THE NATURE OF WAVES

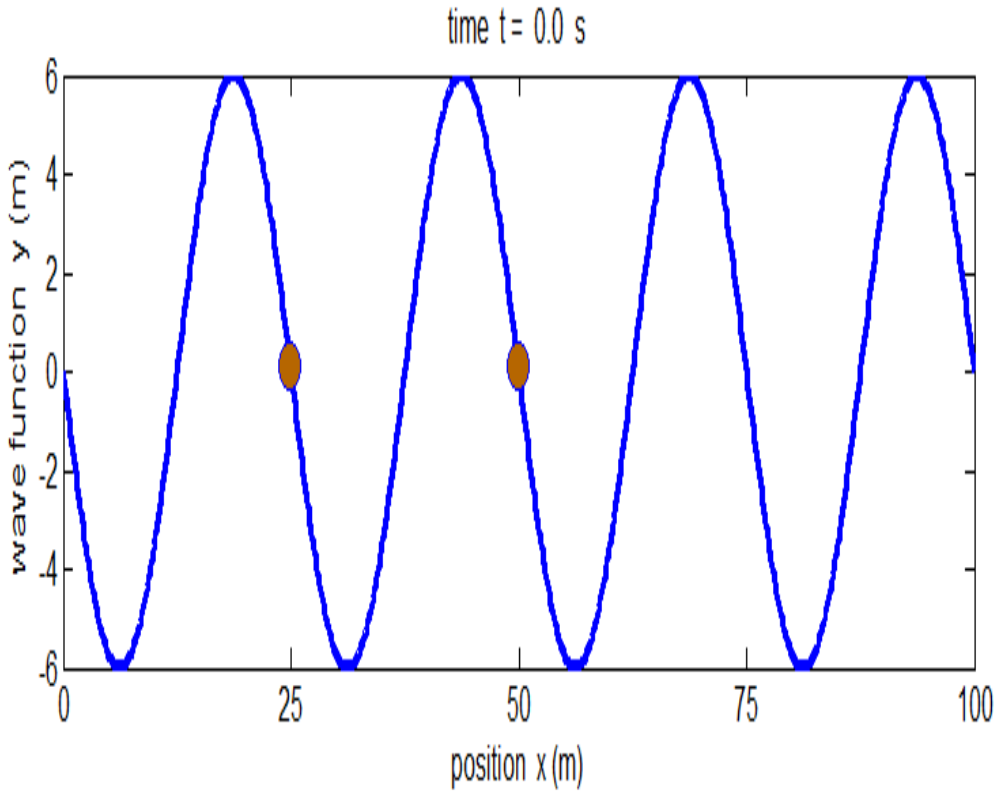
Chapter 10

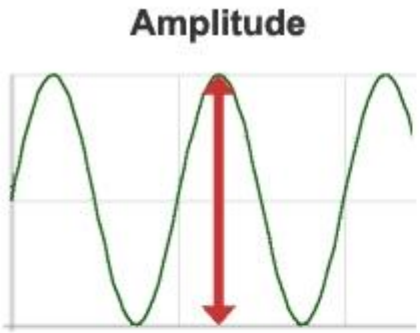
Mr. Davis, M.Ed.

Physical Science - 2017

Amplitude

- THE HEIGHT OF A WAVE.
- THE AMPLITUDE OF A WAVE IS THE MAXIMUM DISTANCE THAT THE PARTICLES OF A MEDIUM VIBRATE FROM THEIR REST POSITION.
- A WAVE WITH A LARGE AMPLITUDE CARRIES MORE ENERGY THAN A WAVE WITH A SMALLER AMPLITUDE.

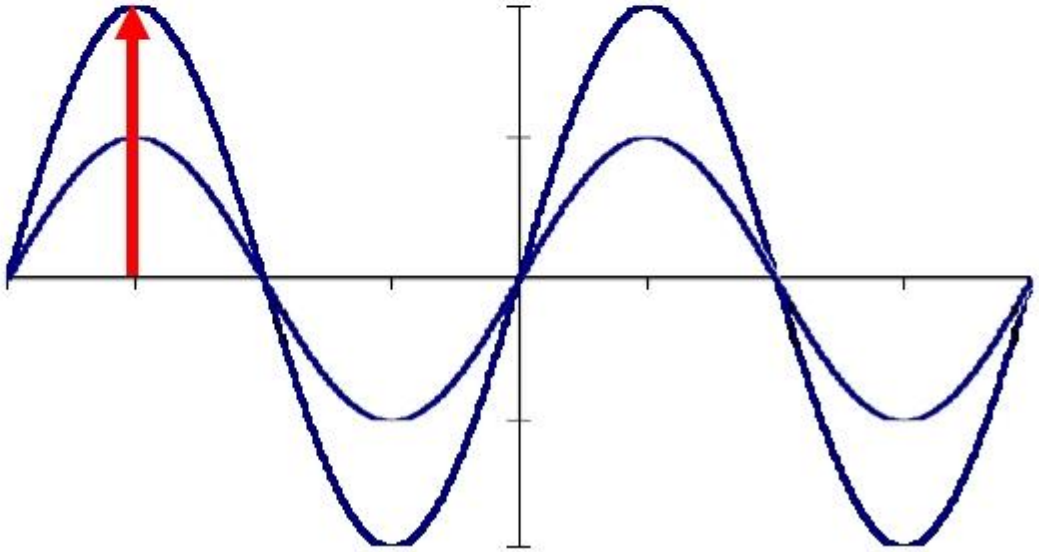


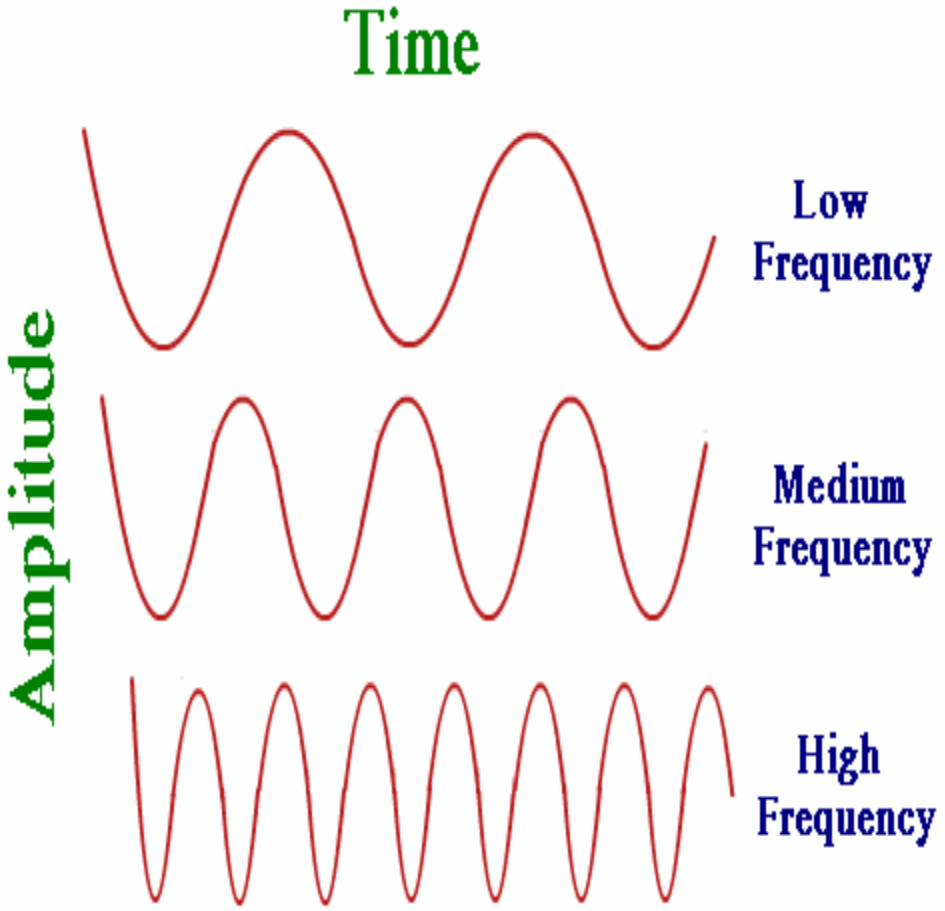


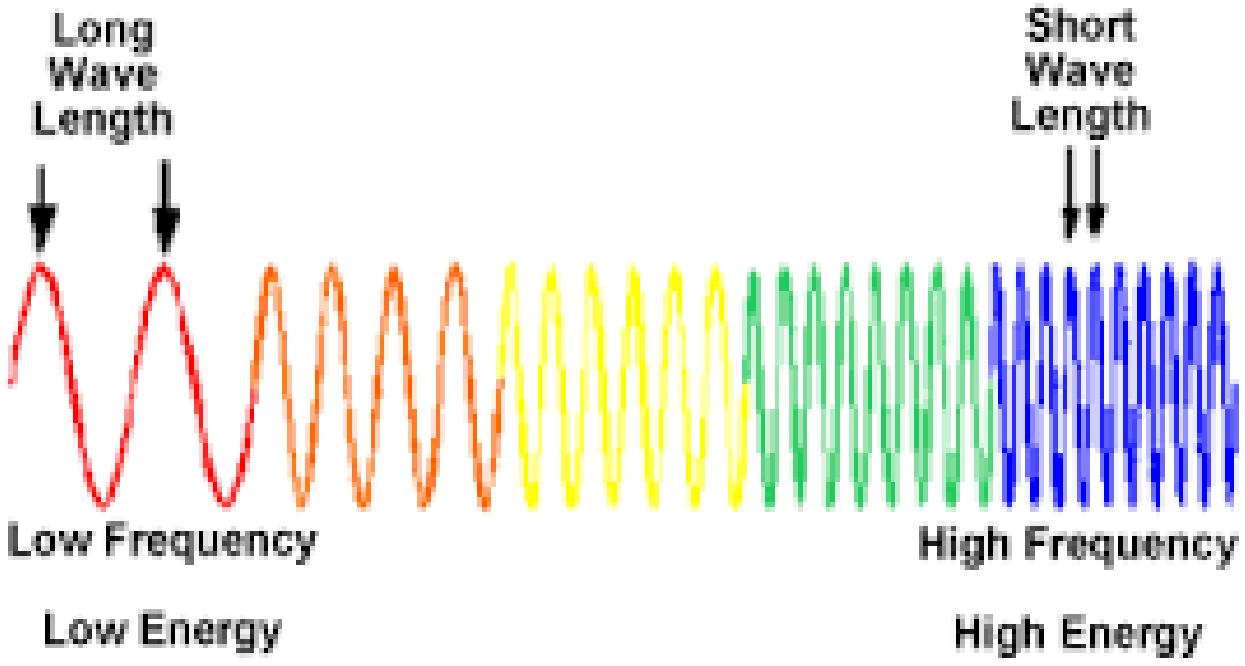
Amplitude

Amplitude = Loudness = Volume

Higher amplitudes are interpreted as a higher volume, hence the name "amplifier" for a device which increases amplitude.





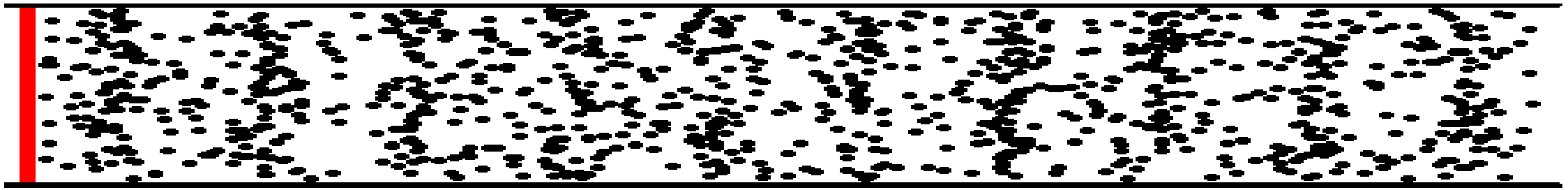


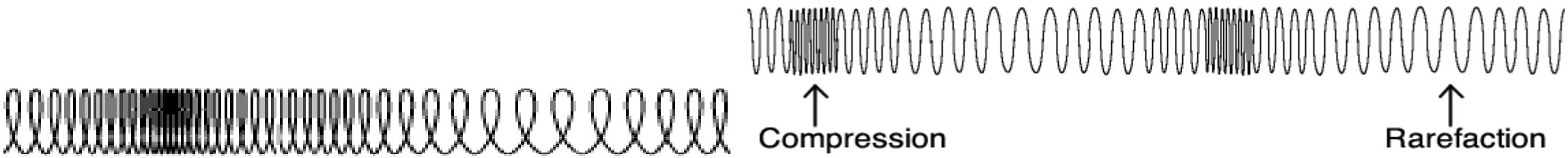
Amplitude: This is the height of a wave.

Compressional Wave

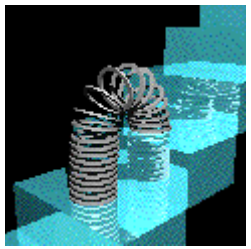
A Wave in which matter moves back and forth along the same direction that the waves travels.

- Compressional waves have compression and rarefactions.
- Compressional waves are also called longitudinal waves.



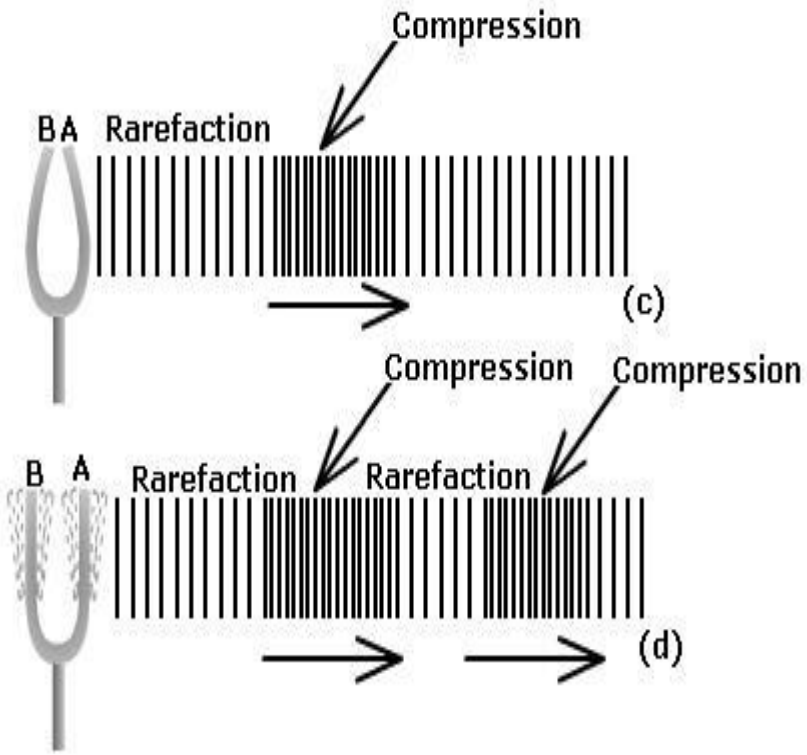


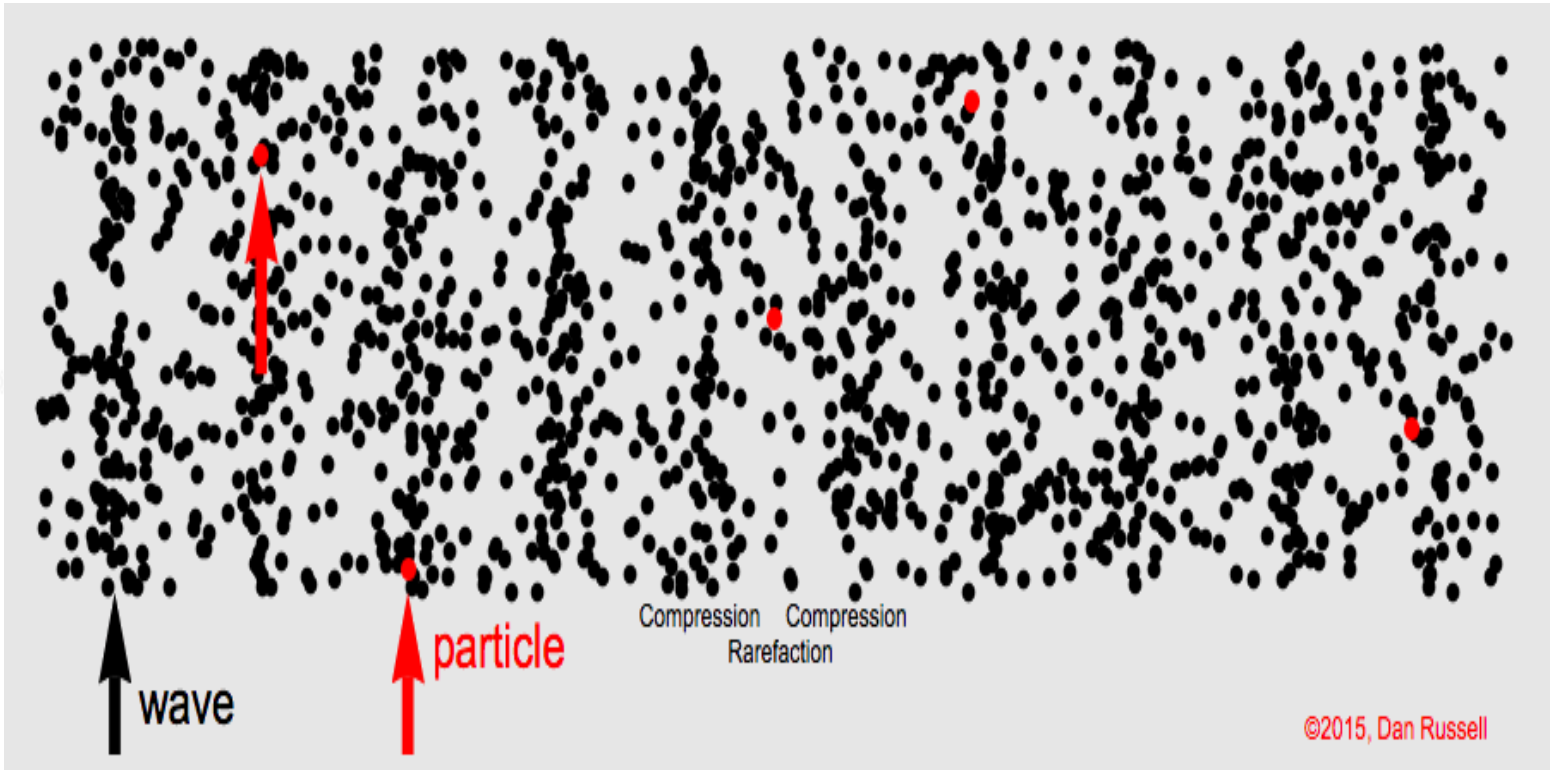
Slinky – Compressional wave toy



In a compressional wave in a coiled spring toy, the waves travels horizontally along the spring.

