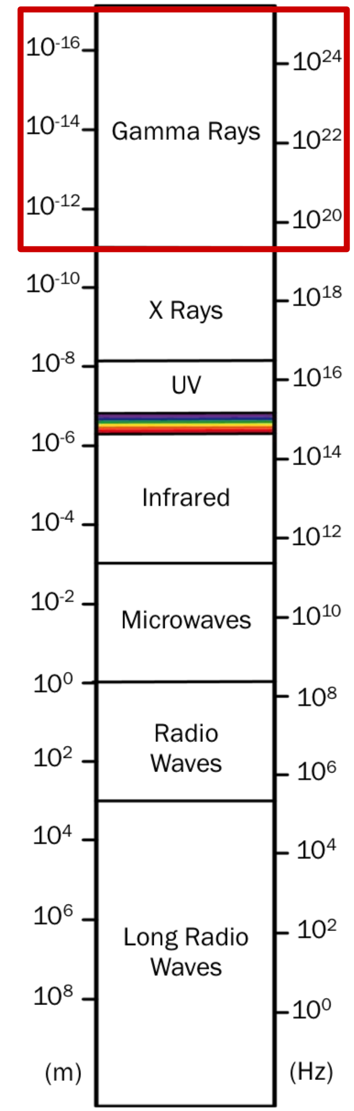
X-RAYS

- Overexposure to x-rays can damage cells and cause them to become abnormal or cancerous. Interestingly, x-rays can be used to damage cells *intentionally*.
- Radiation therapy is treatment that uses x-rays or gamma rays to cure cancer. Here's how it works:
  - Doctors determine where the cancer is in the body.
  - A focused, high dose of radiation is beamed to where the cancer is in the body.
  - The radiation kills the cancer cells.



GAMMA RAYS

- Gamma rays are produced by radioactive substances undergoing radioactive decay.
- Gamma rays are also produced during fission (the splitting of atoms).

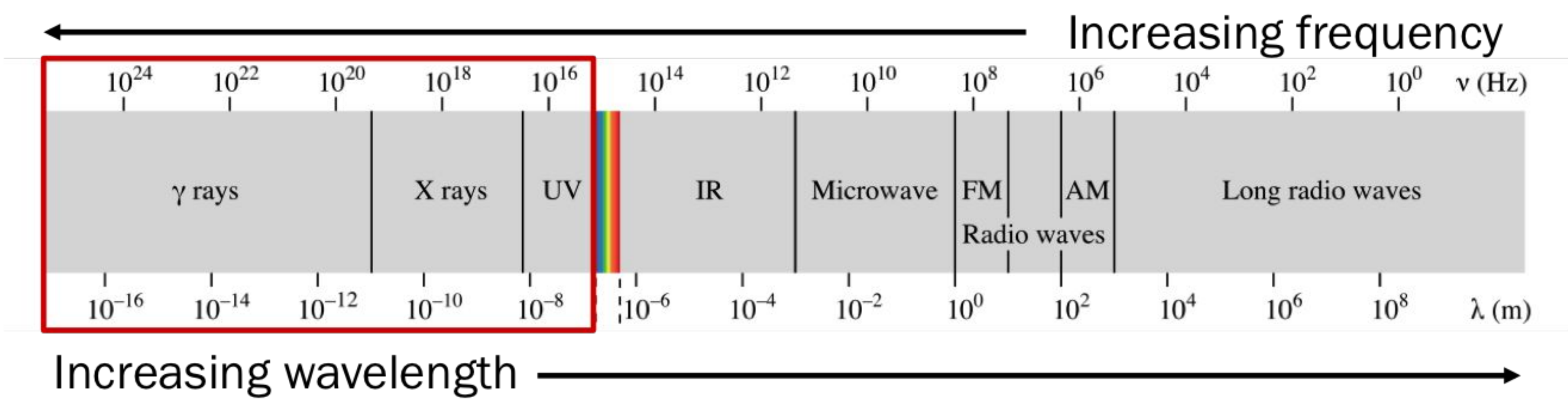


GAMMA RAYS

- Like x-rays, gamma rays damage and kill cells.
- Gamma rays are considered more dangerous because they are more damaging and more penetrating.
- Exposure to gamma radiation can cause radiation poisoning. The greater the exposure to gamma radiation, the more severe the radiation poisoning.
- Radiation poisoning can cause death in weeks (4-6 weeks in moderate cases) or days (1-2 days in severe cases).