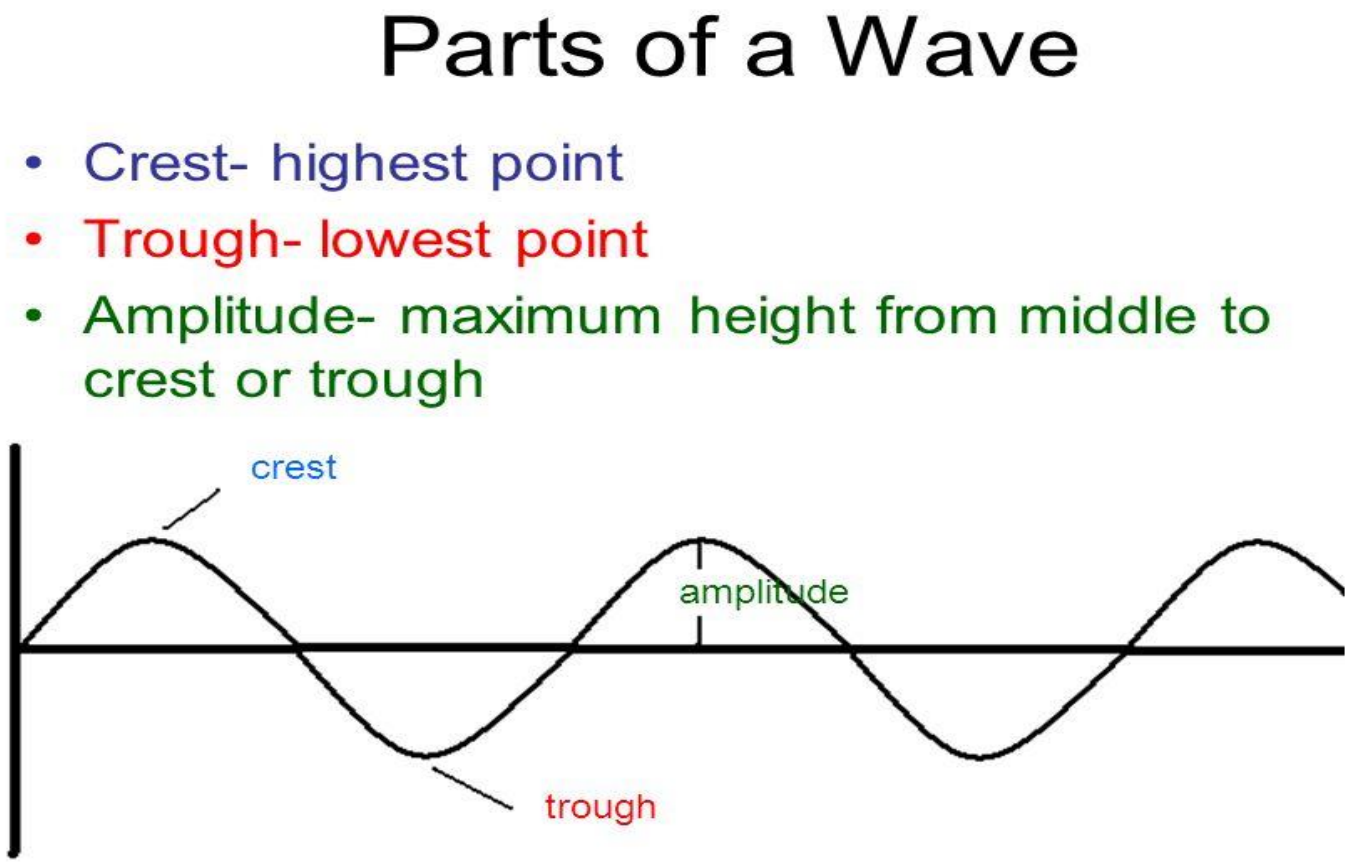
Compressional wave



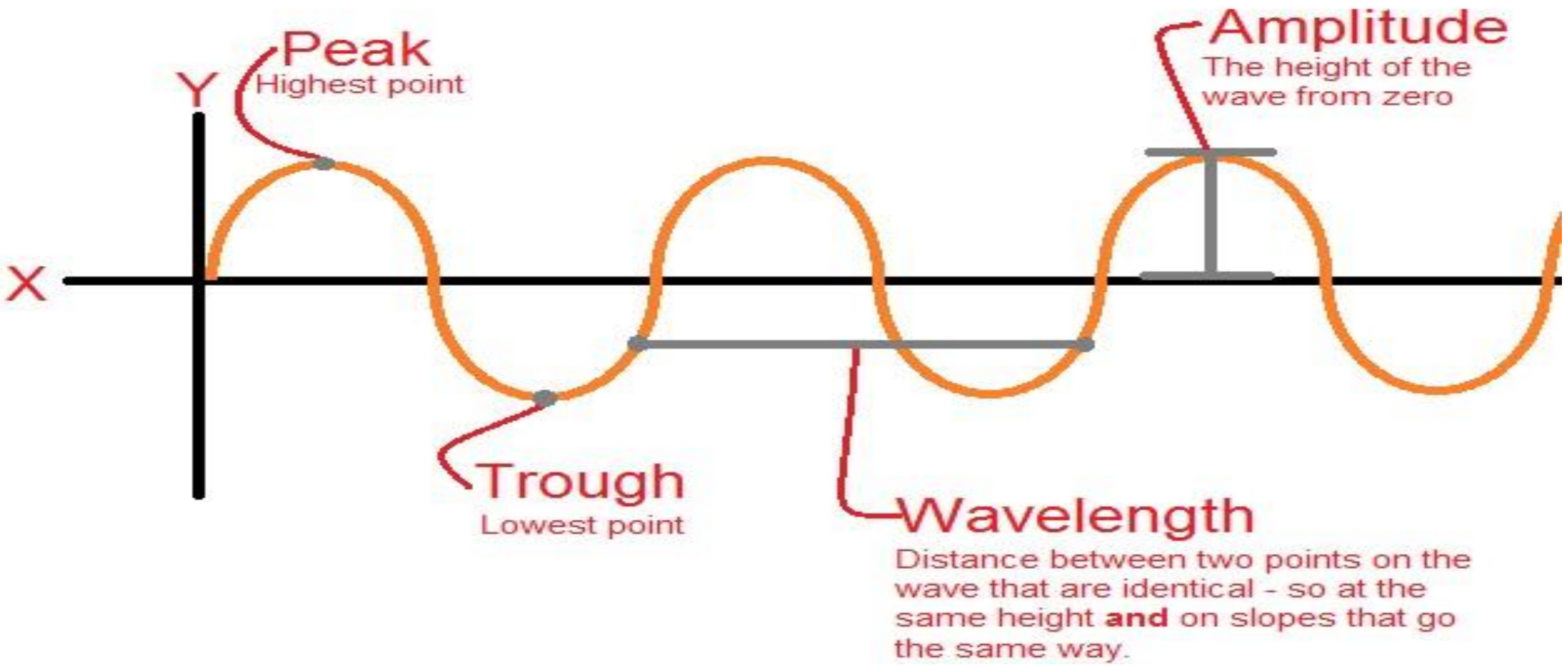


Crest

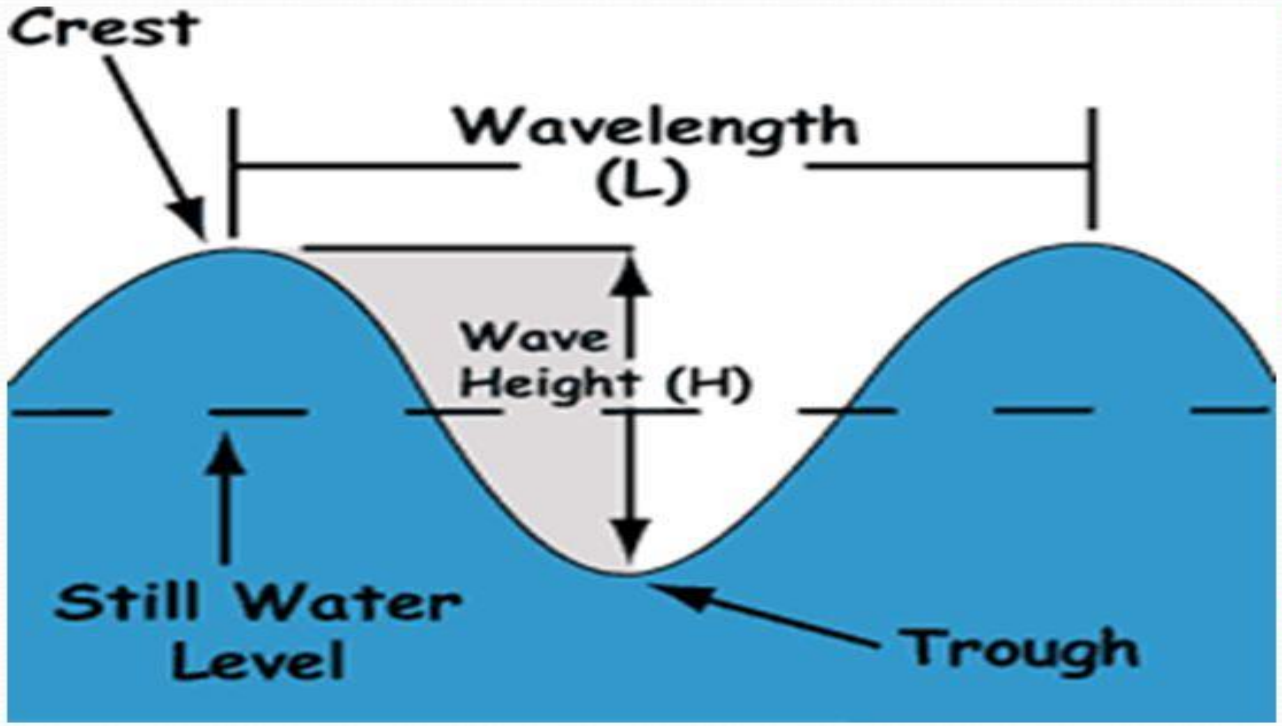
Crest is the highest point on a wave.



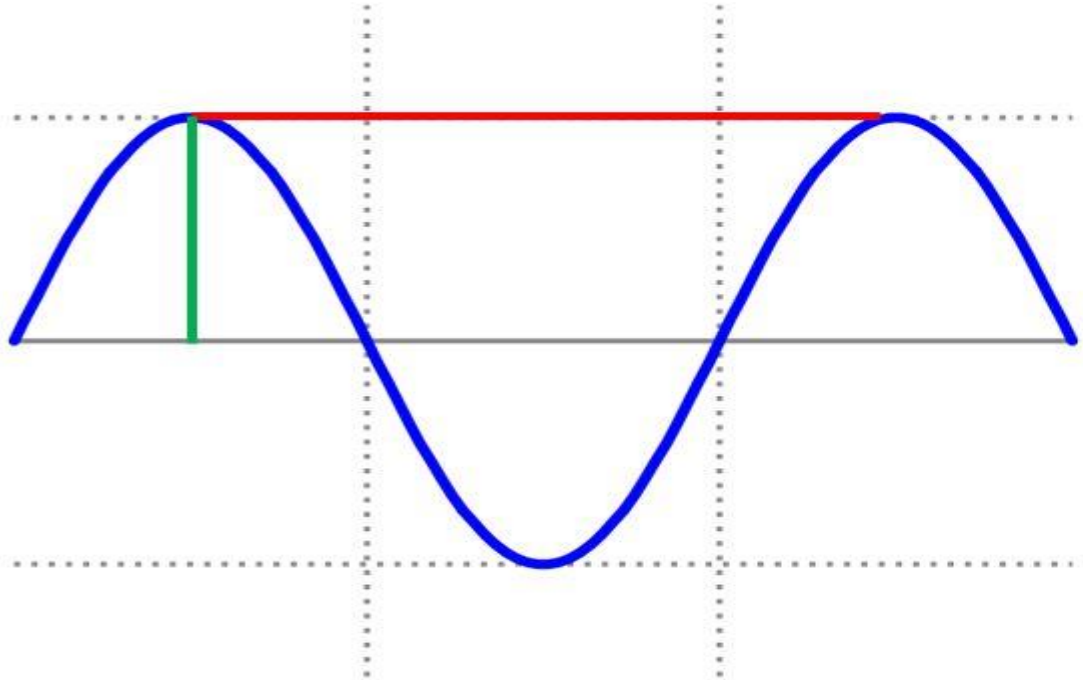
Anatomy of a simple wave



Anatomy of a Wave



- Crest – the highest point of a wave
- Trough – the lowest point
- Wavelength – the distance from crest to crest OR trough to trough
- Wave height – vertical distance from crest to trough



Wavelength (λ)

Distance between identical points on consecutive waves

Amplitude

Distance between origin and crest (or trough)

Frequency (ν)

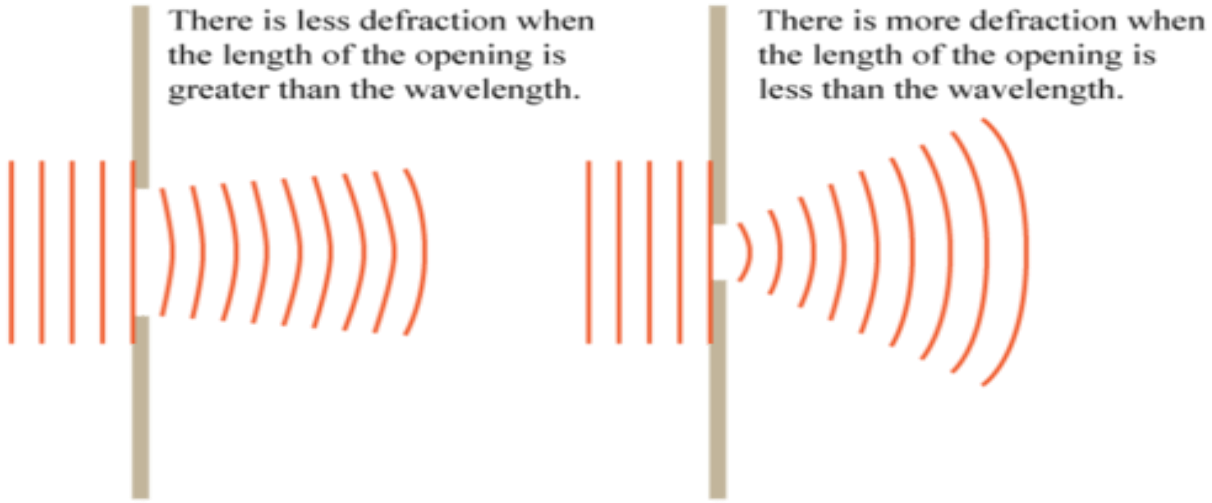
Number of waves that pass a point per unit time

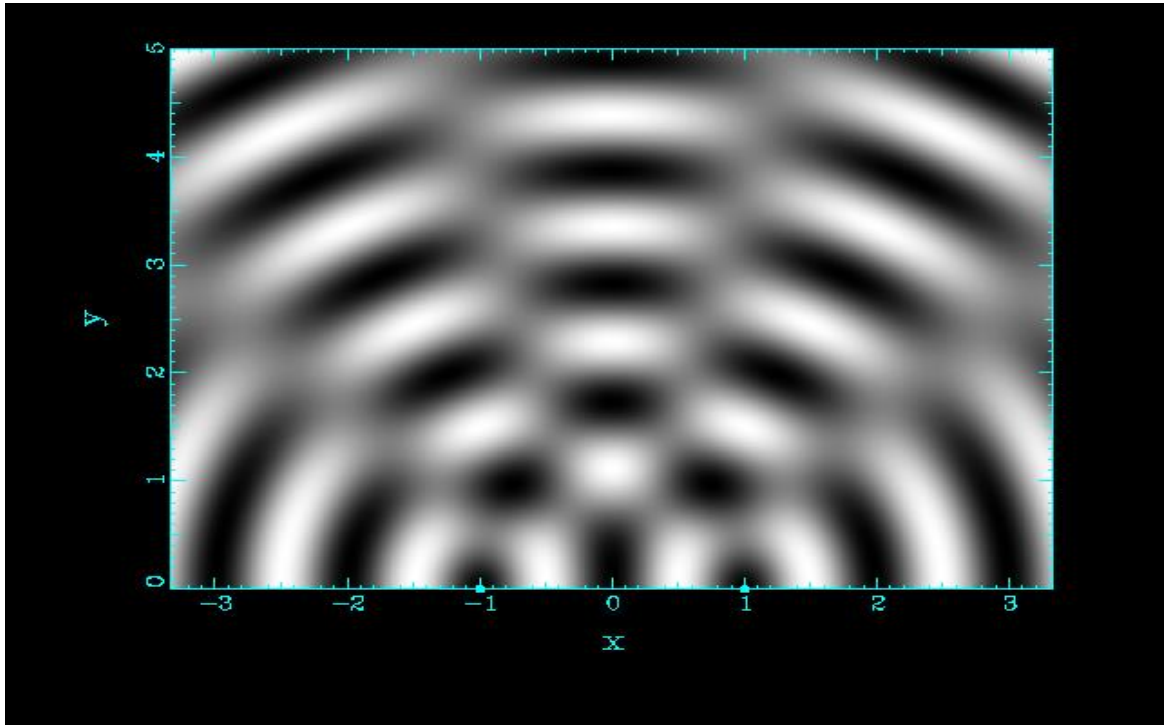
Speed

= wavelength x frequency

Diffraction

Diffraction occurs when a wave encounters a barrier or aperture in its path which causes the wave to bend and spread out. The amount of diffraction is most noticeable when the size of the wavelength is bigger than the size of the barrier.





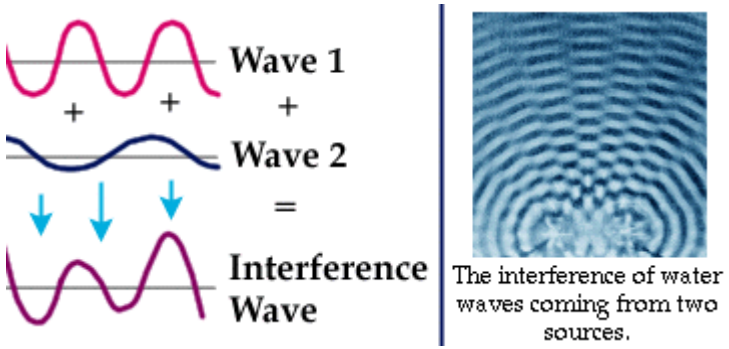
Frequency

Frequency is the number of waves that pass a given point over time in one second.

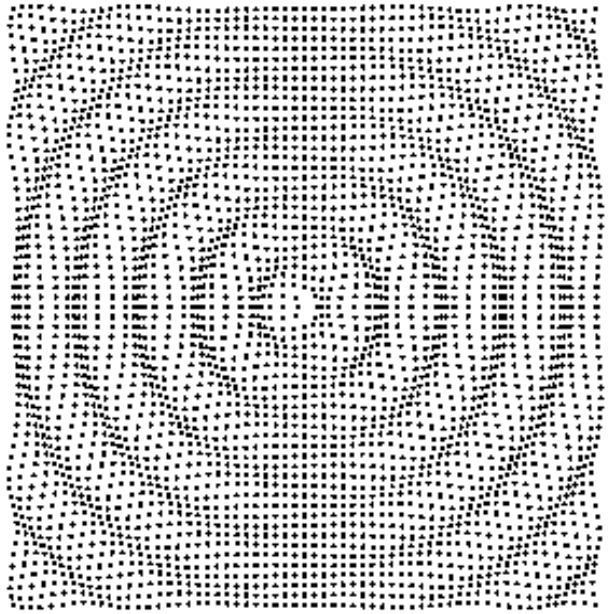
- Frequency refers to the number of crests of waves of the same wavelength that pass by a point in one second.

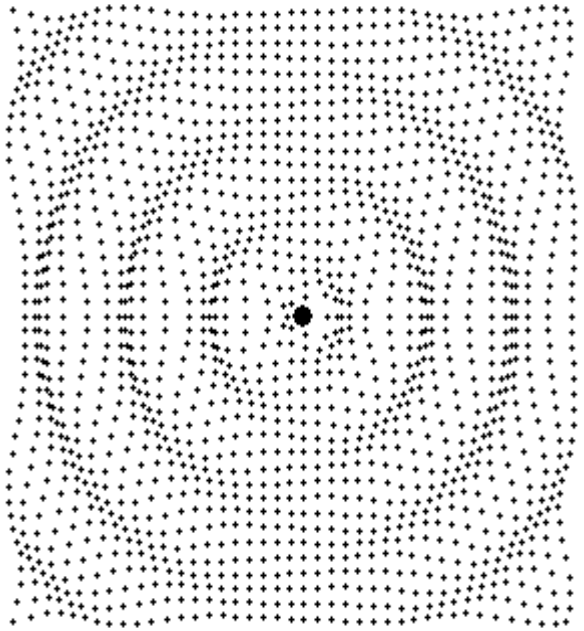
Interference

Interference occurs when two or more waves overlap and combine to form a new wave.



The interference of water waves coming from two sources.



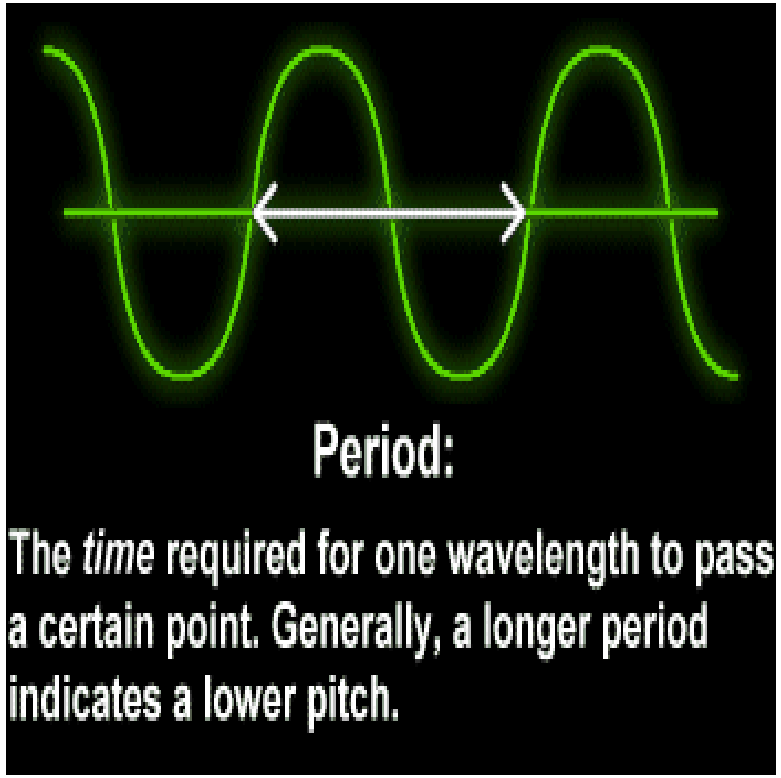


Medium

Medium is the material through which a wave travels.
A medium can be a gas, liquid, or a solid.
Waves that need a medium = mechanical waves.

Period

The **period** of a wave is the time for a particle on a medium to make one complete vibrational cycle. Period, being a time, is measured in units of time such as seconds, hours, days or years.



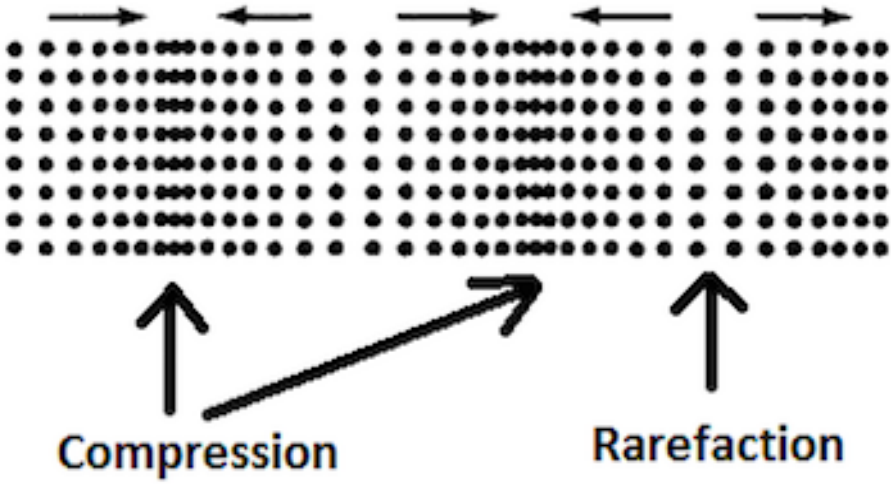
$$Wave\ Period = \frac{1}{Frequency} \quad or \quad T = \frac{1}{f}$$

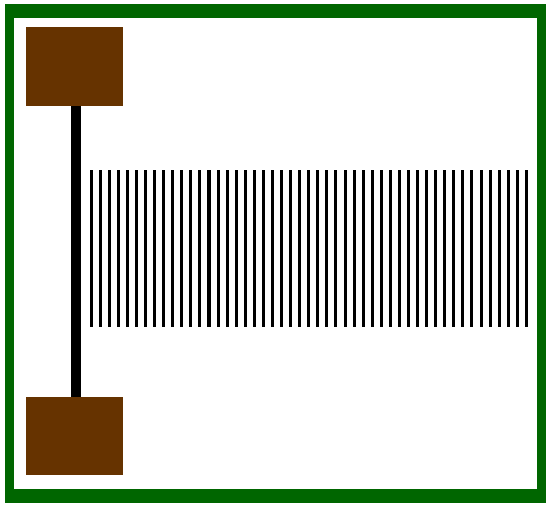
$$Wave\ Period = \frac{Wavelength}{velocity} \quad or \quad T = \frac{\lambda}{v}$$

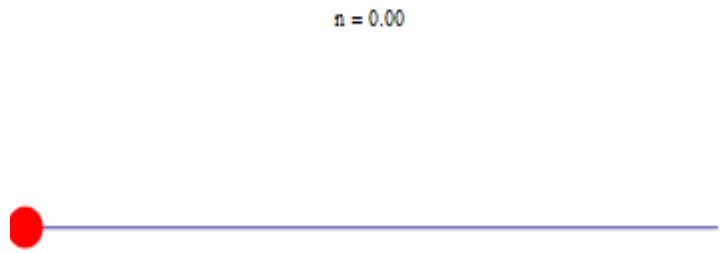
Unit of Wave Period: s

Rarefaction

A **rarefaction** is the area of a wave (or Slinky) that is spread out. This is the wave's trough. The **rarefaction** is the part of the wave that has the lowest density



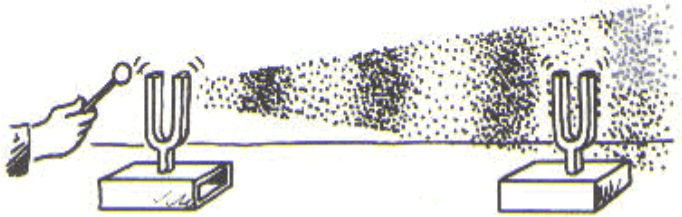




A **wave rarefaction** is a particular feature of a longitudinal wave in which the vibration is parallel to the direction of motion.

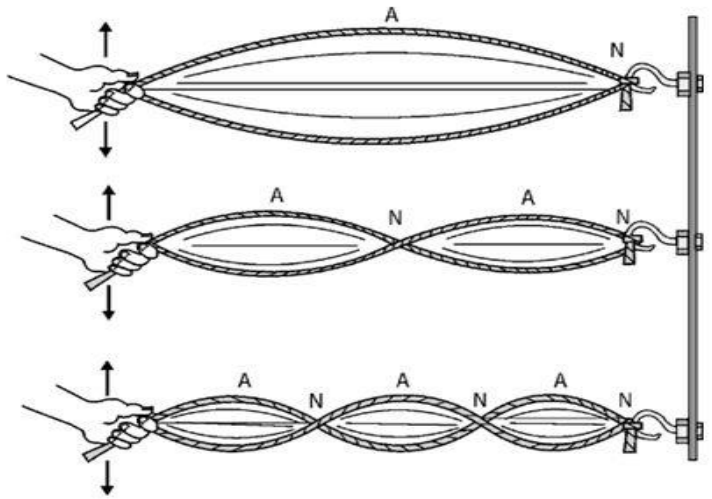
Resonance

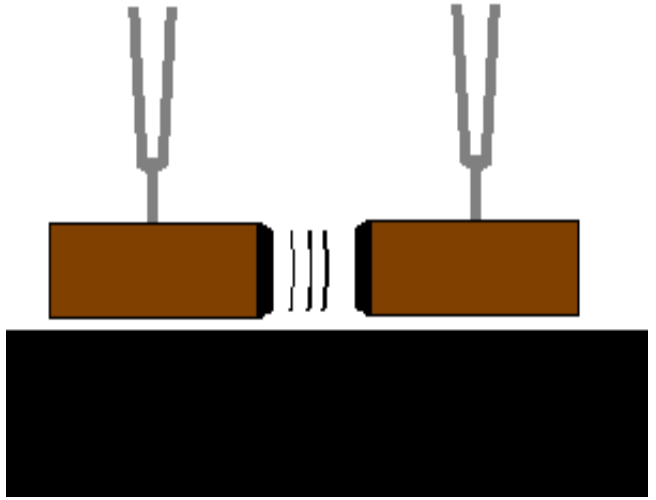
Resonance - Sent wave causes other tuning fork to vibrate



Resonance and Standing Waves

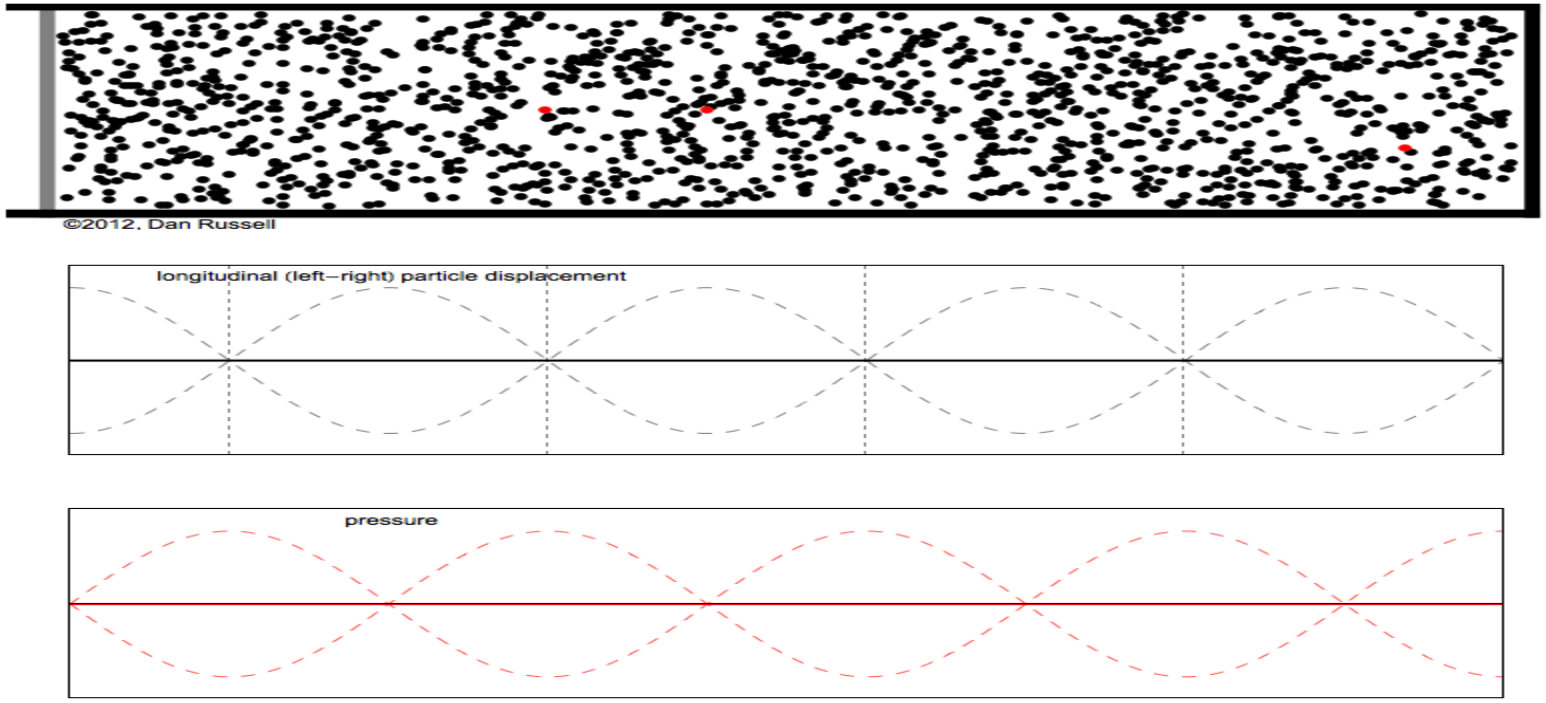
- **Resonance** – achieved when energy is added to a system at the same frequency as its natural frequency;
- Results in maximum amplitude.
- Standing Wave – example of resonance





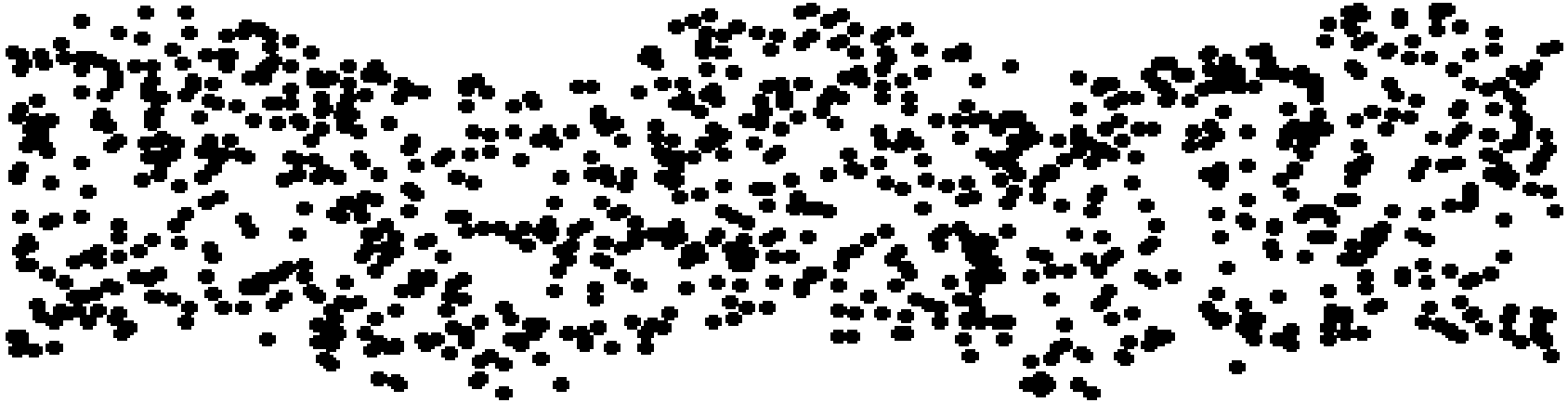
Standing Wave

a **standing wave pattern** was described as a vibrational pattern created within a medium when the vibrational frequency of a source causes reflected waves from one end of the medium to interfere with incident waves from the source.

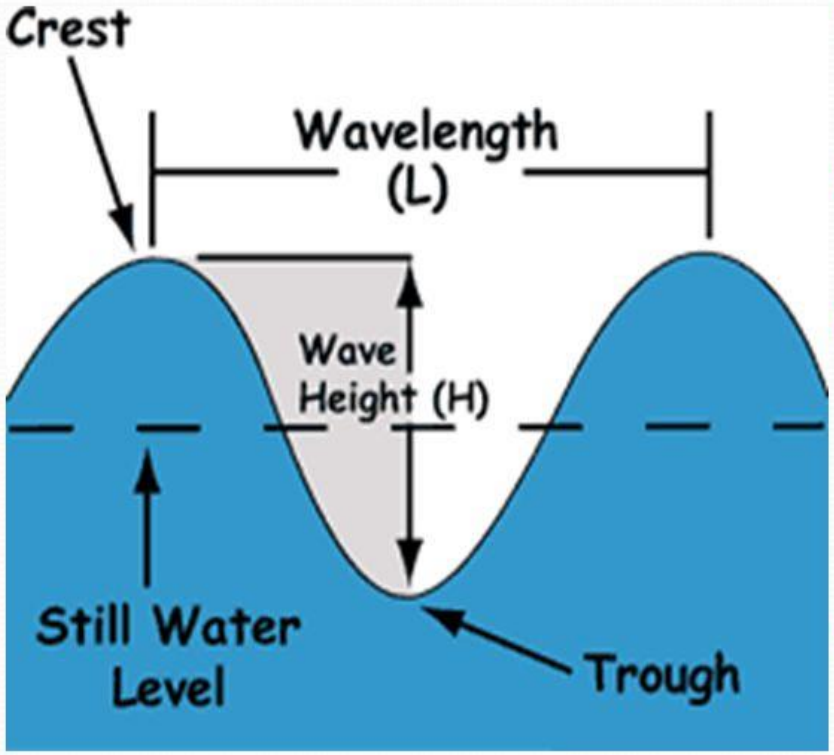


Transverse wave

A wave that moves back and forth at right angles to the direction of the wave.



Anatomy of a Wave



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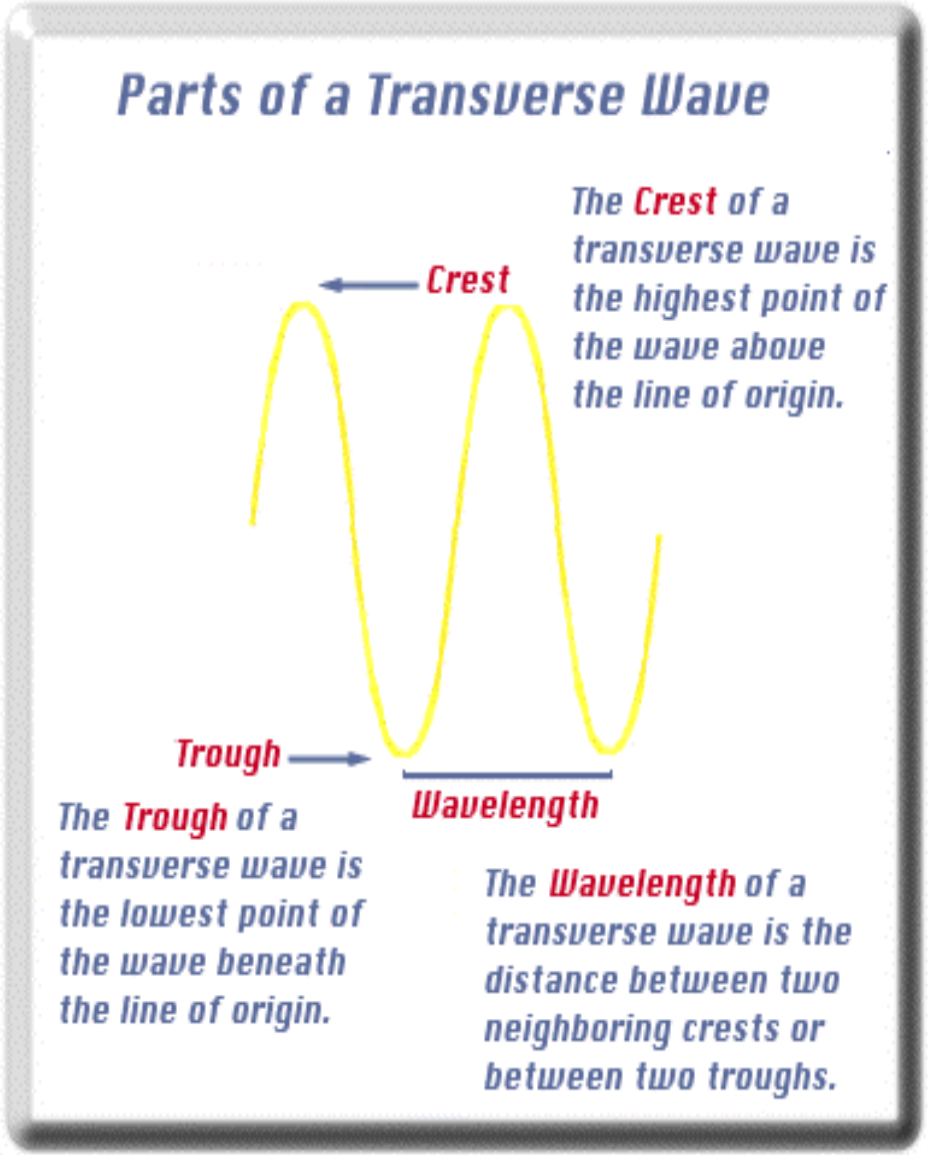
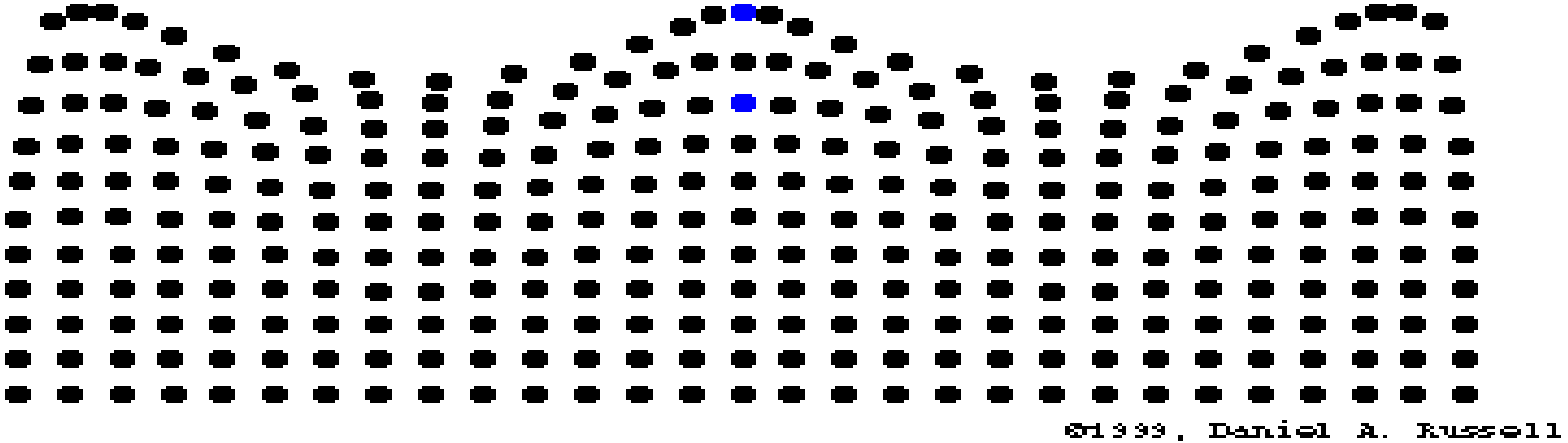


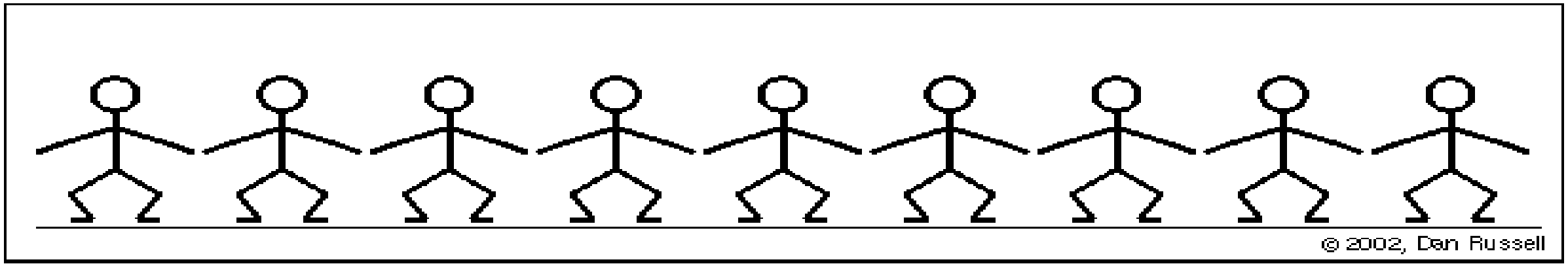
Water Waves



- Water waves are an example of waves that involve a combination of both longitudinal and transverse motions. As a wave travels through the waver, the particles travel in *clockwise circles*. I have identified two particles in **blue** to show that each particle indeed travels in a clockwise circle as the wave passes

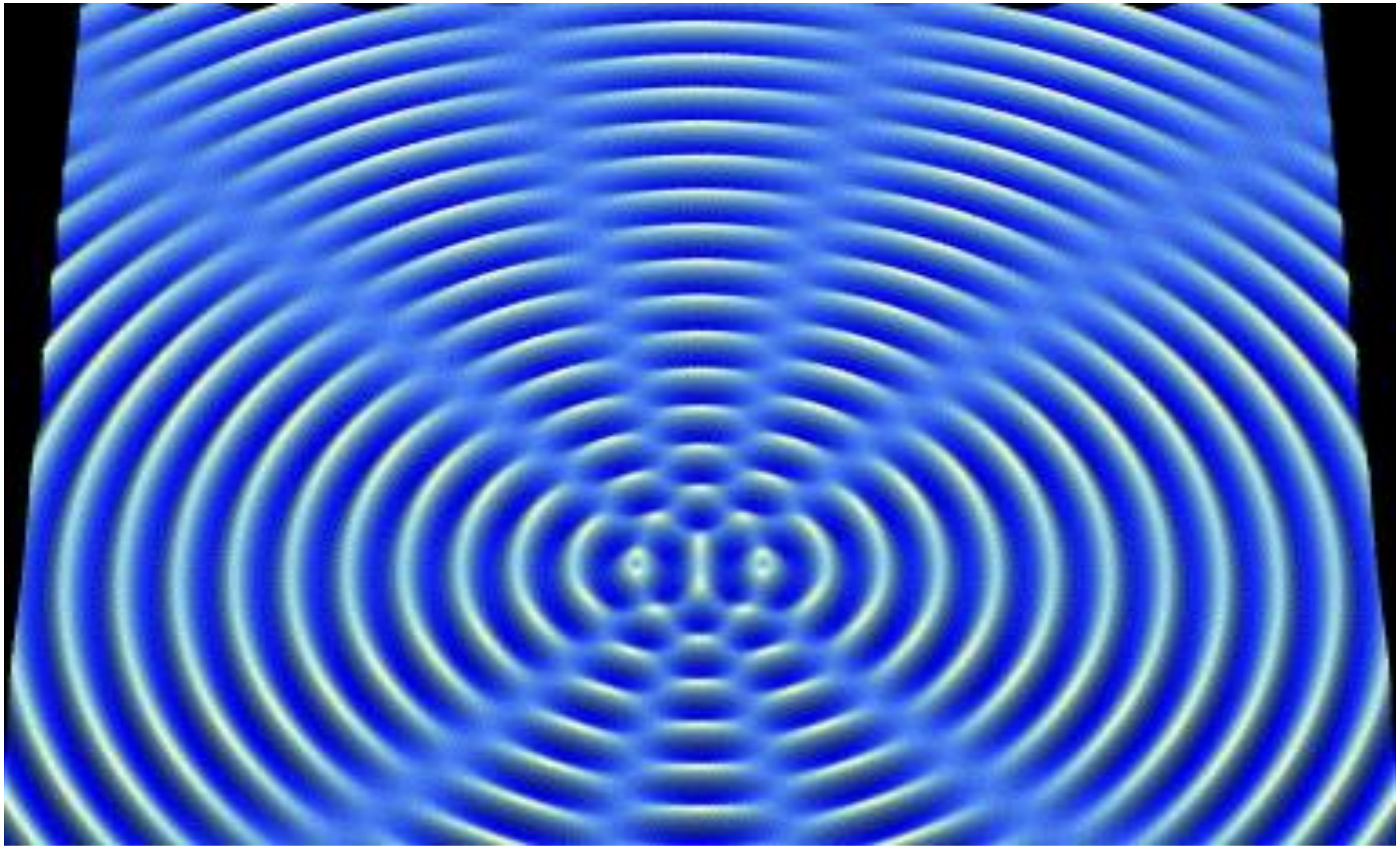
Wave

A **wave** is a repeating disturbance or movement that transfers energy through matter or space.



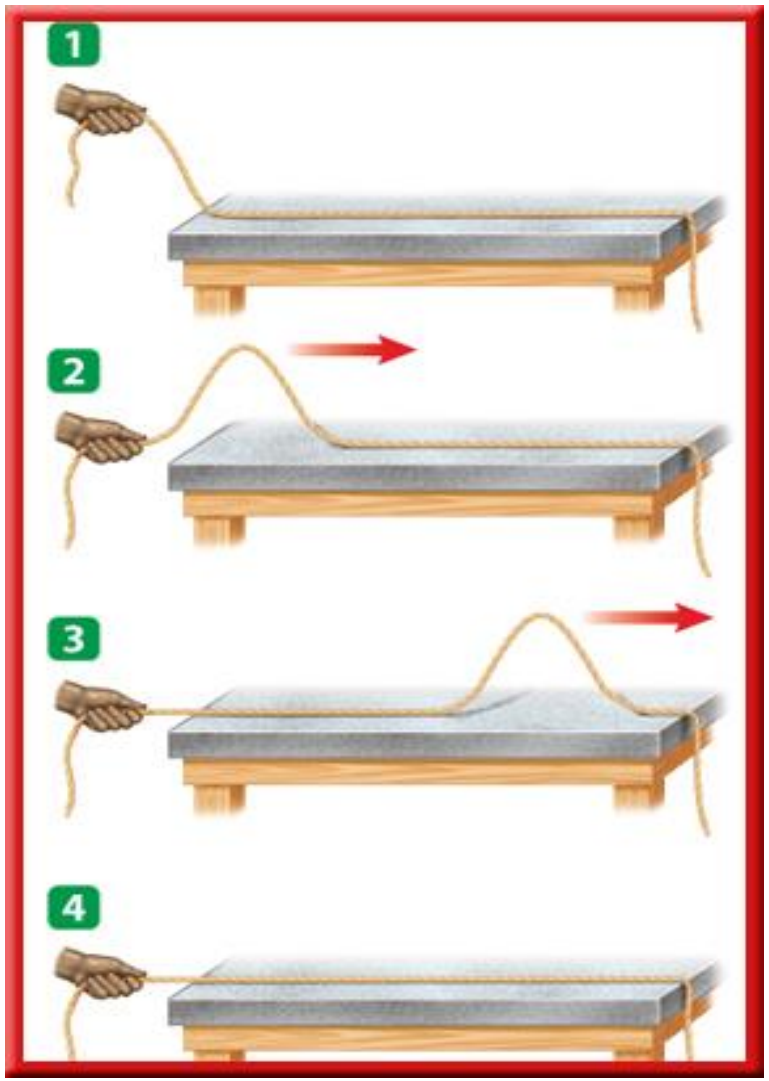
The wave is the disturbance (people jumping up and sitting back down), and it travels around the stadium .

Waves



The kinetic energy from a pebble is transferred to the particles of water in a pond, forming circular waves in all directions.

Waves

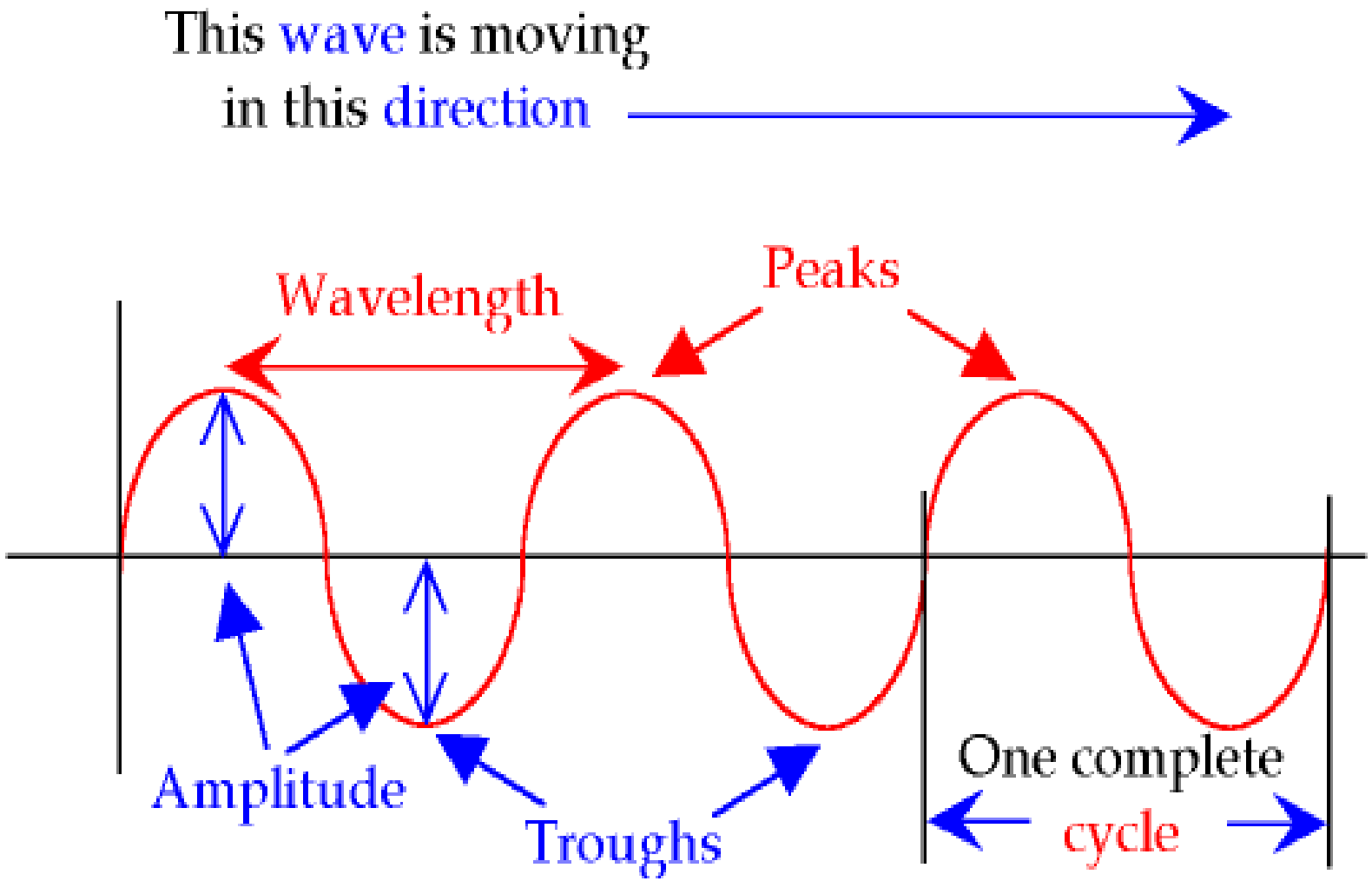


- A wave will exist only as long as it has energy to carry.
- Anything that moves up or down or back and forth in a rhythmic way is vibrating producing a wave.
- The vibrating movement of your hand at the end of a rope will create a wave.