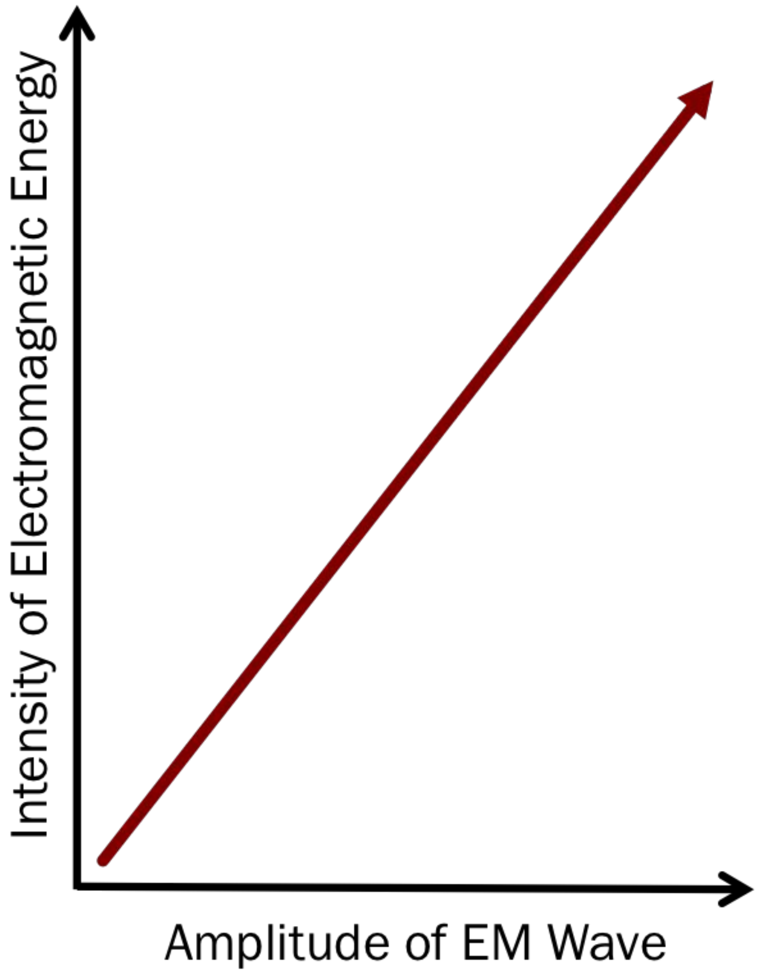
Electromagnetic ENERGY

- *As you've just learned, the electromagnetic energy (also called radiation) carried by electromagnetic waves can be harmful and even deadly.*
- The radiation of ultraviolet light, x-rays and gamma rays is most harmful. These electromagnetic waves have the highest frequency and thus, the most energy.