Waves

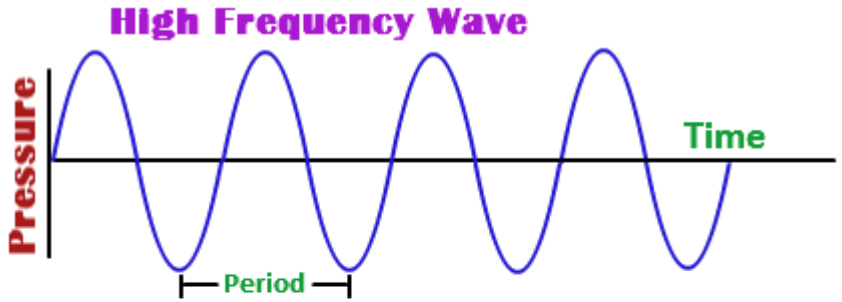
- All waves have wavelength
- All waves have amplitude
- All waves have frequency

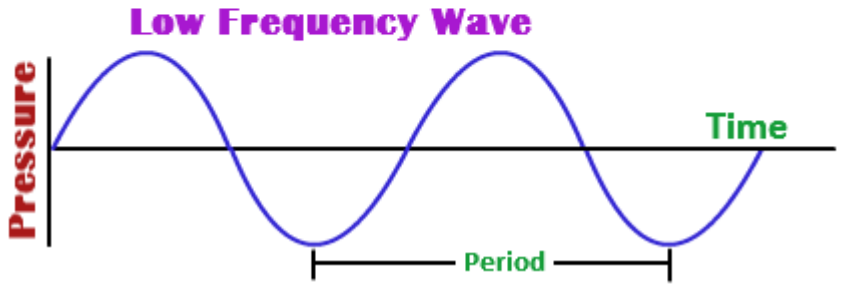
2 types of mechanical waves:
Transverse wave
Compressional Wave

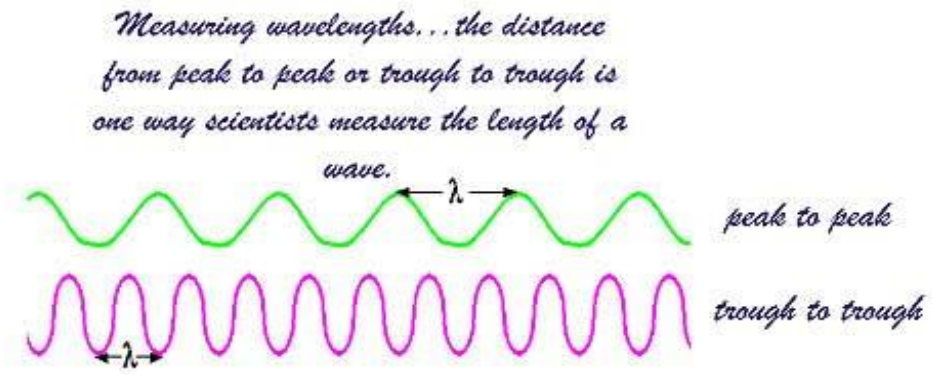


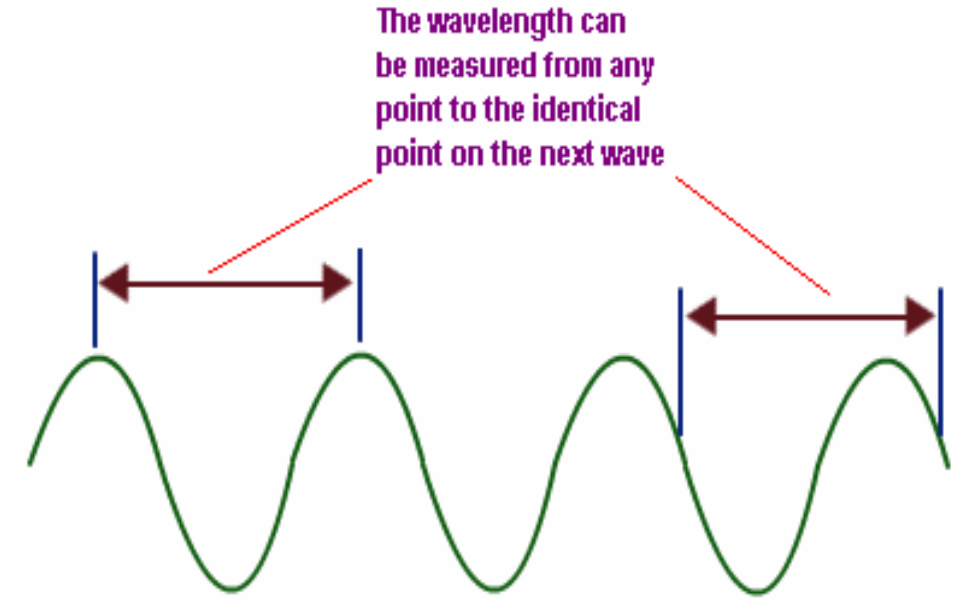
Wavelength

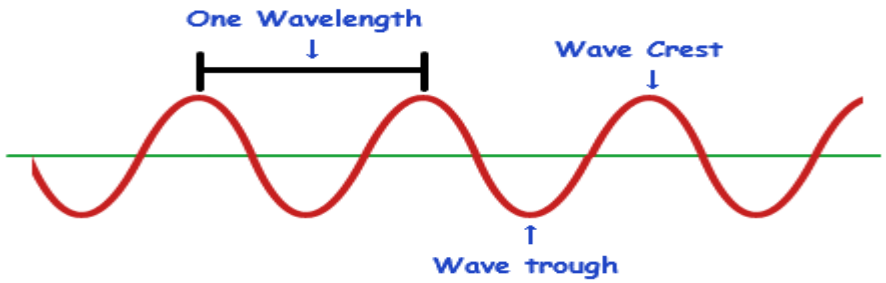
Wavelength is the horizontal distance between crest and trough.





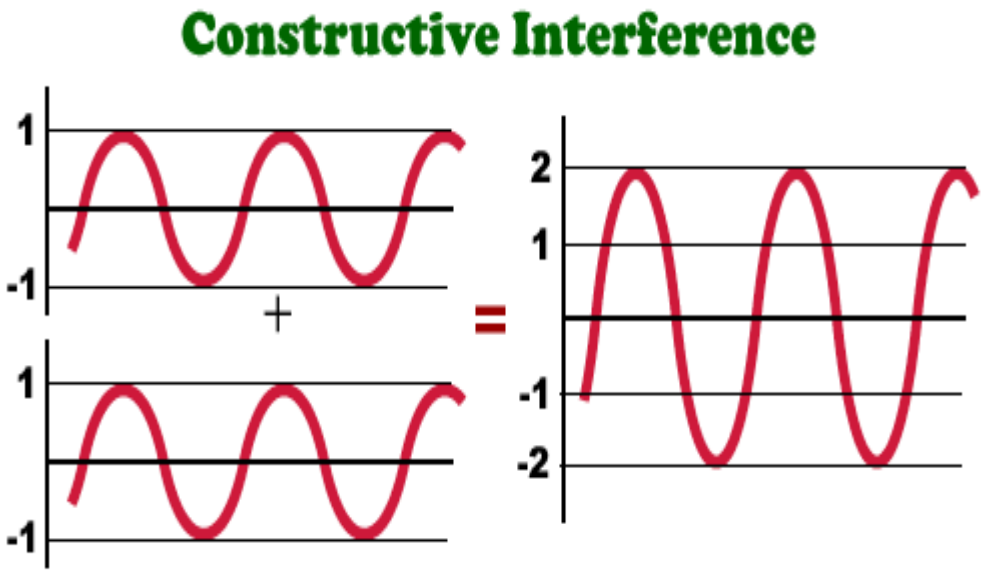


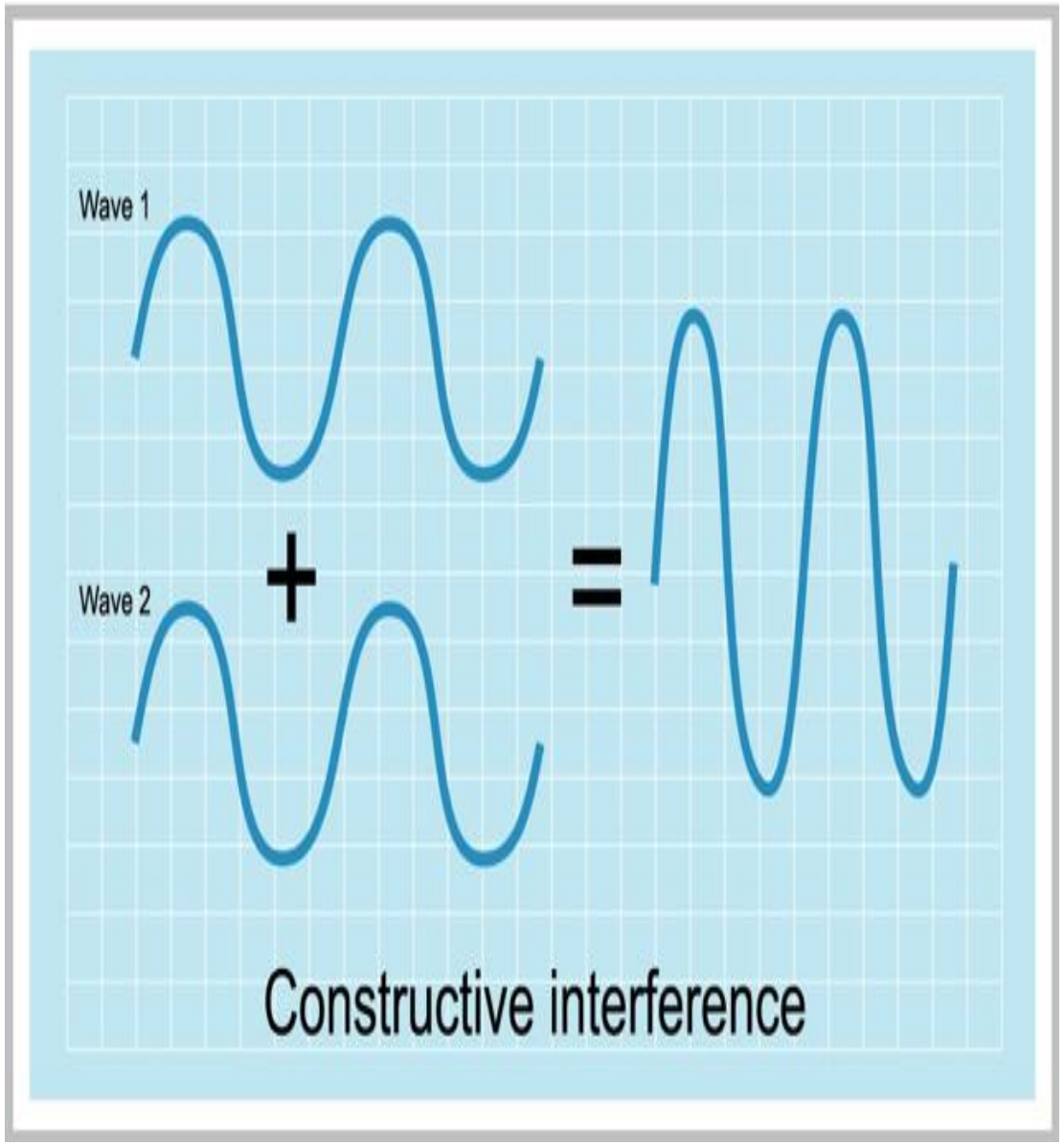




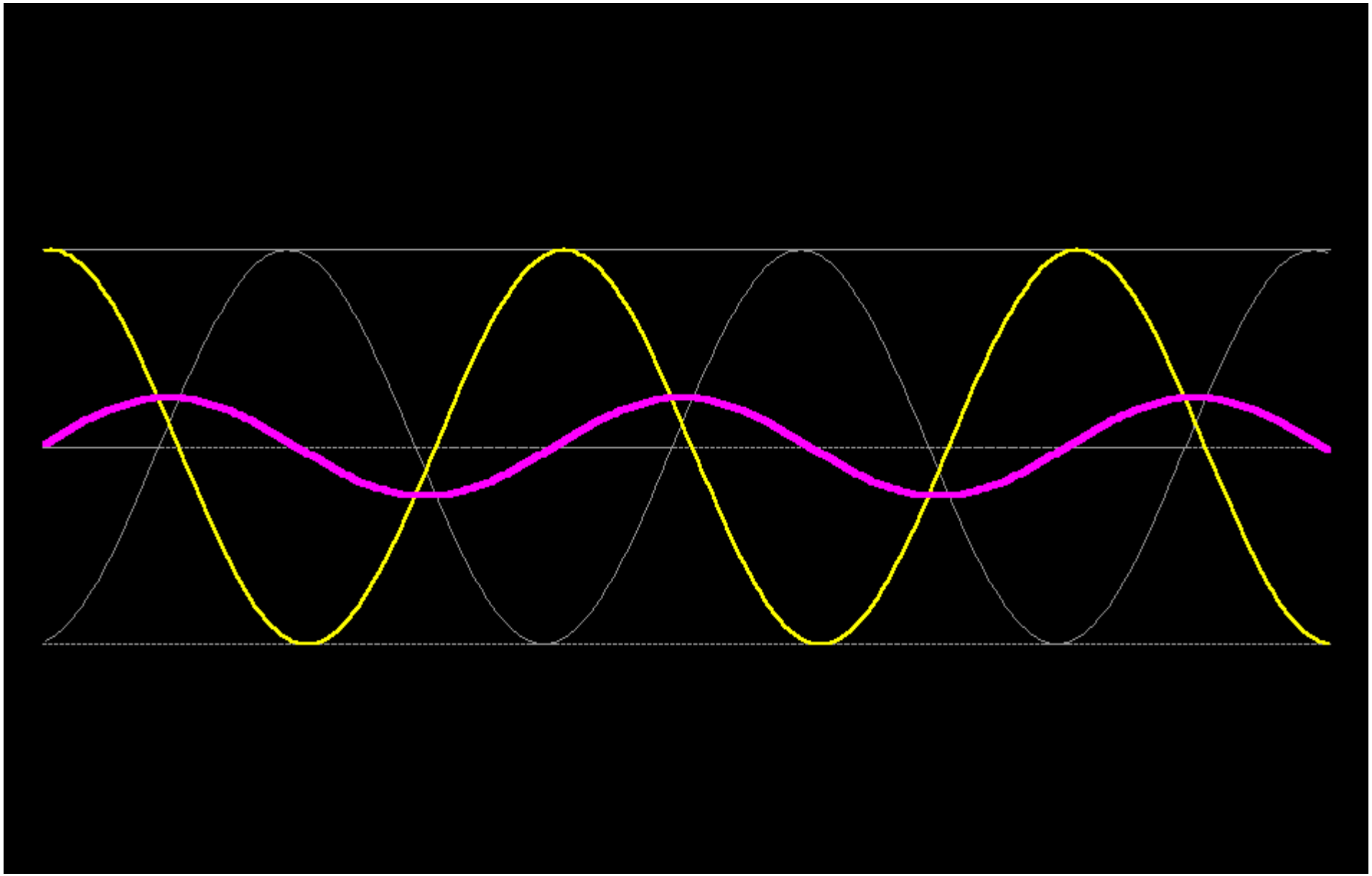
Constructive Inference

When two waves meet in such a way that their crests line up together, then it's called **constructive interference**. The resulting wave has a higher amplitude.



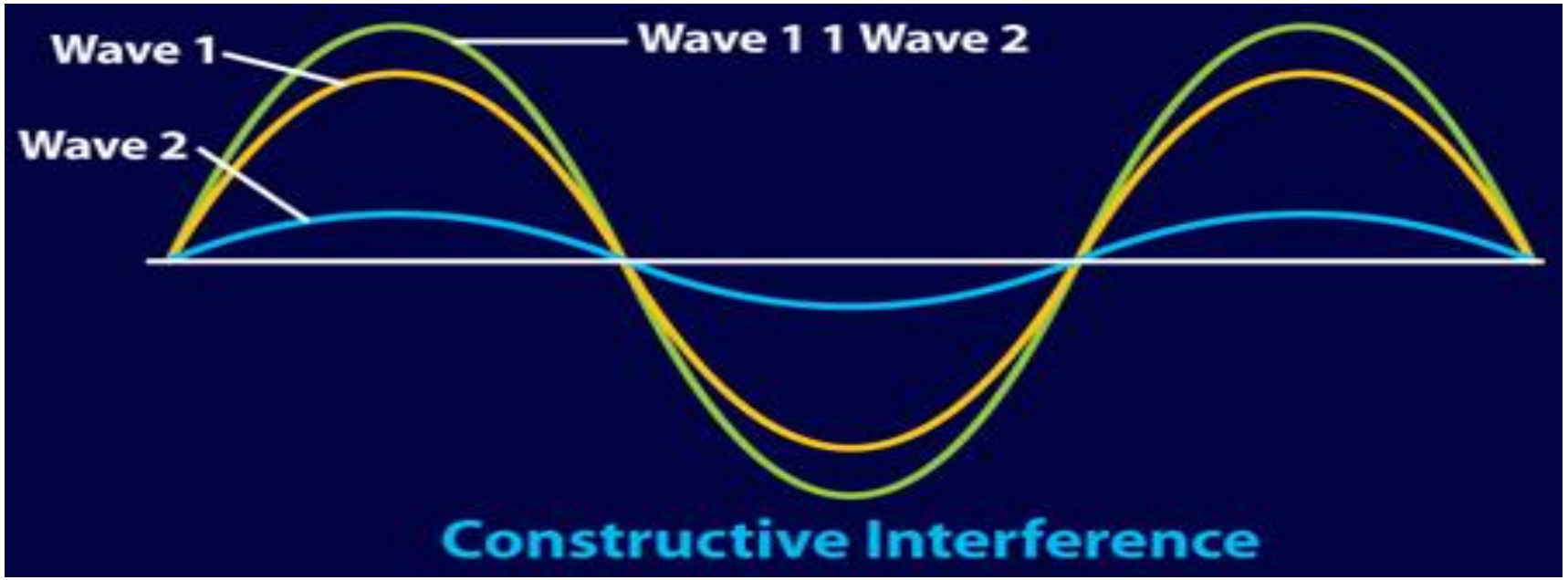


Constructive Inference



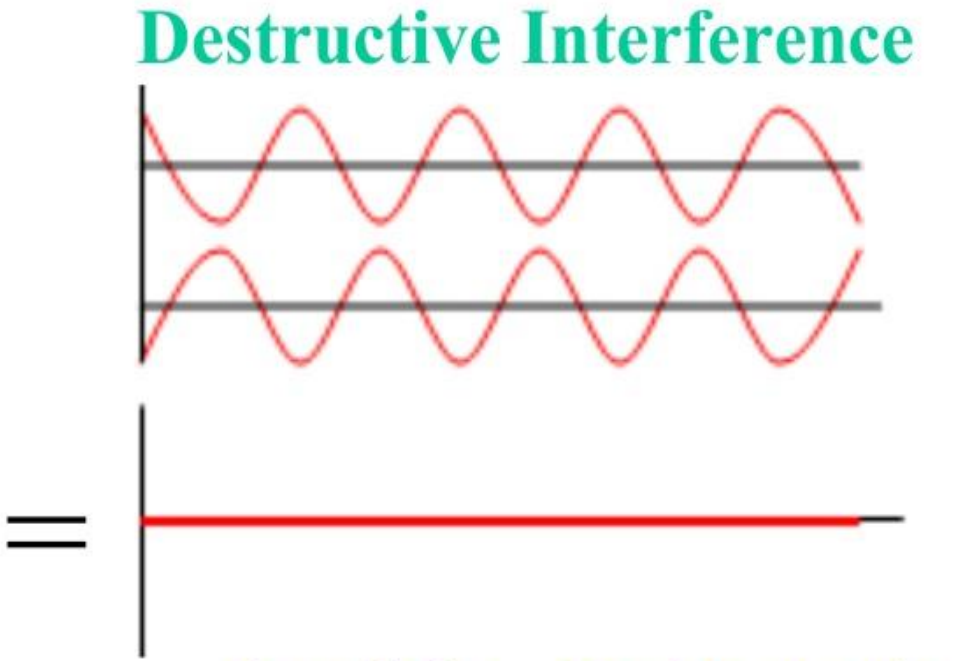
Constructive Interference

- The amplitude of the new wave that forms is equal to the sum of the amplitudes of the original waves.



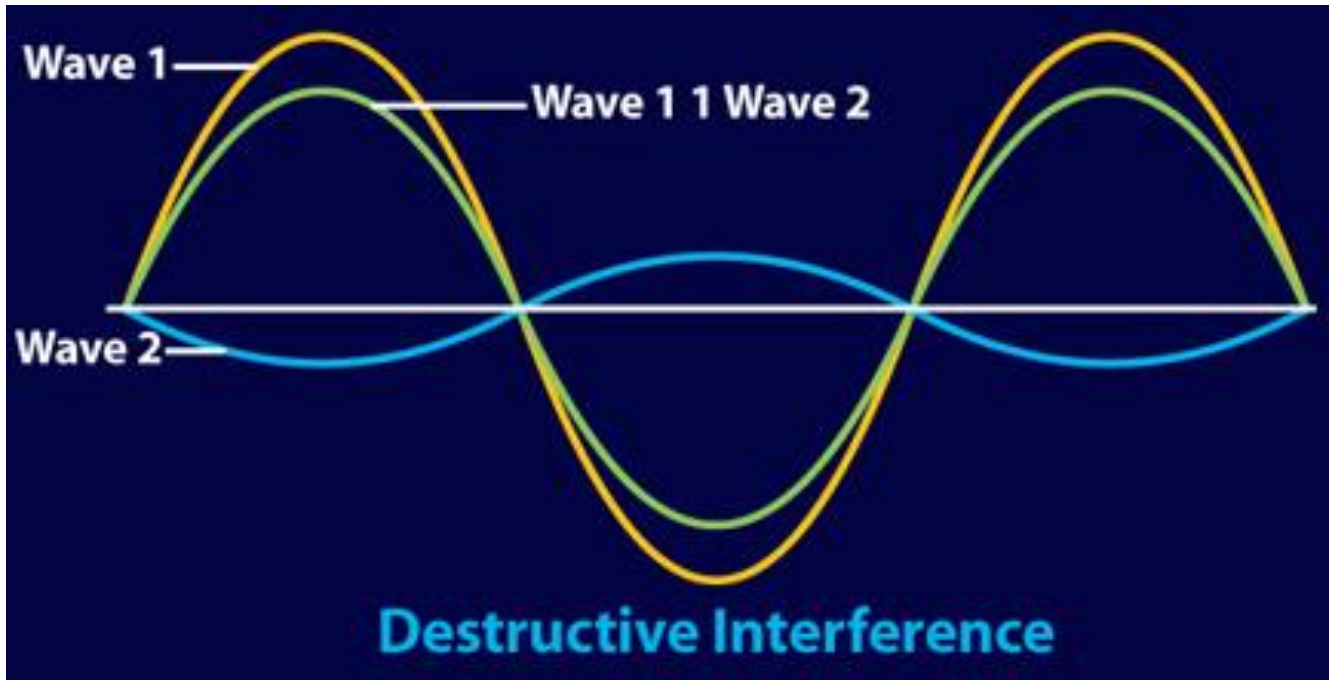
Destructive inference

Destructive interference is a type of interference that occurs at any location along the medium where the two interfering waves have a displacement in the opposite direction.



Destructive Interference

- In **destructive interference**, the waves subtract from each other as they overlap.
- This happens when the crests of one transverse wave meet the troughs of another transverse wave.



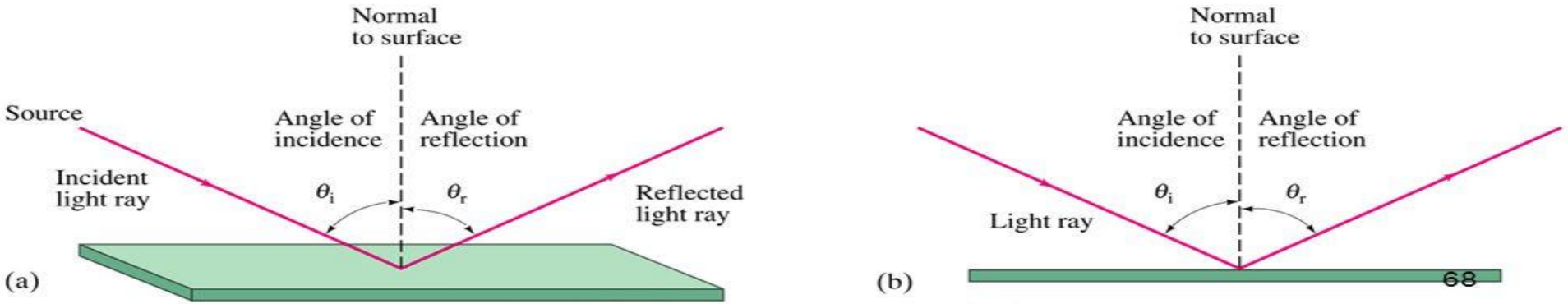
The Law of Reflection

Reflection: Law of Reflection

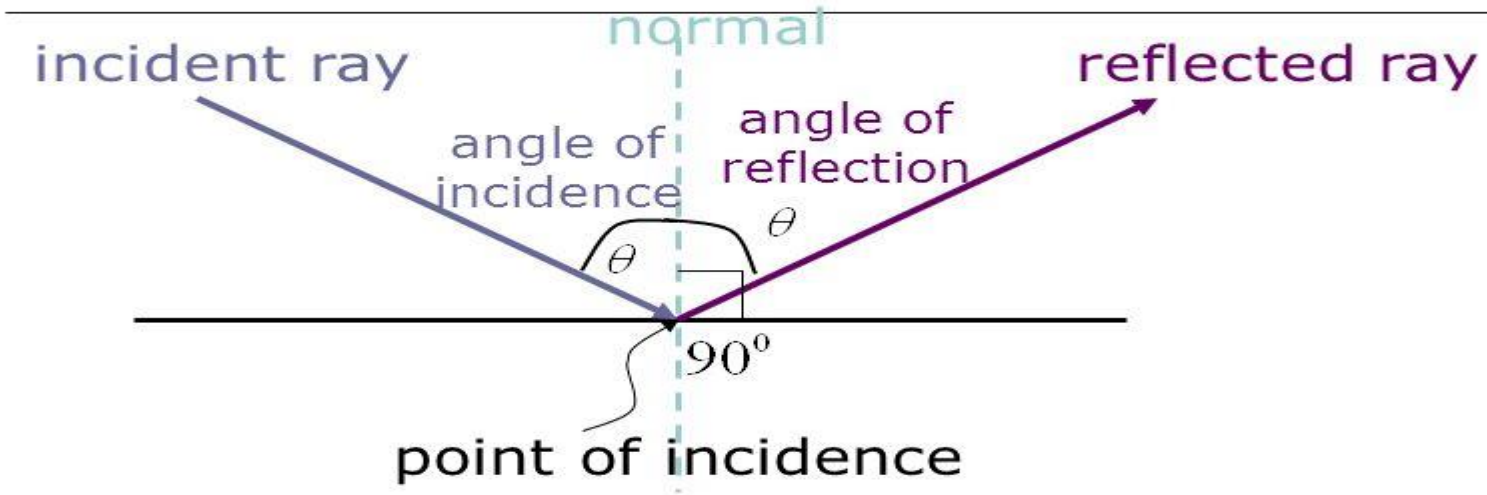
Law of reflection: the angle of reflection (that the ray makes with the normal to a surface) equals the angle of incidence.

angle of incidence = angle of reflection

$$\theta_i = \theta_r$$

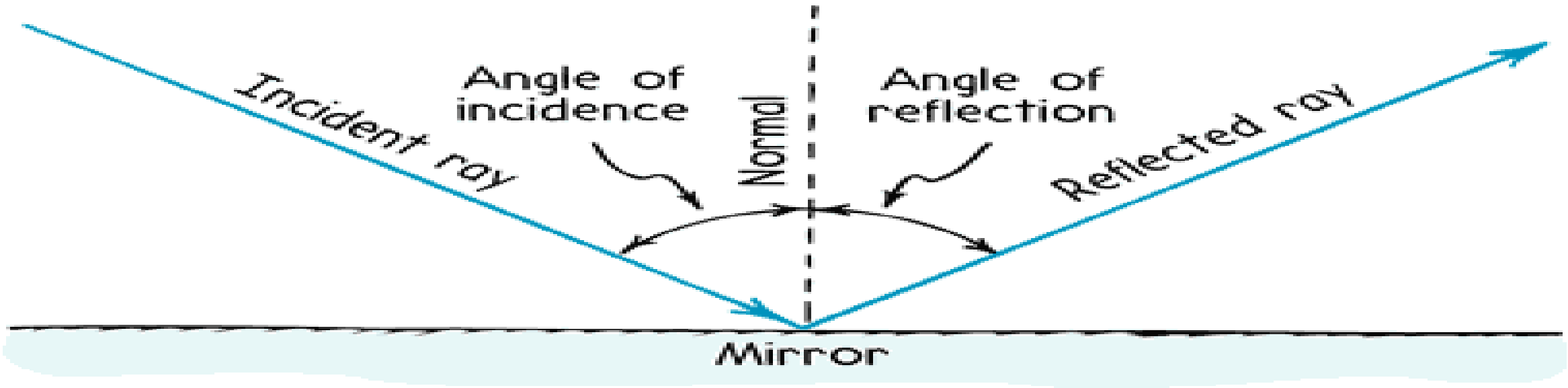


Laws of Reflection – Plane Mirror:



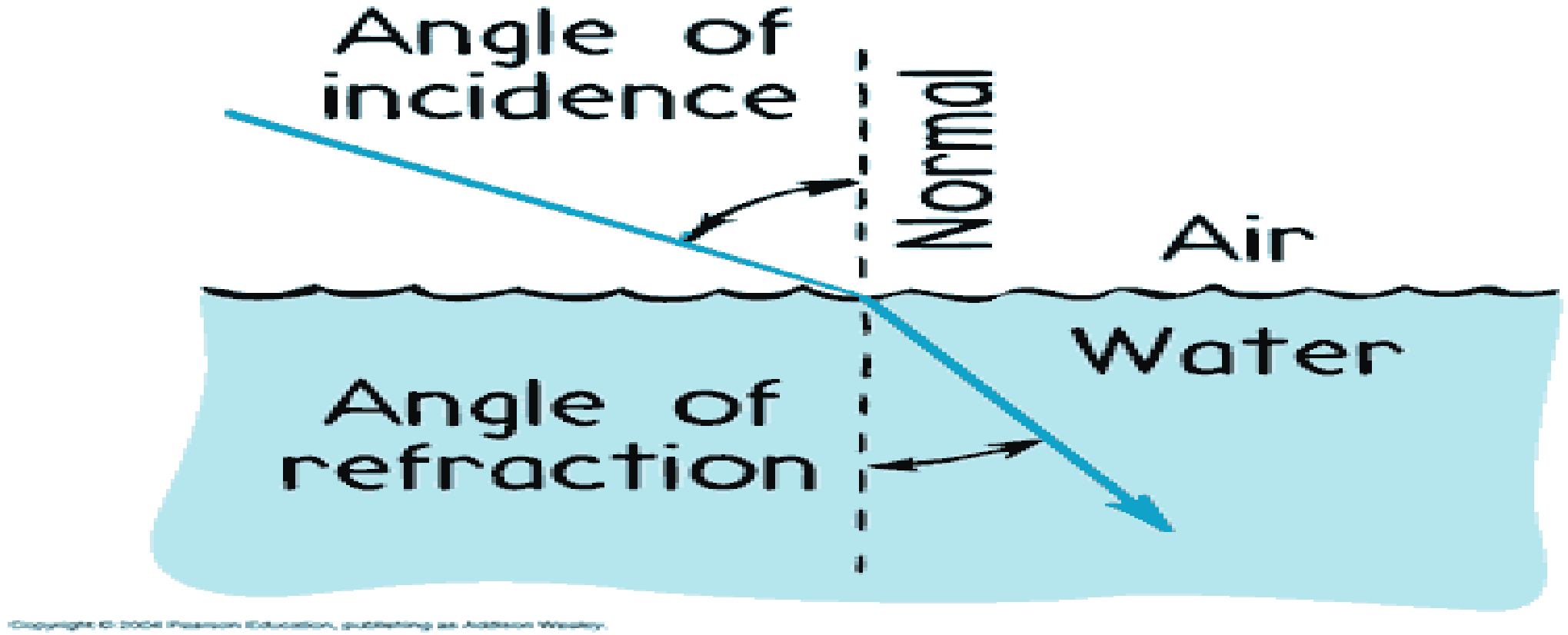
- The angle of incidence is **equal** to the angle of reflection
- The incident ray, the reflected ray & the normal all lie in the **same plane**.

Wave Interactions



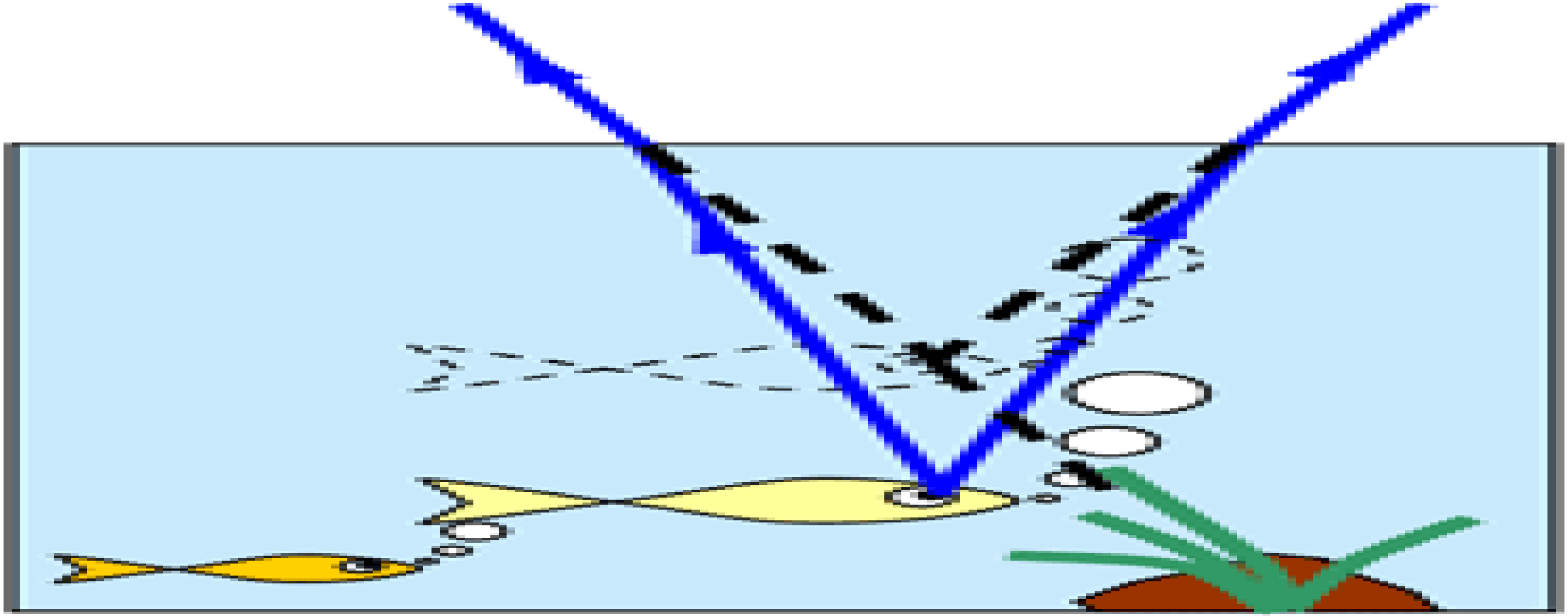
Reflection: bouncing back of waves after striking a barrier

Refraction



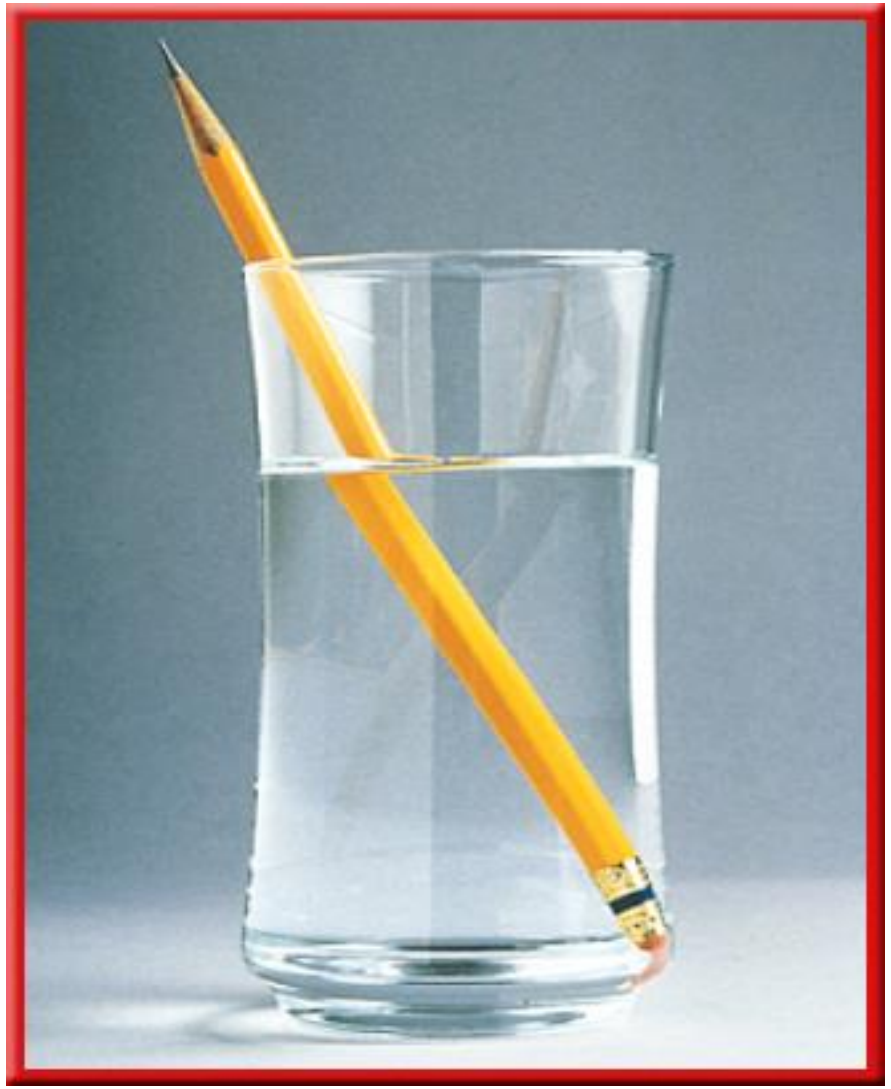
Refraction the bending of a wave when it enters a new medium at an angle.

Refraction

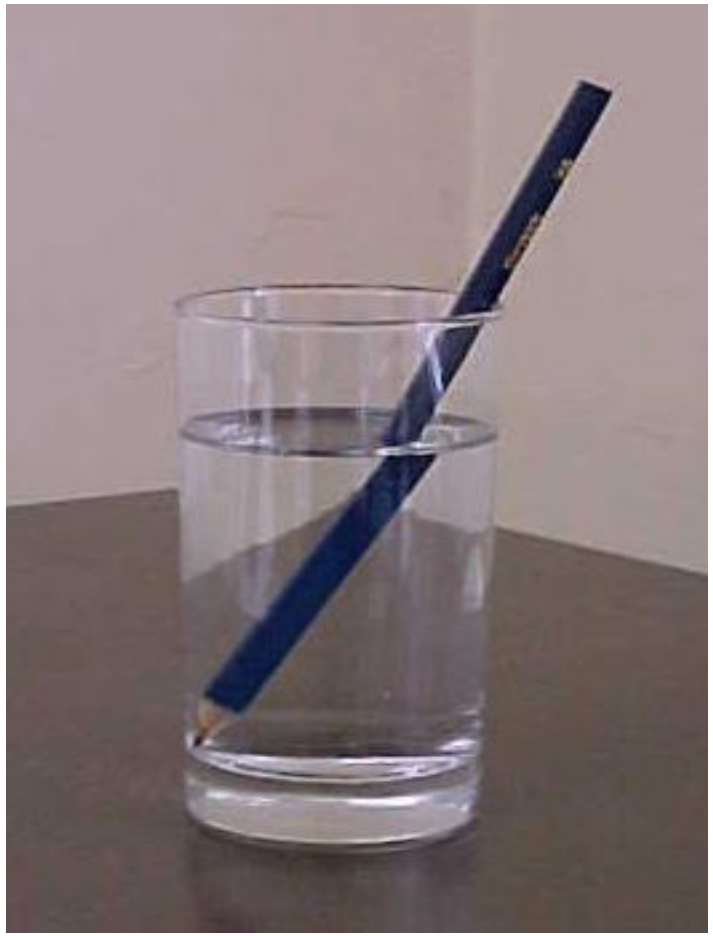


Refraction the bending of a wave when it enters a new medium at an angle.

- **Refraction** is the bending of a wave caused by a change in its speed as it moves from one medium to another.



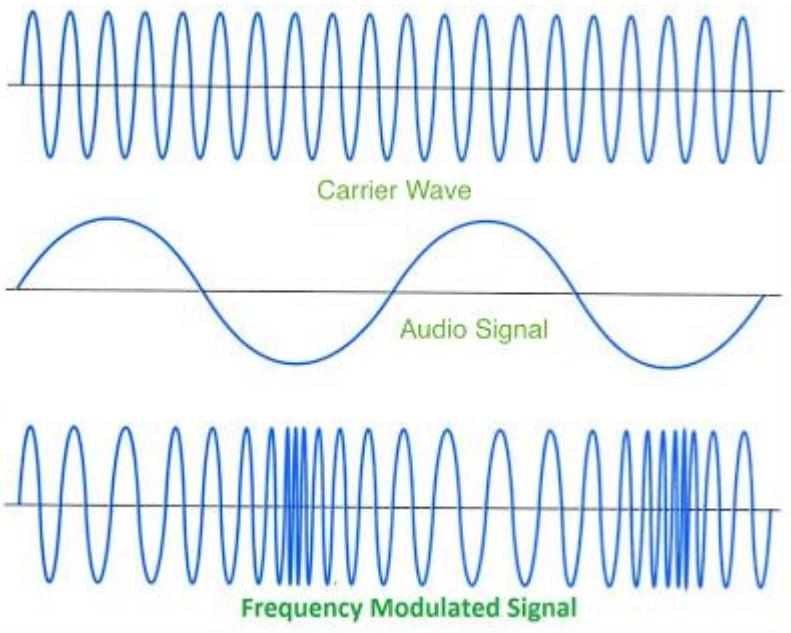
Refraction

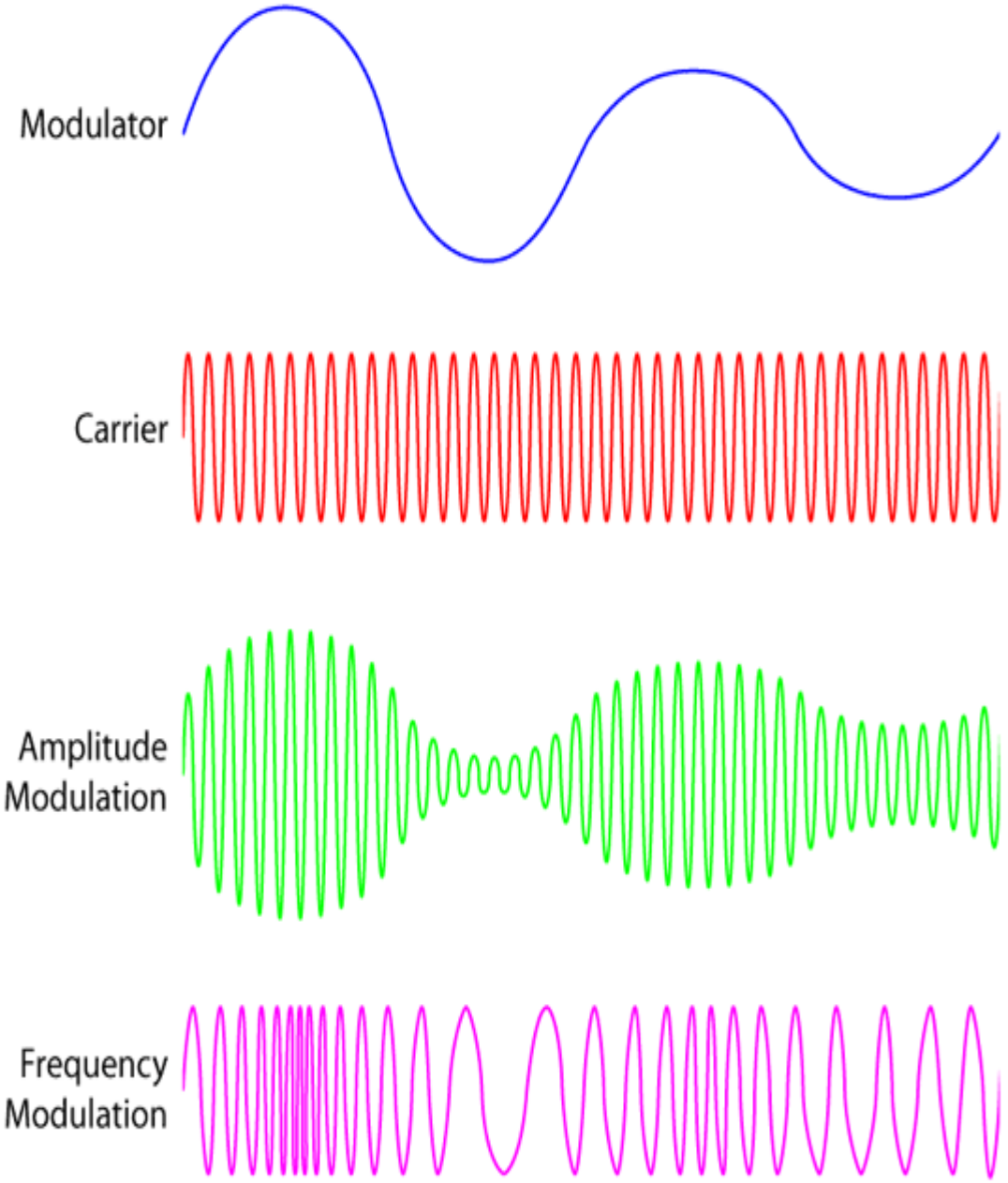


The light bends as it passes from air to water.

Carrier wave

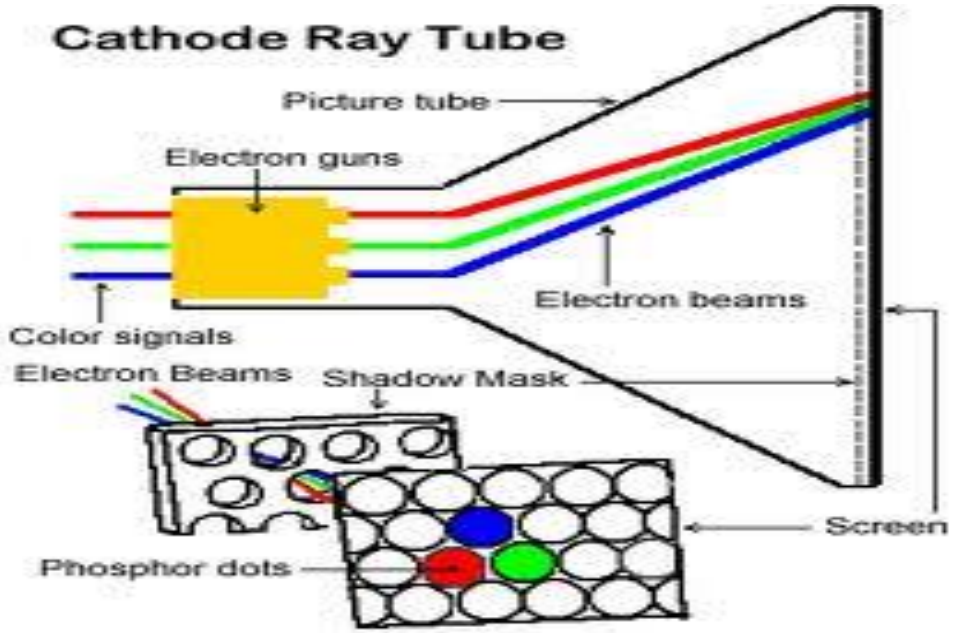
- A HIGH-FREQUENCY ELECTROMAGNETIC WAVE MODULATED IN AMPLITUDE OR FREQUENCY TO CONVEY A SIGNAL.