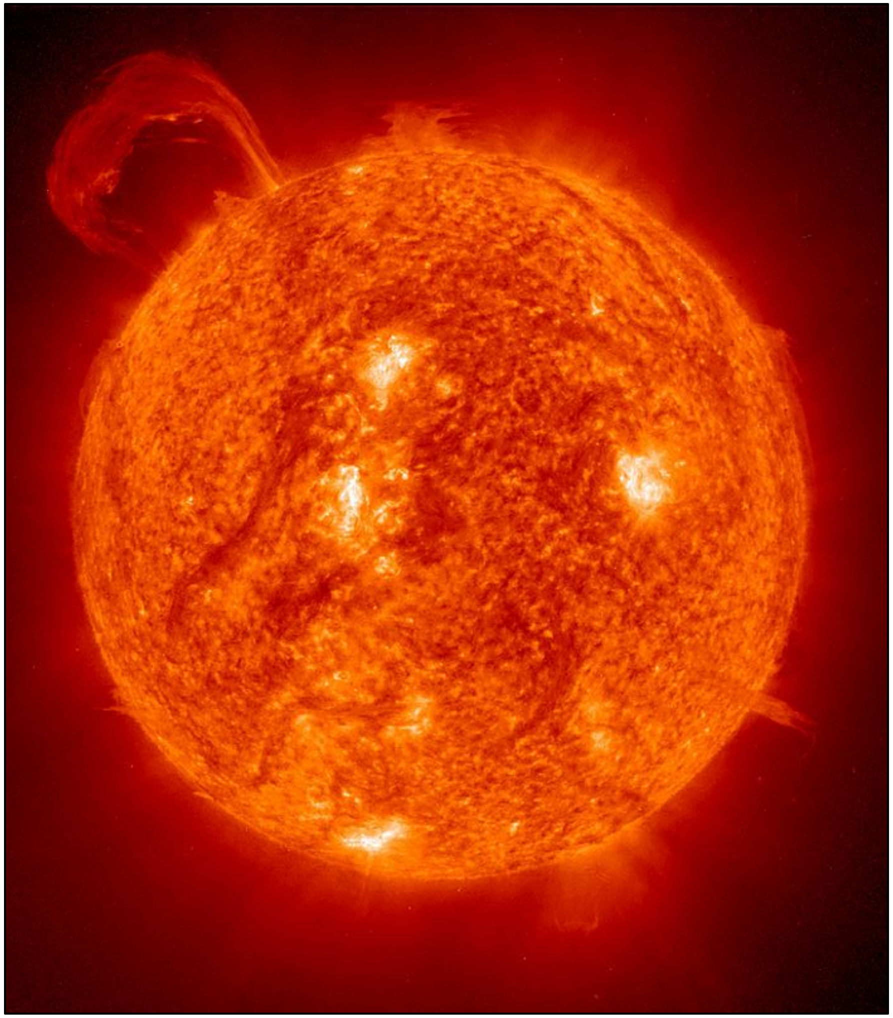
Electromagnetic ENERGY

- The amplitude of a electromagnetic wave determines the *intensity* of the electromagnetic energy.
- For example, a higher amplitude of visible light will give you a brighter, more intense light. A lower amplitude of visible light will give you a dim, less intense light.



EM WAVES & THE SUN

- The Sun emits electromagnetic radiation. This electromagnetic radiation is extremely important to life on Earth. In fact, life on Earth would not exist without the Sun!



EM WAVES & THE SUN

Three types of electromagnetic radiation emitted by the sun are important to life on Earth:

1. **Infrared**. Infrared warms Earth. If the sun did not provide infrared, Earth would be a very cold place.
2. **Visible Light**. Visible light provides the light we need to see on Earth. Without visible light, Earth would be a very dark place.
3. **Ultraviolet.** UV light helps you make Vitamin D and helps some insects and birds navigate. Remember… UV light also has harmful effects.

SPEED OF LIGHT

- Light travels at the fastest known speed in the universe. NOTHING moves faster than the speed of light!
- Light travels at a speed of 3.0×10^8 m/s in a vacuum.
- *The specific speed is exactly 299,792,458 m/s. We round to 300,000,000 m/s or 3.0×10^8 in scientific notation.*
- Light travels slightly slower when traveling through matter (solid, liquid or gas).
  - The speed of light **insignificantly** changes when traveling through air. Therefore, we say the speed of light in dry air is 3.0×10^8 m/s.
  - The speed of light in water is 2.25×10^8 m/s.

SPEED OF LIGHT

- We can manipulate the speed of light so to use it to measure distance. We call this measurement a light year.
- A light year is the distance light travels in one year. This distance is 9.45×10^{15} meters –nearly 6 TRILLION miles!
- We use light years to describe how far distant stars, planets and galaxies are from Earth.