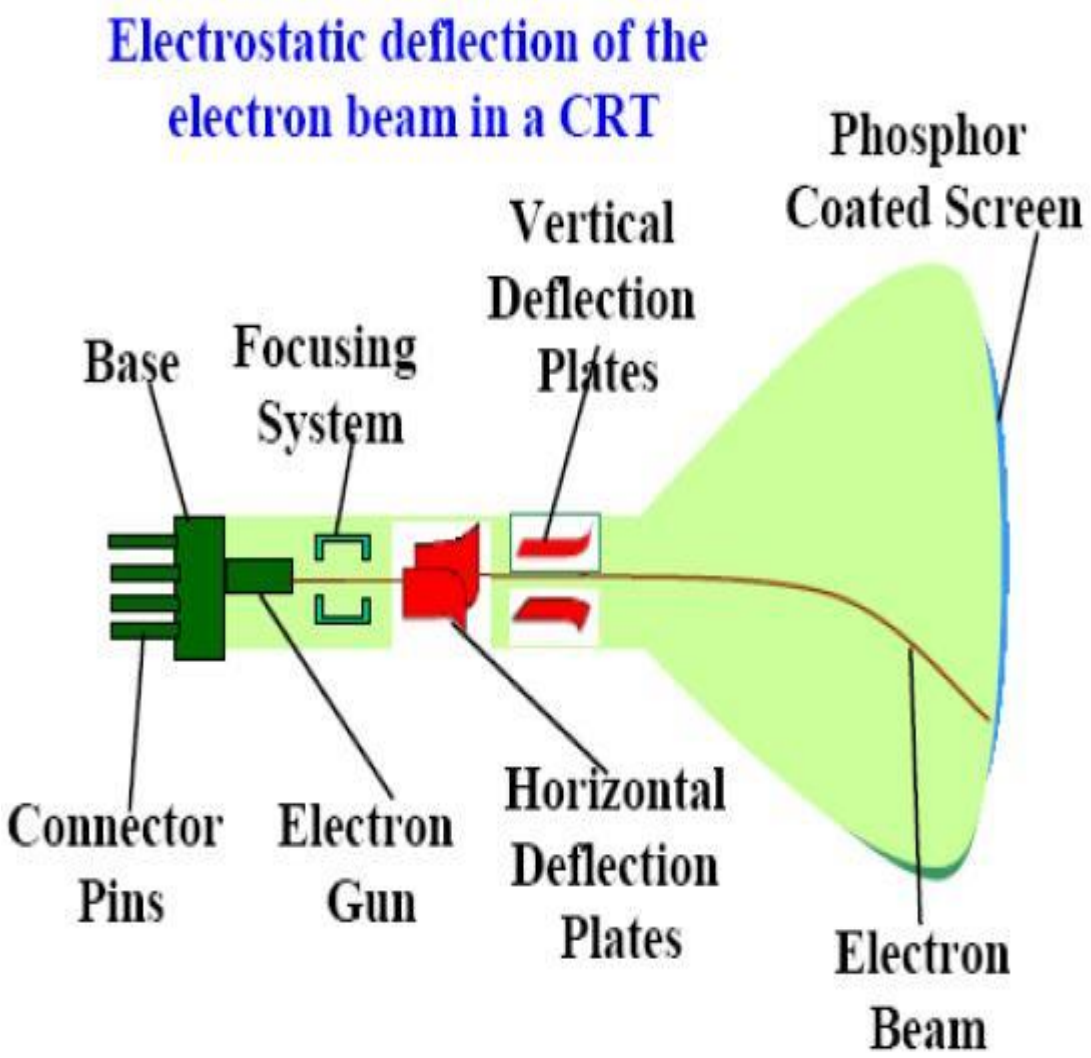




Cathode-ray tube

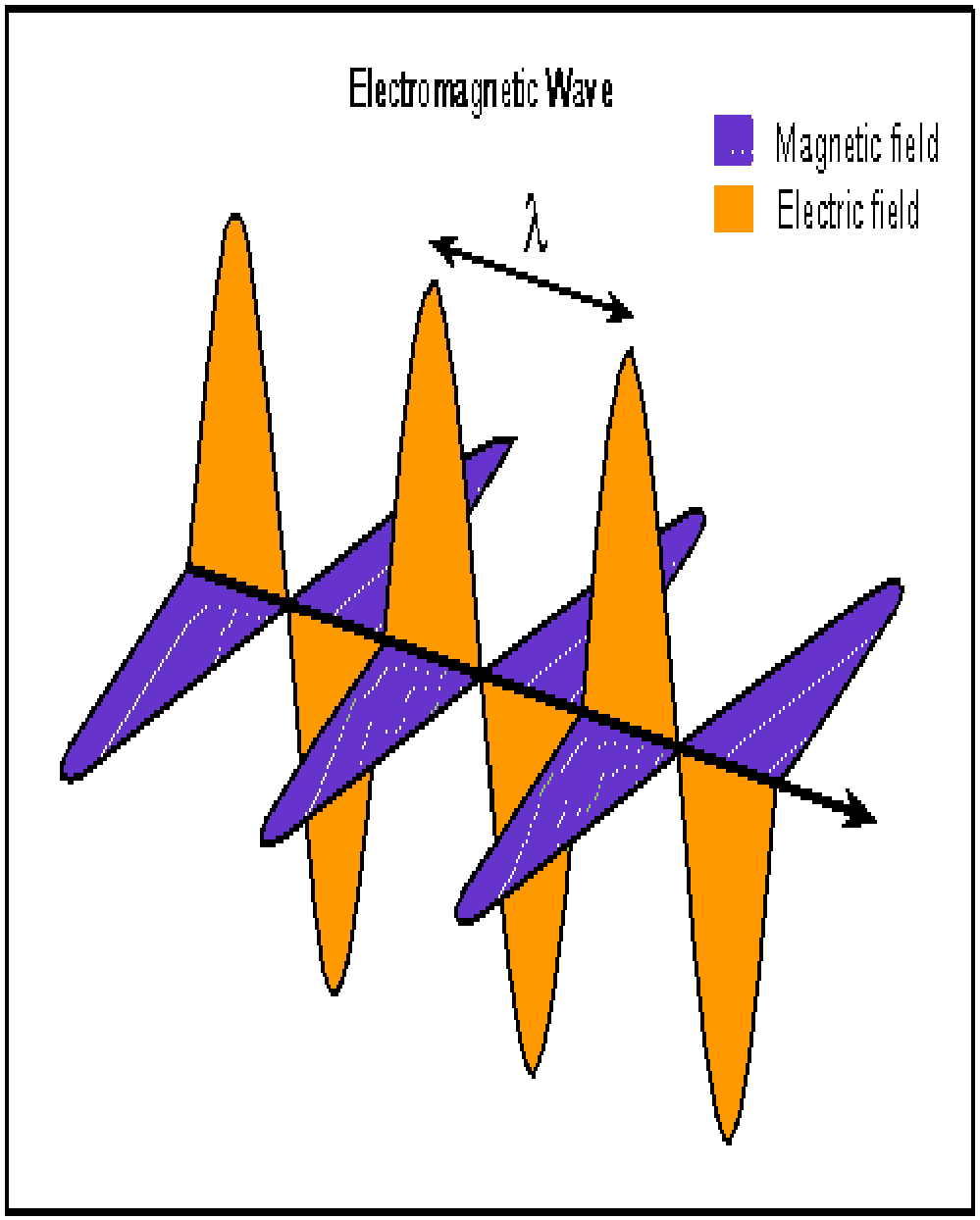
- A HIGH-VACUUM TUBE IN WHICH CATHODE RAYS PRODUCE A LUMINOUS IMAGE ON A FLUORESCENT SCREEN, USED CHIEFLY IN TELEVISIONS AND COMPUTER TERMINALS.





Electromagnetic Wave

Electromagnetic waves are formed by the vibrations of electric and magnetic fields. These fields are perpendicular to one another in the direction the **wave** is traveling. Once formed, this energy travels at the speed of light until further interaction with matter.

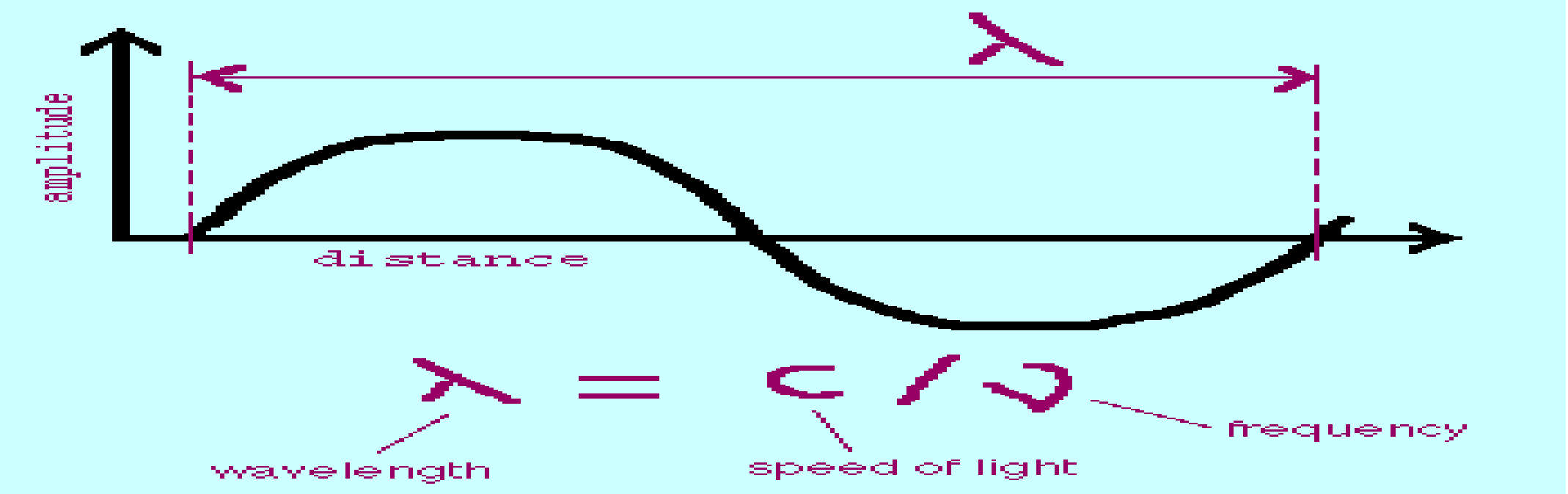


Electromagnetic Spectrum

- **Electromagnetic waves** are made by vibrating electric charges that can travel through space where matter is not present.

- Instead of transferring energy from particle to particle, electromagnetic waves travel by transferring energy between vibrating electric and magnetic fields.

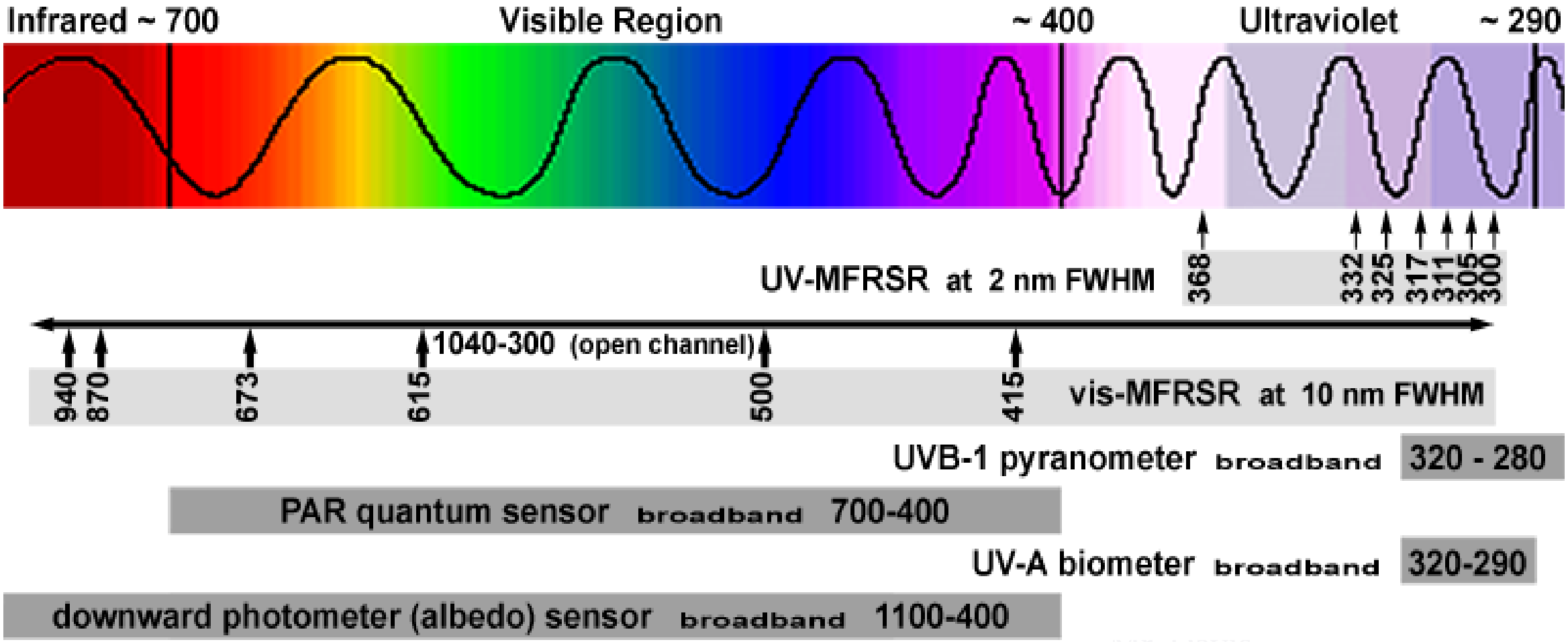
- The **electromagnetic spectrum** can be expressed in terms of energy, wavelength or frequency. The relationships are: the wavelength equals the speed of light divided by the frequency



- **Electromagnetic waves** are produced when something vibrates - an electric charge that moves back and forth.

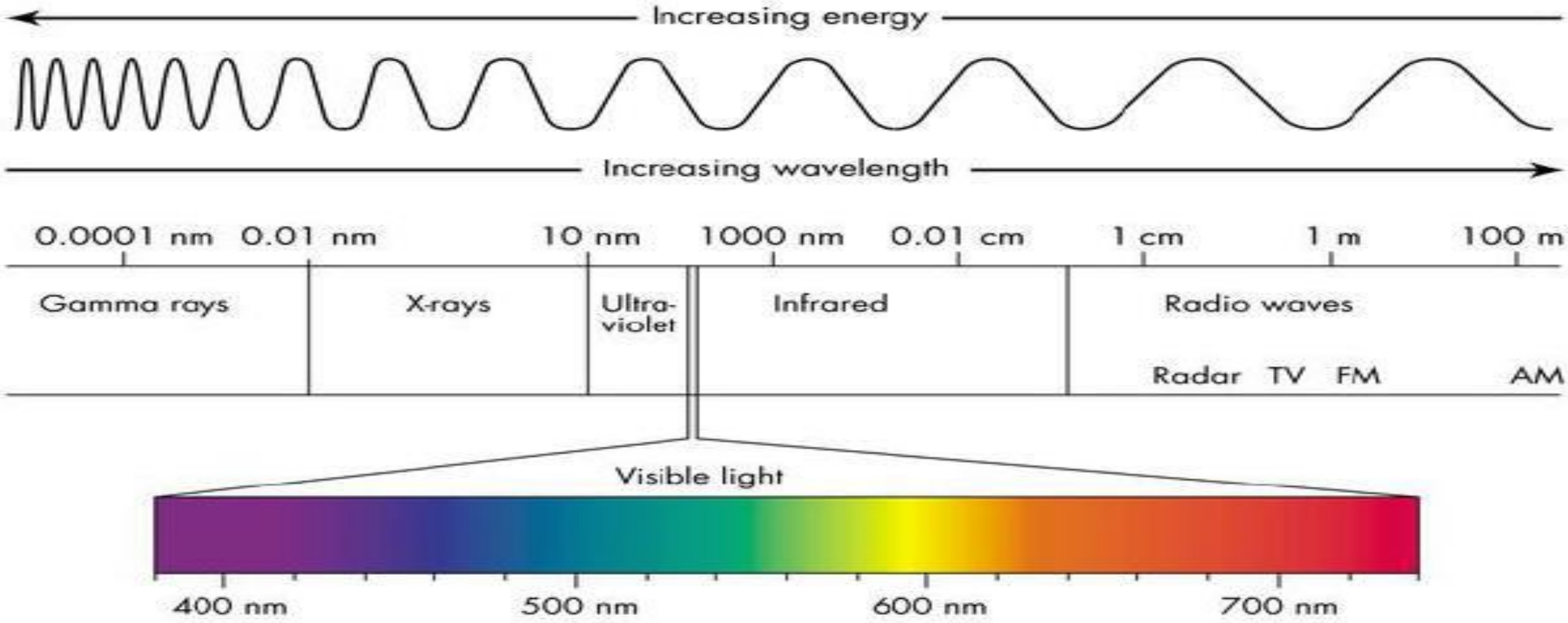
ELECTROMAGNETIC SPECTRUM

range of broad and discrete wavelengths (nanometers) as measured by UVMRP instruments

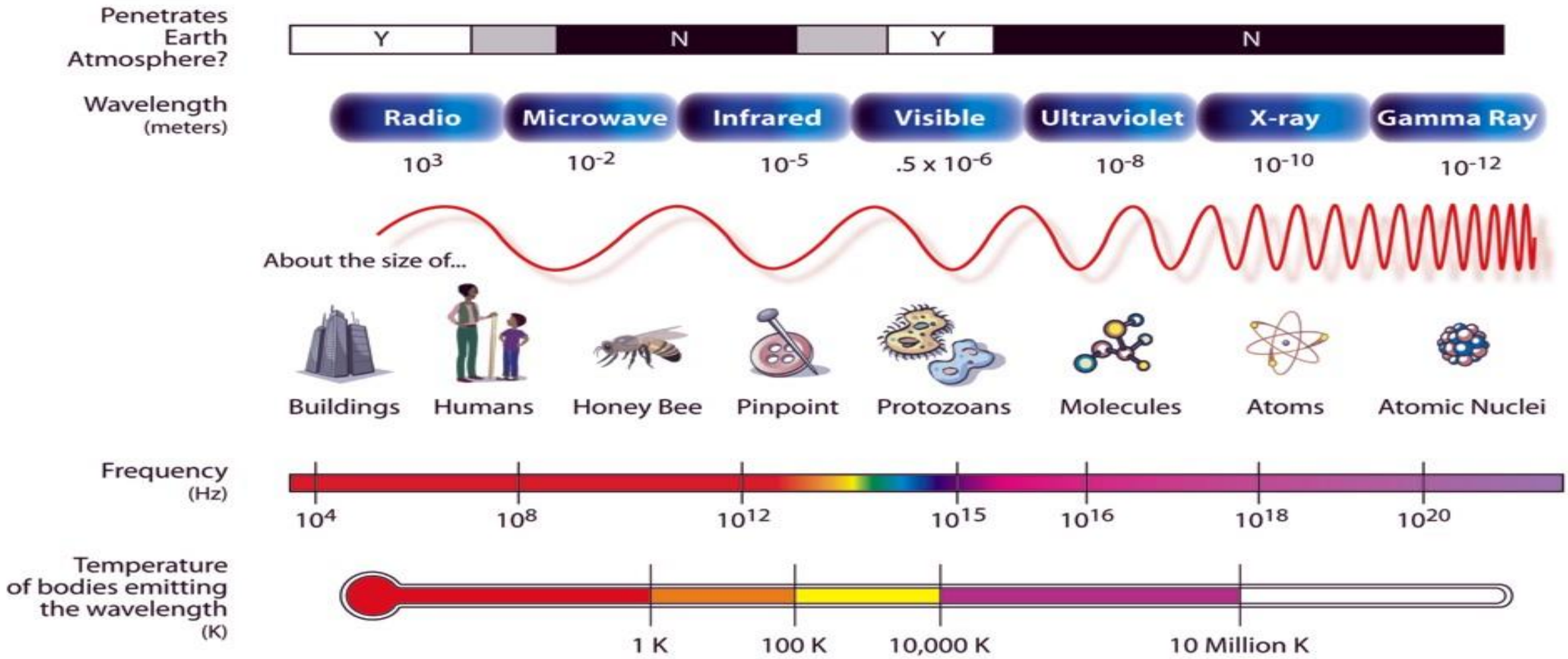


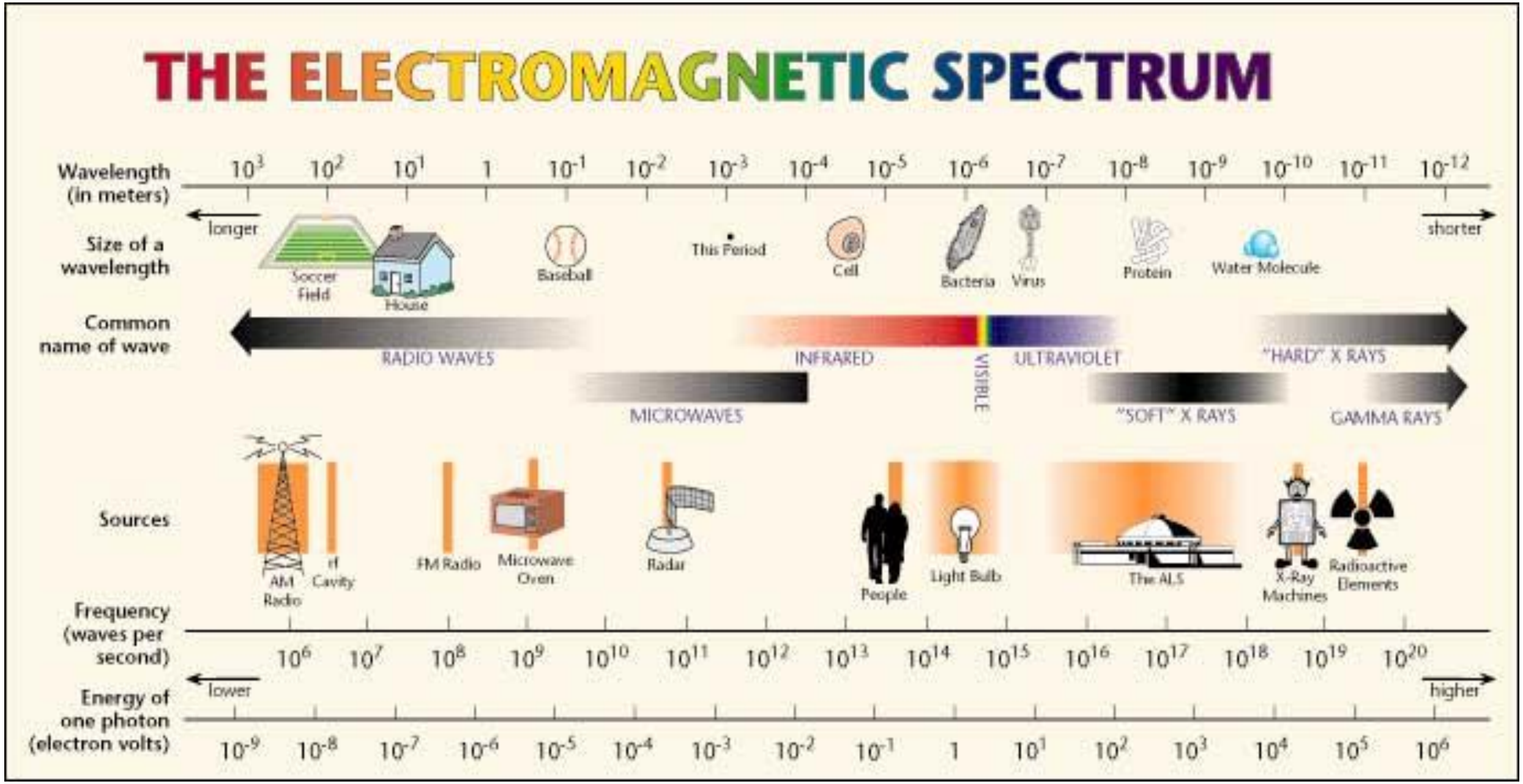
Mr. Davis

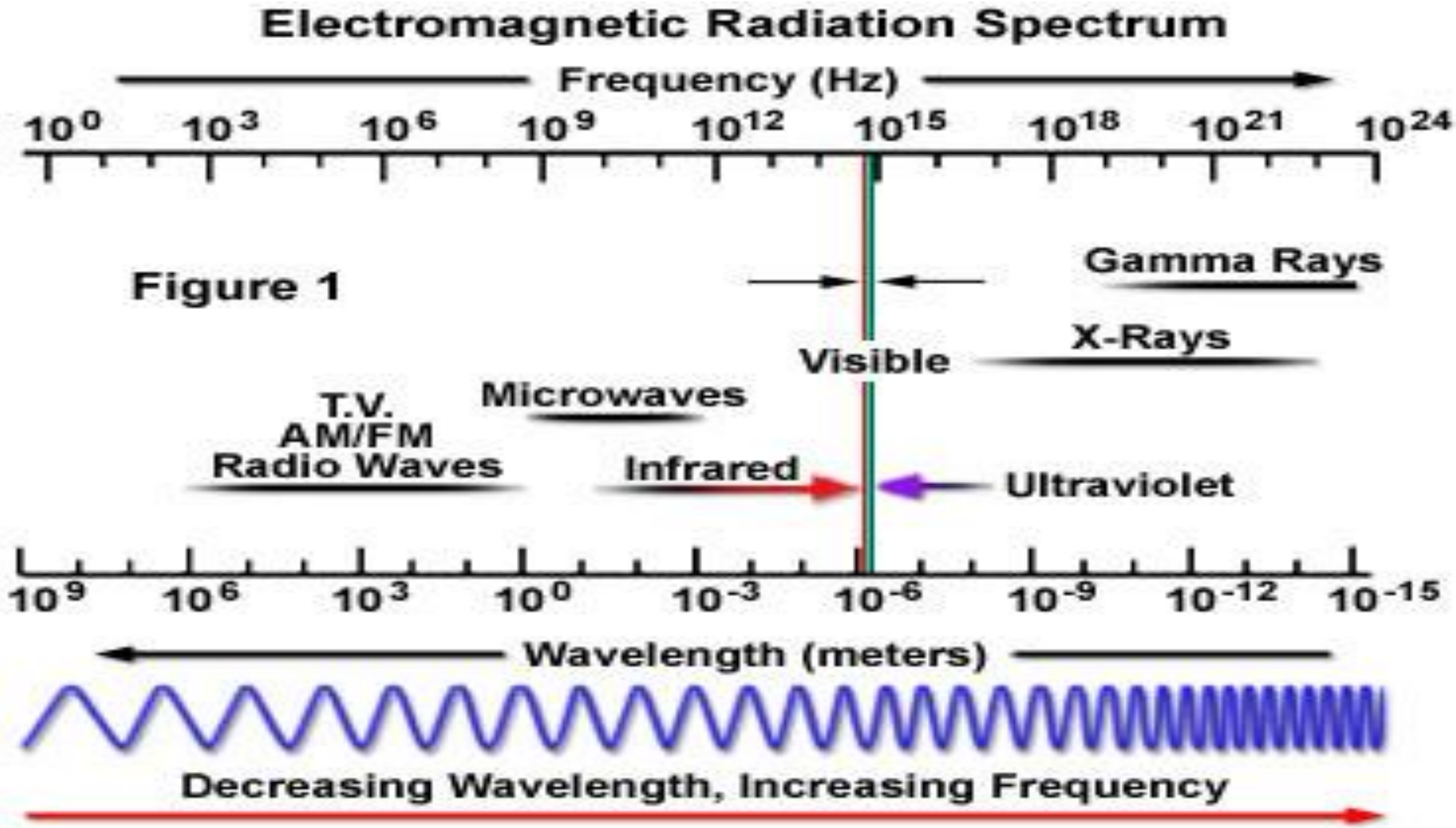
The Electromagnetic Spectrum

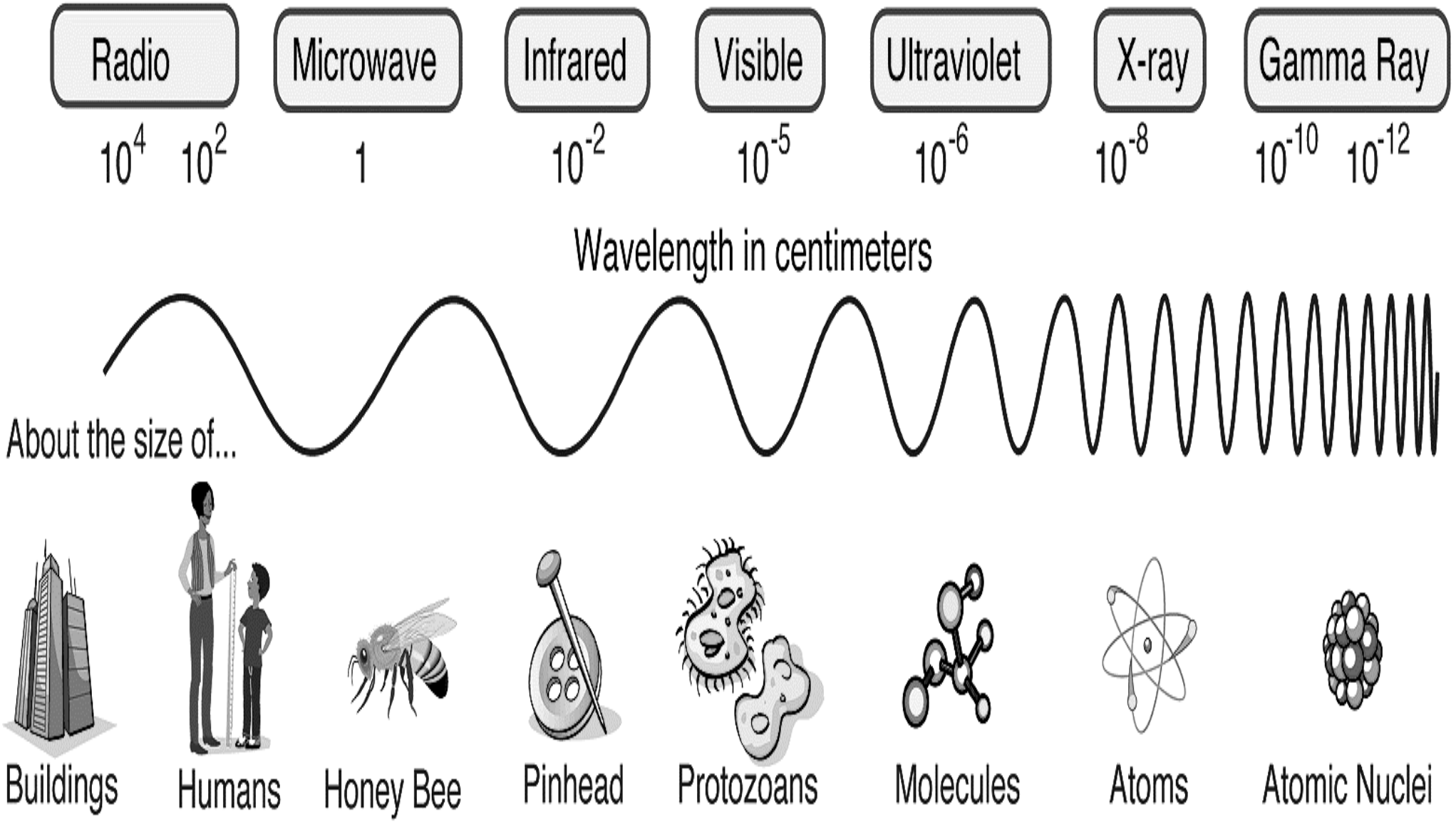


THE ELECTROMAGNETIC SPECTRUM




THE ELECTROMAGNETIC SPECTRUM
Wavelength (in meters)
10^3 10^2 10^1 1 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} 10^{-12}
longer
shorter
Size of a wavelength
Soccer Field
House
Baseball
This Period
Cell
Bacteria
Virus
Protein
Water Molecule
Common name of wave
RADIO WAVES
INFRARED
VISIBLE
ULTRAVIOLET
"HARD" X RAYS
MICROWAVES
"SOFT" X RAYS
GAMMA RAYS
Sources
AM Radio
rf Cavity
FM Radio
Microwave Oven
Radar
People
Light Bulb
The ALS
X-Ray Machines
Radioactive Elements
Frequency (waves per second)
10^6 10^7 10^8 10^9 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20}
lower
higher
Energy of one photon (electron volts)
10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10^1 10^2 10^3 10^4 10^5 10^6

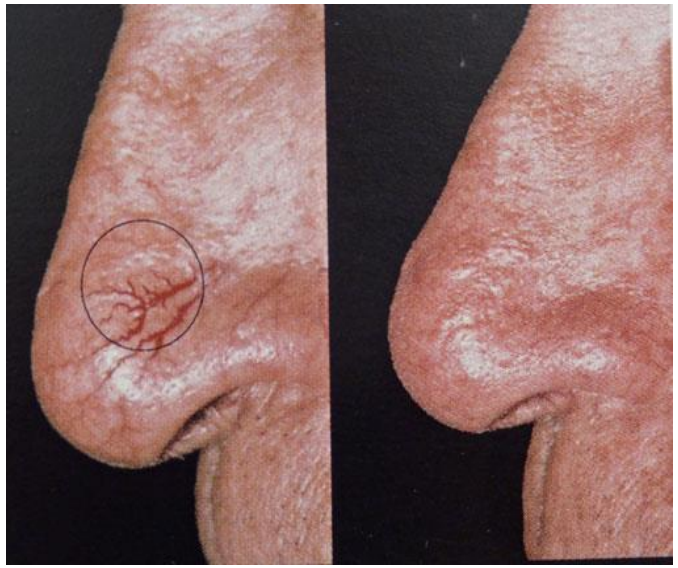

Electromagnetic Radiation Spectrum
Frequency (Hz)
10^0 10^3 10^6 10^9 10^{12} 10^{15} 10^{18} 10^{21} 10^{24}
Figure 1
Gamma Rays
X-Rays
Visible
Microwaves
T.V.
AM/FM
Radio Waves
Infrared
Ultraviolet
10^9 10^6 10^3 10^0 10^{-3} 10^{-6} 10^{-9} 10^{-12} 10^{-15}
Wavelength (meters)
Decreasing Wavelength, Increasing Frequency


Radio
Microwave
Infrared
Visible
Ultraviolet
X-ray
Gamma Ray
10^{4} 10^{2}
1
10^{-2}
10^{-5}
10^{-6}
10^{-8}
10^{-10} 10^{-12}
Wavelength in centimeters
About the size of...
Buildings
Humans
Honey Bee
Pinhead
Protozoans
Molecules
Atoms
Atomic Nuclei

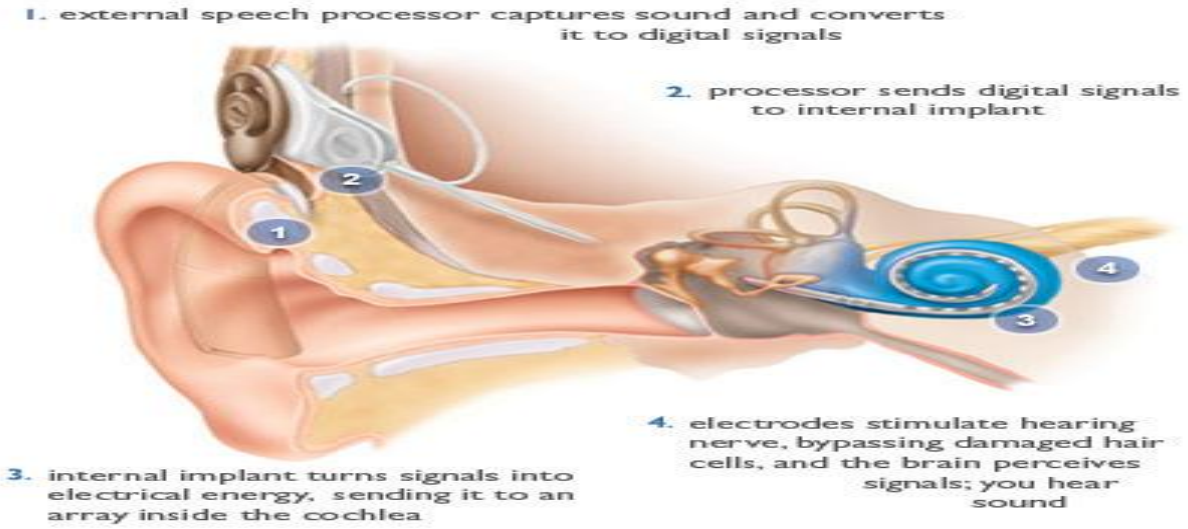
Radio waves

- are made by various types of **transmitter**, depending on the wavelength. They are also given off by stars, sparks and lightning, which is why you hear interference on your radio in a thunderstorm.

Large doses of radio waves are believed to cause **cancer**, leukaemia and other disorders.

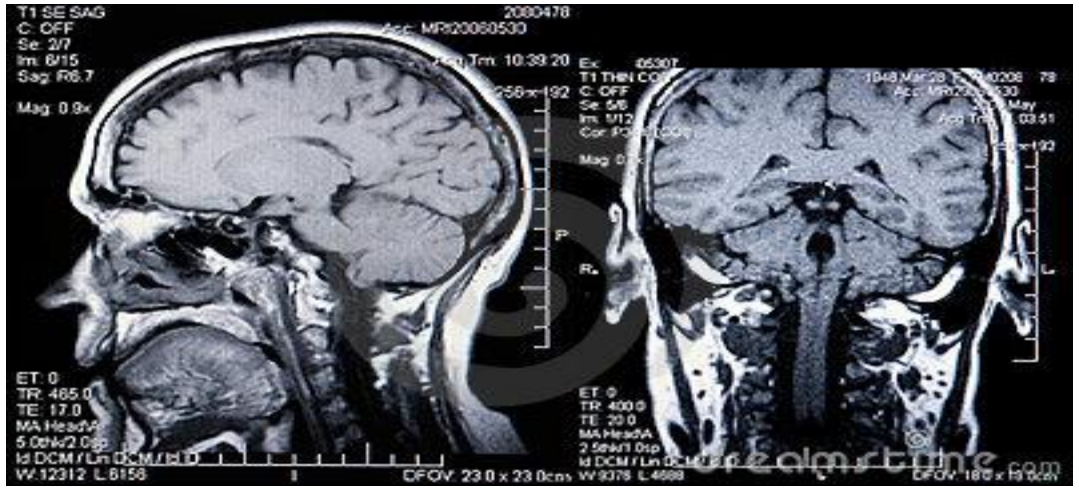


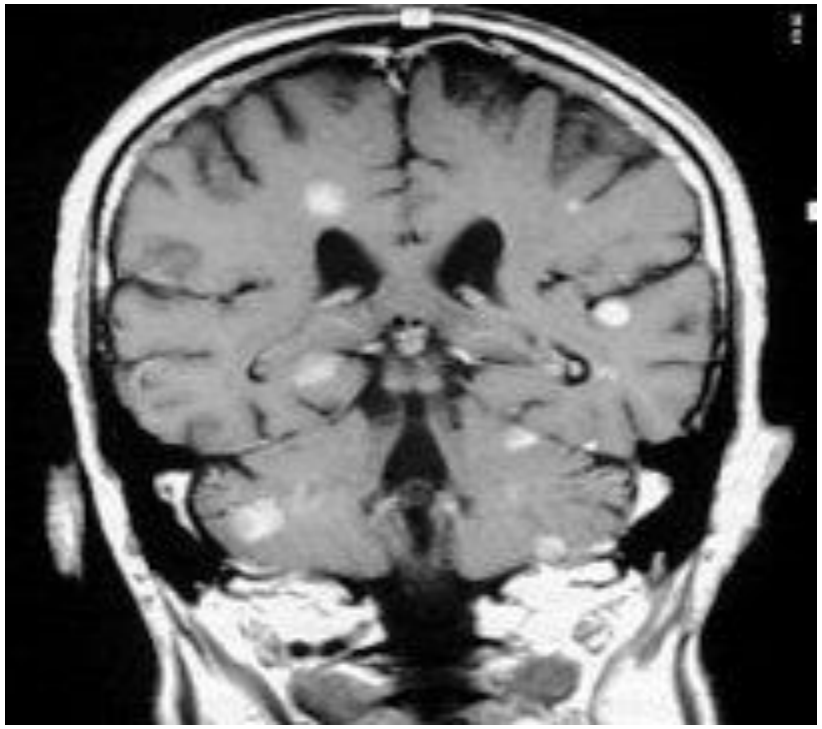
- **Radio waves** are low-frequency electromagnetic waves with wavelengths longer than about 1 mm.

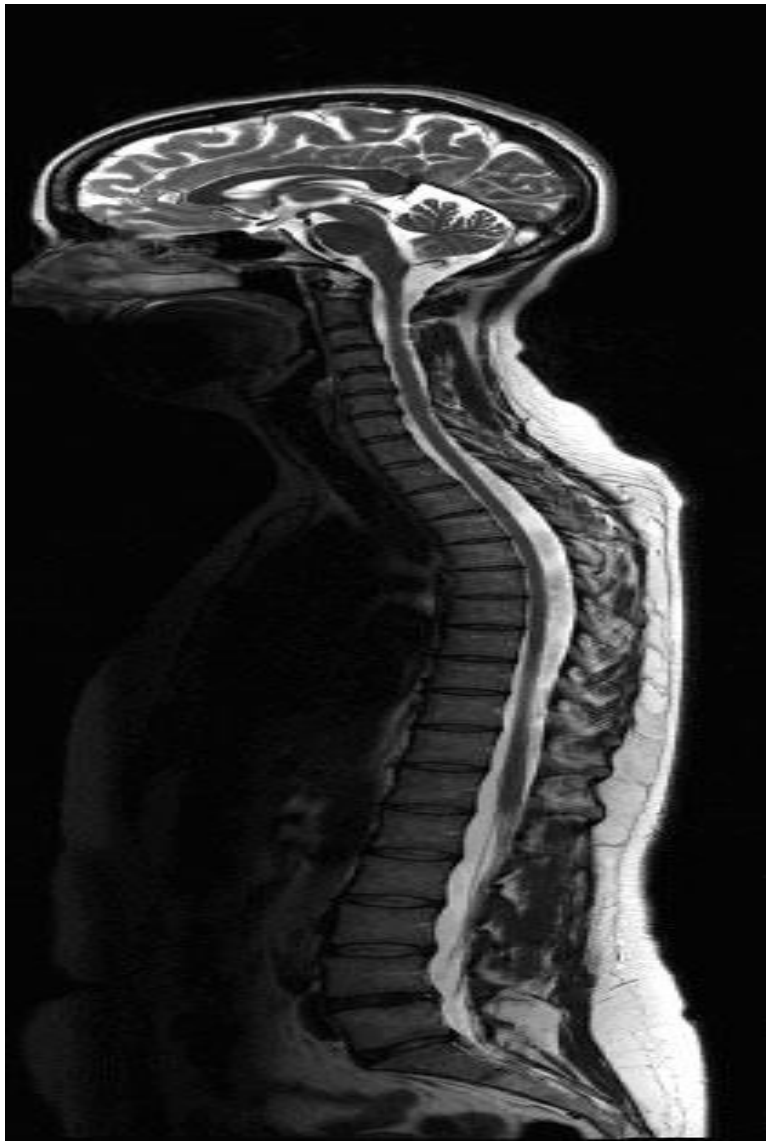


Magnetic Resonance Imaging (MRI)

- Magnetic Resonance Imaging uses radio waves to help diagnose illness.
  - The patient lies inside a large cylinder.
- Housed in the cylinder is a powerful magnet, a radio wave emitter, and a radio wave detector.







A 46 year old female presented with right knee pain and a palpable mass posterior to the knee.

Microwaves

- The vibrating electric field inside a microwave oven causes water molecules in food to rotate back and forth billions of times each second.

- This rotation causes a type of friction between water molecules that generates thermal energy.

Microwaves

are basically extremely high frequency radio waves, and are made by various types of **transmitter**.

Exposure to microwaves can cause "**cataracts**" in your eyes. Recent research indicates that microwaves from mobile phones can affect parts of your **brain** - after all, you're holding the transmitter right by your head.

Microwaves are Radio waves with wavelengths of less than 1 mm.

BURN EXAMPLES (left to right)
1st degree burn, 2nd degree burn which the serviceman has, and 3rd degree burn. [4]

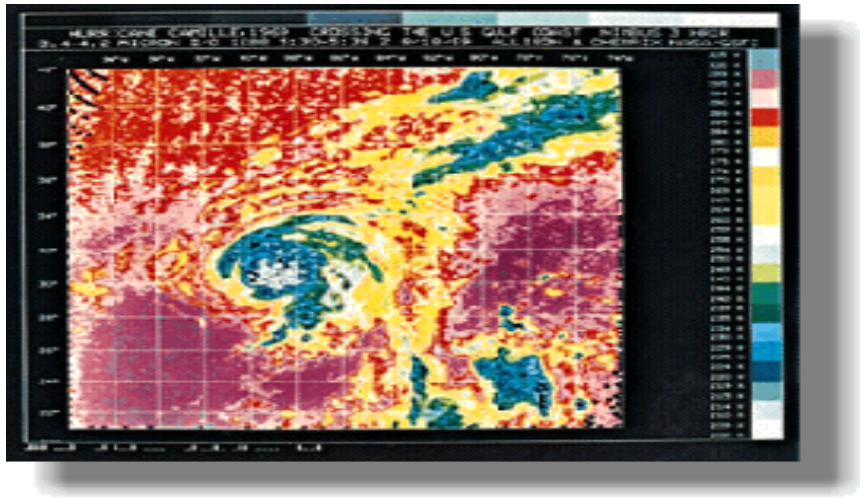
The new non-lethal weapon is based on emitting microwaves which cause a burning sensation to the skin.

Infrared Waves

- **Infrared Waves** are a type of electromagnetic wave with wavelengths between about 1 mm and about 750 billionths of a meter.

Infra-Red waves

- are **called "IR" for short**.
- They are used for many tasks, for example, **remote controls for TVs** and video recorders, and physiotherapists use heat lamps to help **heal sports injuries**.



You probably think of Infra-red waves as heat, because they're given off by **hot objects**, and you can feel them as warmth on your skin.

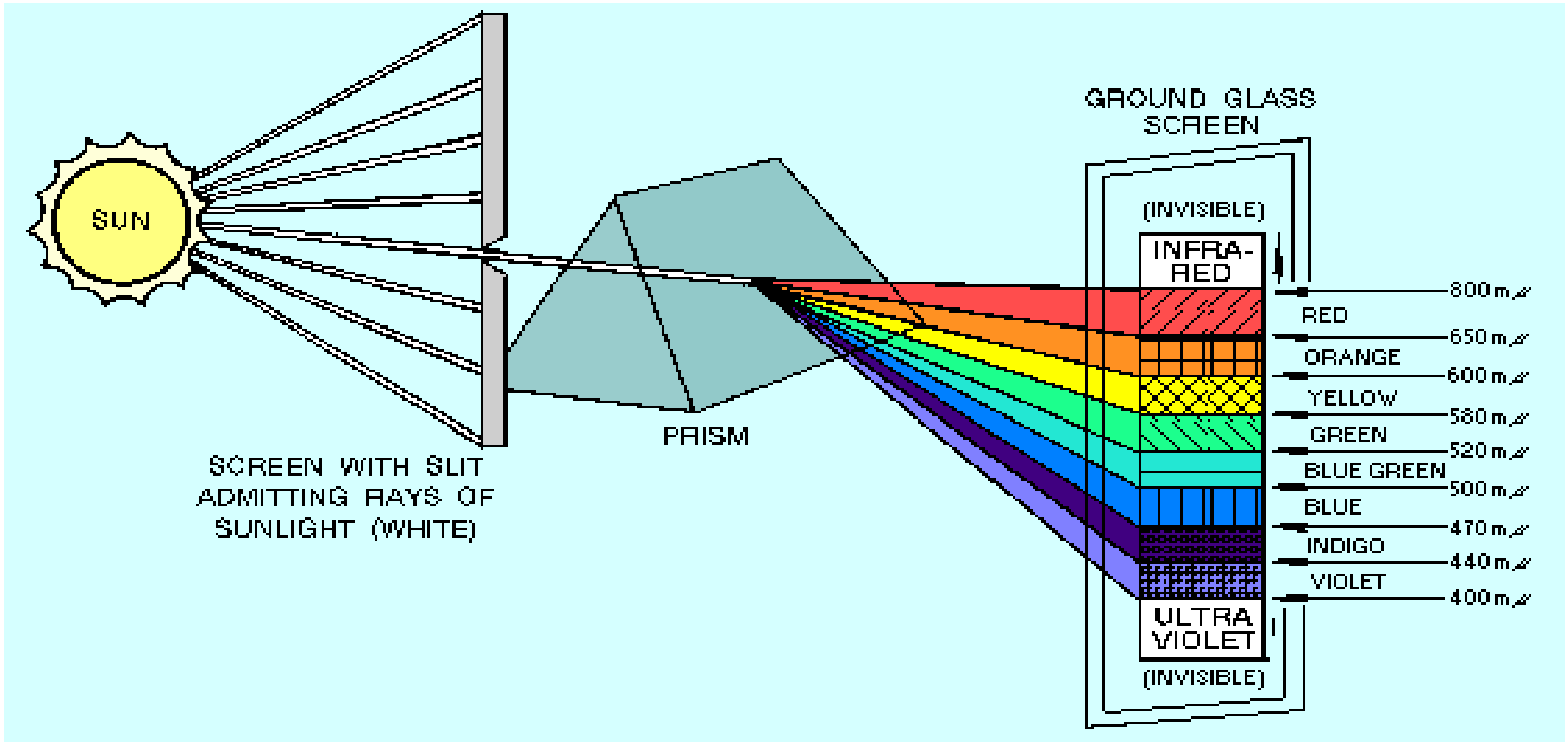
Infra-red waves

Skin injury

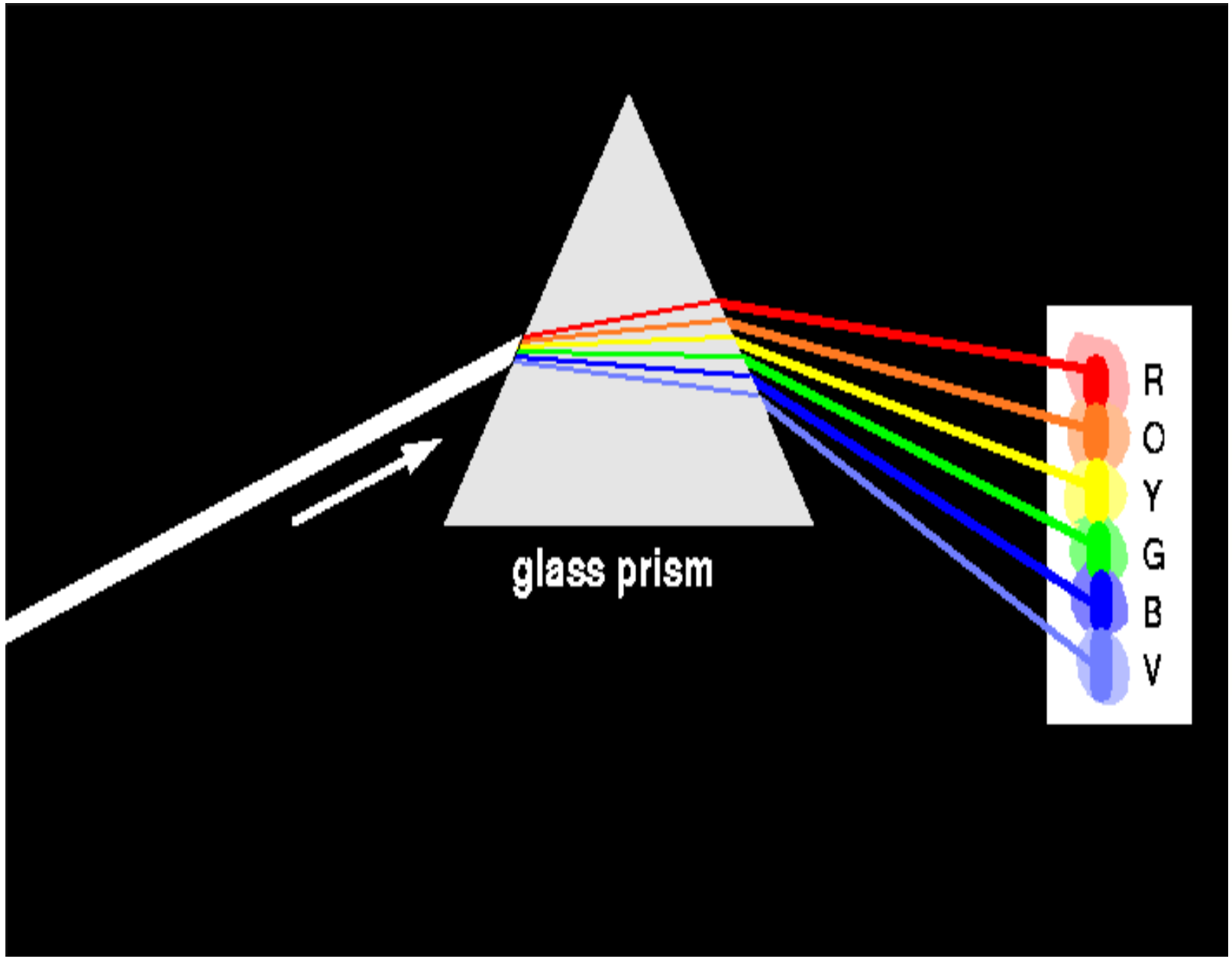
Basal cell carcinoma in the medial canthus poses a high risk of recurrence

Skin injury from laser irradiation can occur due to thermal interaction with tissues. The skin has a higher resistance potential than the eyes, to any kind of intense radiation. The interaction is correlated to the wavelength of the radiation

Visible Light



Visible Light Spectrum



Electromagnetic Radiation

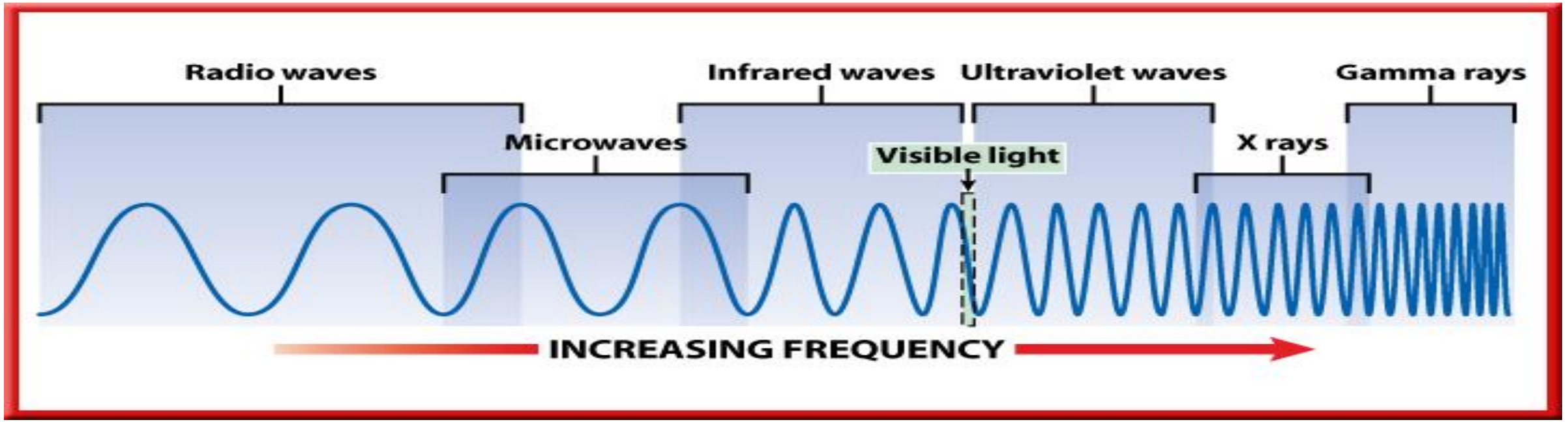
Infrared > 625 nm

visible light	Wavelength (nm)
Red	625 - 740
Orange	590 - 625
Yellow	565 - 590
Green	520 - 565
Cyan	500 - 520
Blue	435 - 500
Violet	380 - 435

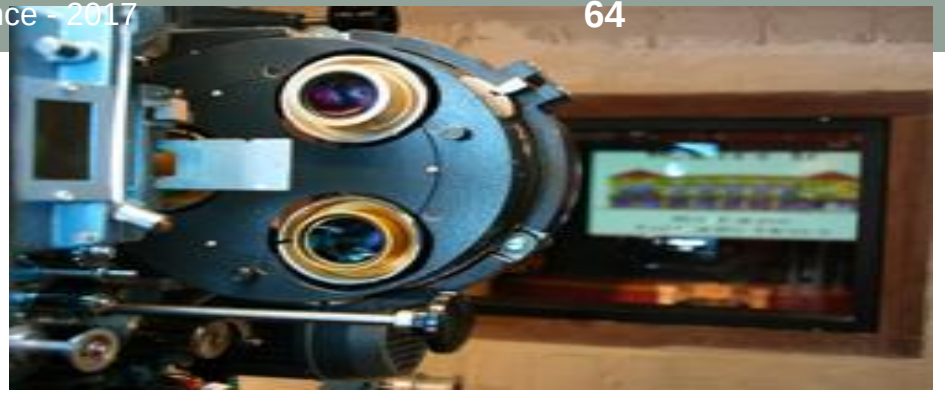
Ultraviolet < 380 nm

Visible Light

- **Visible light** is the range of electromagnetic waves that you can detect with your eyes.
- Visible light has wavelengths around 750 billionths to 400 billionths of a meter.



Visible Light



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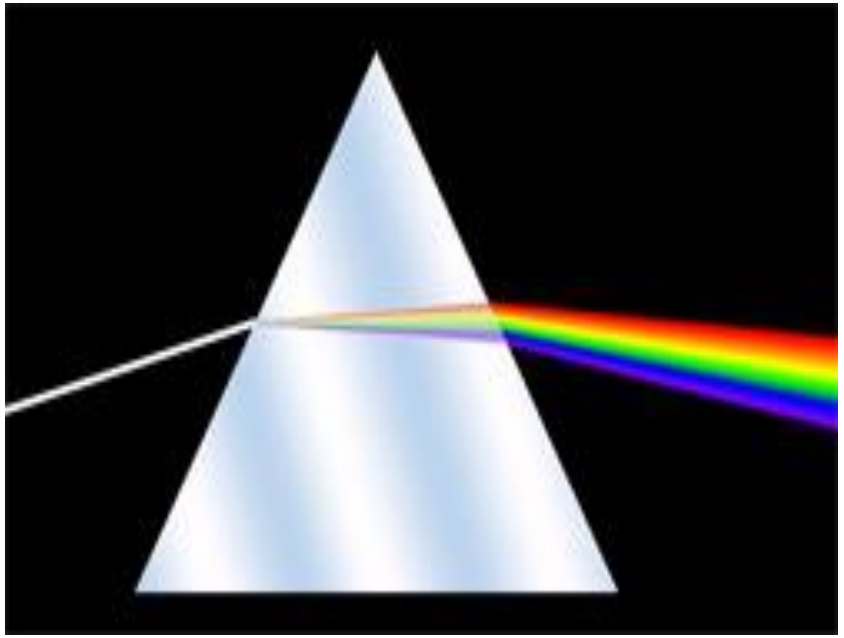
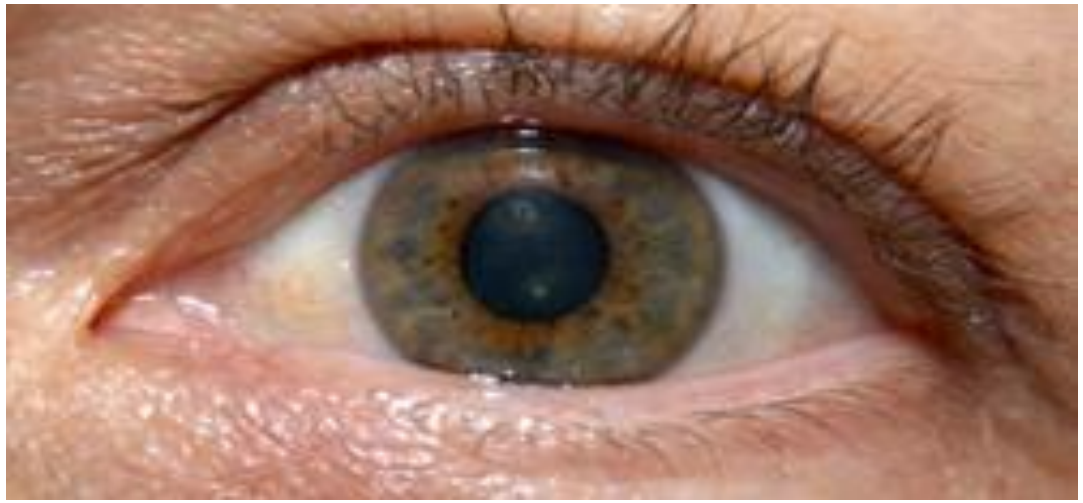




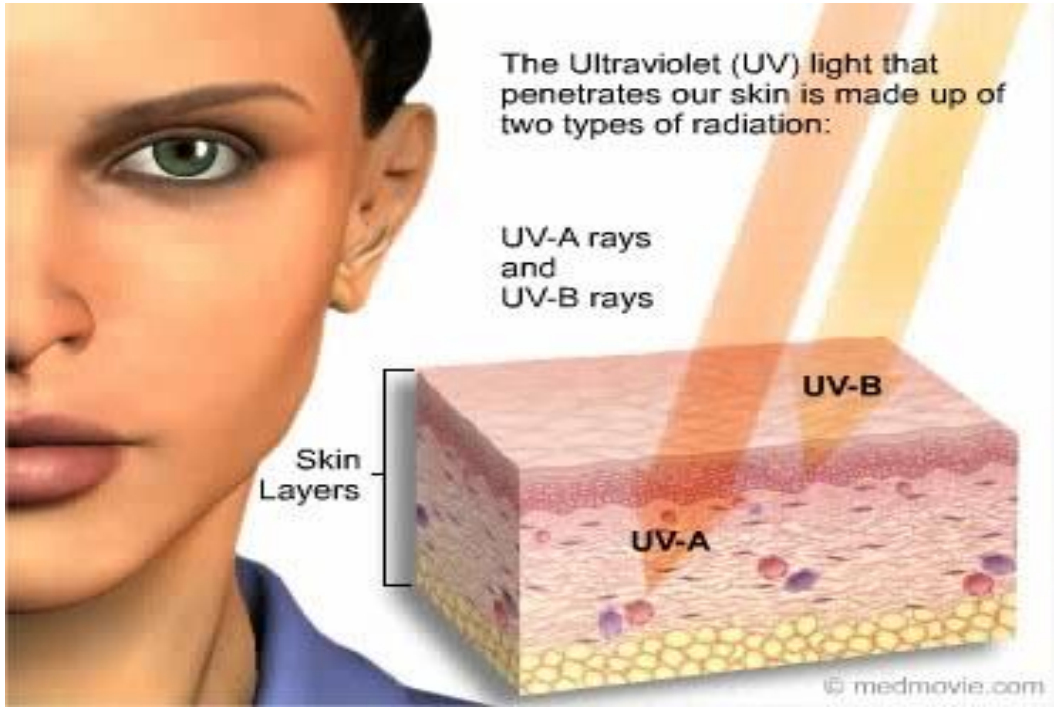
Too much light can **damage the retina** in your eye.

White light is actually made up of a whole range of colours, mixed together.

Ultra-Violet light

- **Ultraviolet waves** are electromagnetic waves with wavelengths from about 400 billionths to 10 billionths of a meter.
- **We call it "UV" for short**. Uses for UV light include getting a **sun tan**, **detecting forged bank notes** in shops, and hardening some types of dental filling.

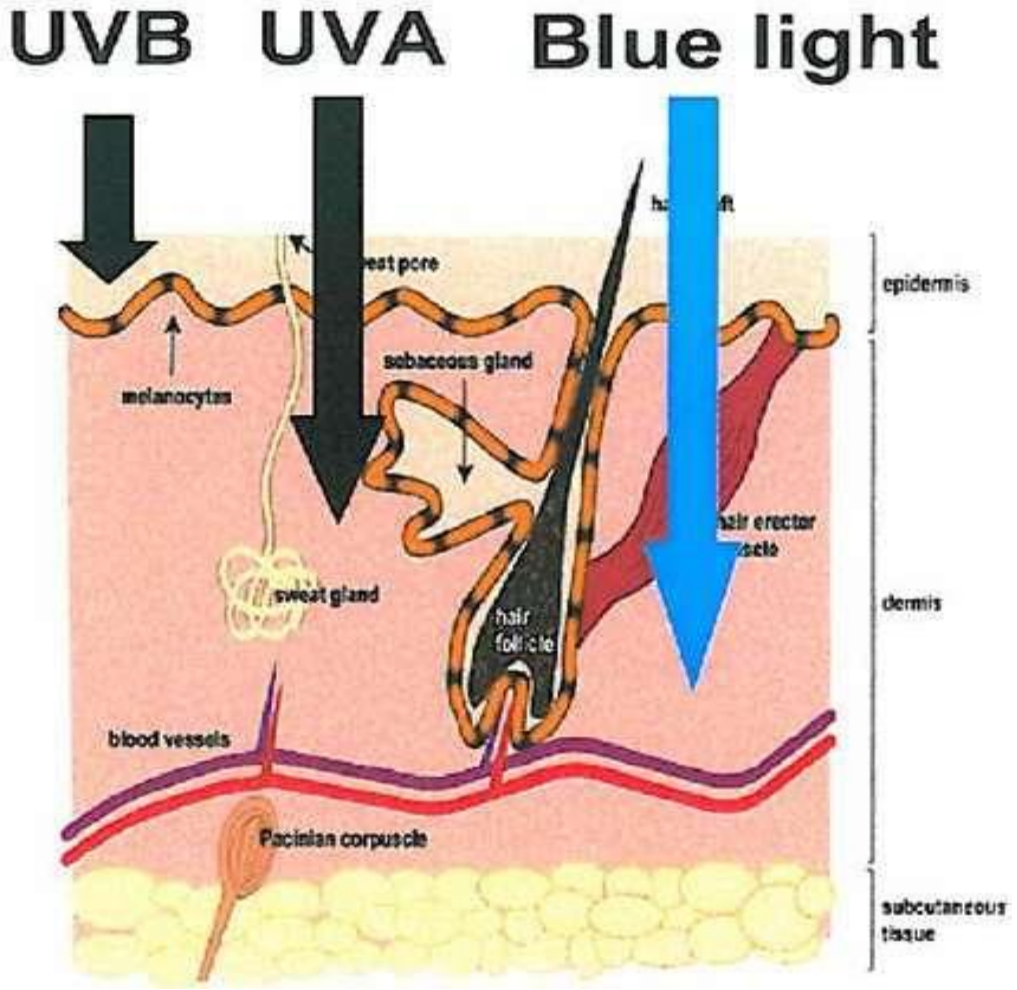
Ultraviolet rays can be used to **kill microbes**.
Food and drug companies also use UV lamps to sterilize their products.



AESTIVÁL®
Radiance

Light exposure

- UVB rays (290-320 nm) : sunburn, skin thickening
- UVA rays (320-400 nm) : fine lines and wrinkling
- Visible blue light (420-480 nm) : free radical damage



UV Photography Reveals Sun Damage

UV Photography Reveals Sun DamageSome dermatologists use ultraviolet (UV) photography to show their patients how the sun has damaged the skin. In the following patient photographs, the two photographs on the left in each series were taken in ordinary light and show what is visible to the naked eye. The picture on the right was taken with a UV-light camera and illustrates the amount of damage that lies beneath the surface of the skin.

At age 18 months, sun damage is not yet apparent.

At age 4 years, early sun damage is evident. Notice the freckling across the nose and cheeks.

The photograph above shows that this 17-year-old already has significant sun damage.

This 37-year-old woman has subsurface sun damage, which is clearly visible in the photo on the right.

At 52, this woman has "prematurely aged" skin in visible light and significantly sun-damaged skin in ultraviolet light.

This 64-year-old beach community resident has skin that chronicles a lifetime of chronic sun exposure. UV photography is not necessary to see that her skin is dry, inelastic, wrinkled, and heavily mottled.

(Photos provided courtesy of David H. McDaniel, M.D.)

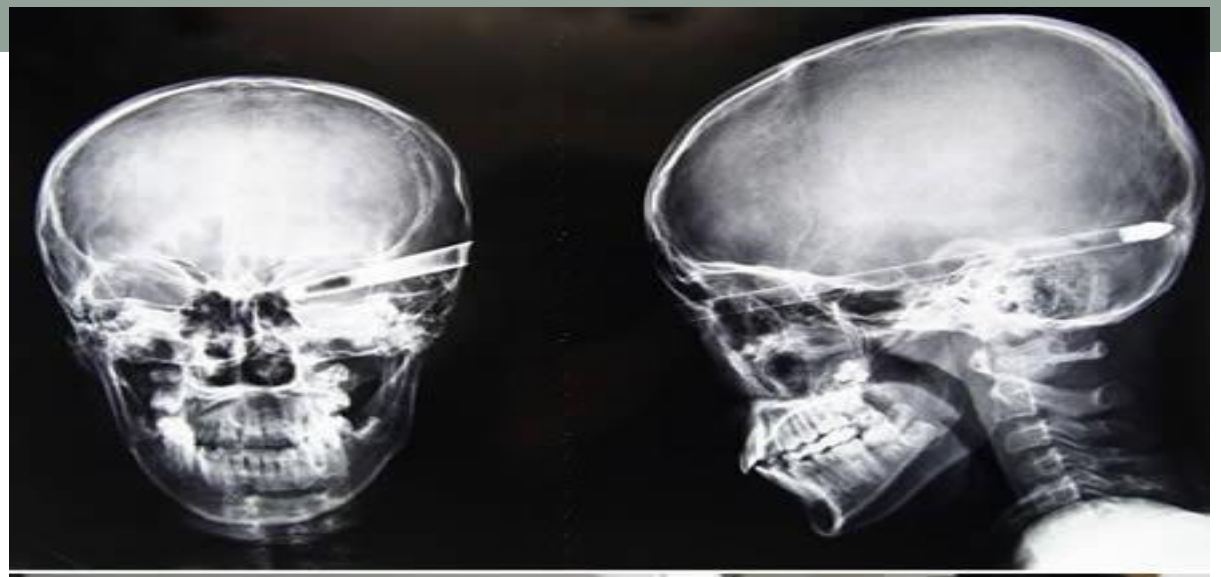
AAD

An educational program brought to you by the American Academy of Dermatology.

X-rays

- are very high frequency waves, and carry a lot of energy. They will pass through most substances, and this makes them useful in medicine and industry to see inside things.
- An **X-ray machine** works by firing a beam of electrons at a "target".

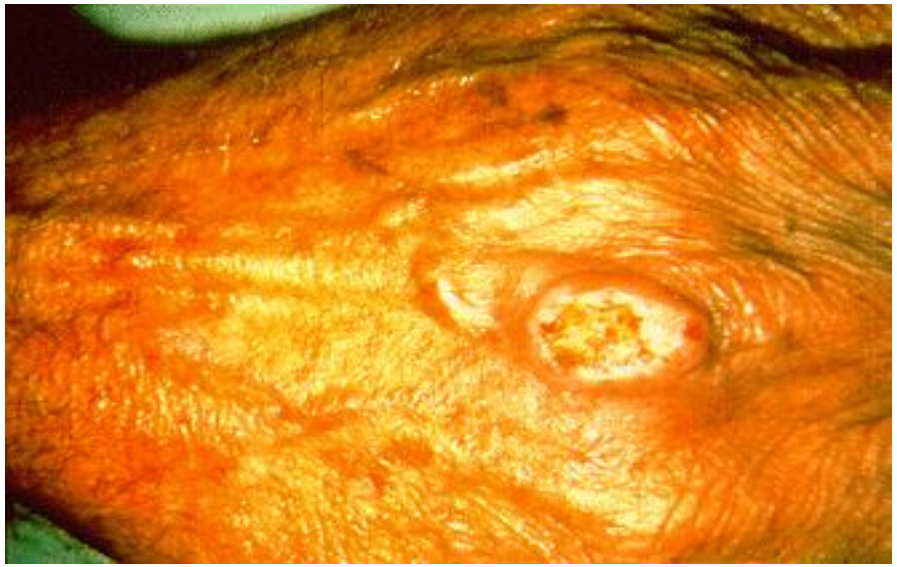
X-Rays can cause **cell damage** and **cancers**.



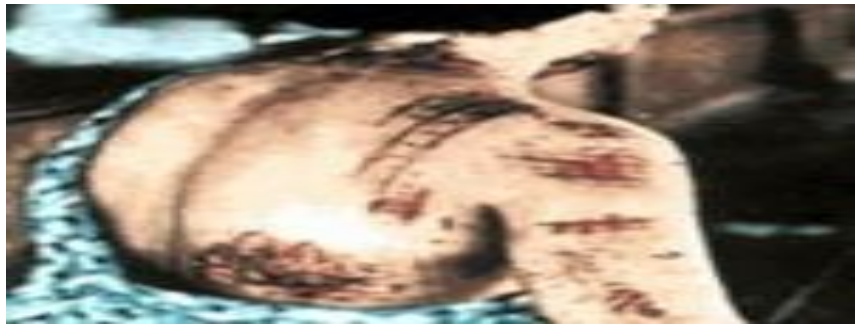
Teenage boy cheated death when a 5-inch knife was plunged into his head.

Chinese schoolboy had a brush with death when his friend shot him in the head with a 16-inch arrow

Gamma Rays



Squamous cell skin cancer and basal cell skin cancers are common complications of chronic radiodermatitis



The EM Spectrum - (Uses & Dangers)

Wave	Uses	Dangers
RADIO WAVES	Radio transmitters Radar Television	None
MICROWAVES	Microwave ovens Communication system	Internal heating of body tissue
INFRA-RED WAVES	Thermal imaging Remote controls	Burns skin
LIGHT WAVES	Optic fibers Seeing!	Strong light causes damage to vision.
ULTRA-VIOLET WAVES	Washing powder (whiter than white) Security marking	Skin cancer and blindness
X RAYS	Taking images of the skeleton	Mutations in cells and severe burns to the skin.
GAMMA RAYS	Cancer treatment Sterilisation of equipment	Cancers and cell mutation

amma Rays

- They are extremely high frequency waves, and carry a large amount of energy.
- Gamma rays can kill living cells, they are used to **kill cancer cells** without having to resort to difficult surgery.

Gamma rays cause **cell damage** and can cause a variety of cancers.
They cause **mutations** in growing tissues, so unborn babies are especially vulnerable.

EM Spectrum

Type of EM Wave	Typical Unit of Measure
radio	meter (m) centimeter (cm)=0.01 m
microwave (radar)	millimeter (mm)=0.001 m
infrared	micrometer (um)=10^{-6}m
visible	nanometer (nm)=10^{-9}m; 10^{-3}um
ultraviolet	angstrom (Å)=10^{-10}m