Optics

By:

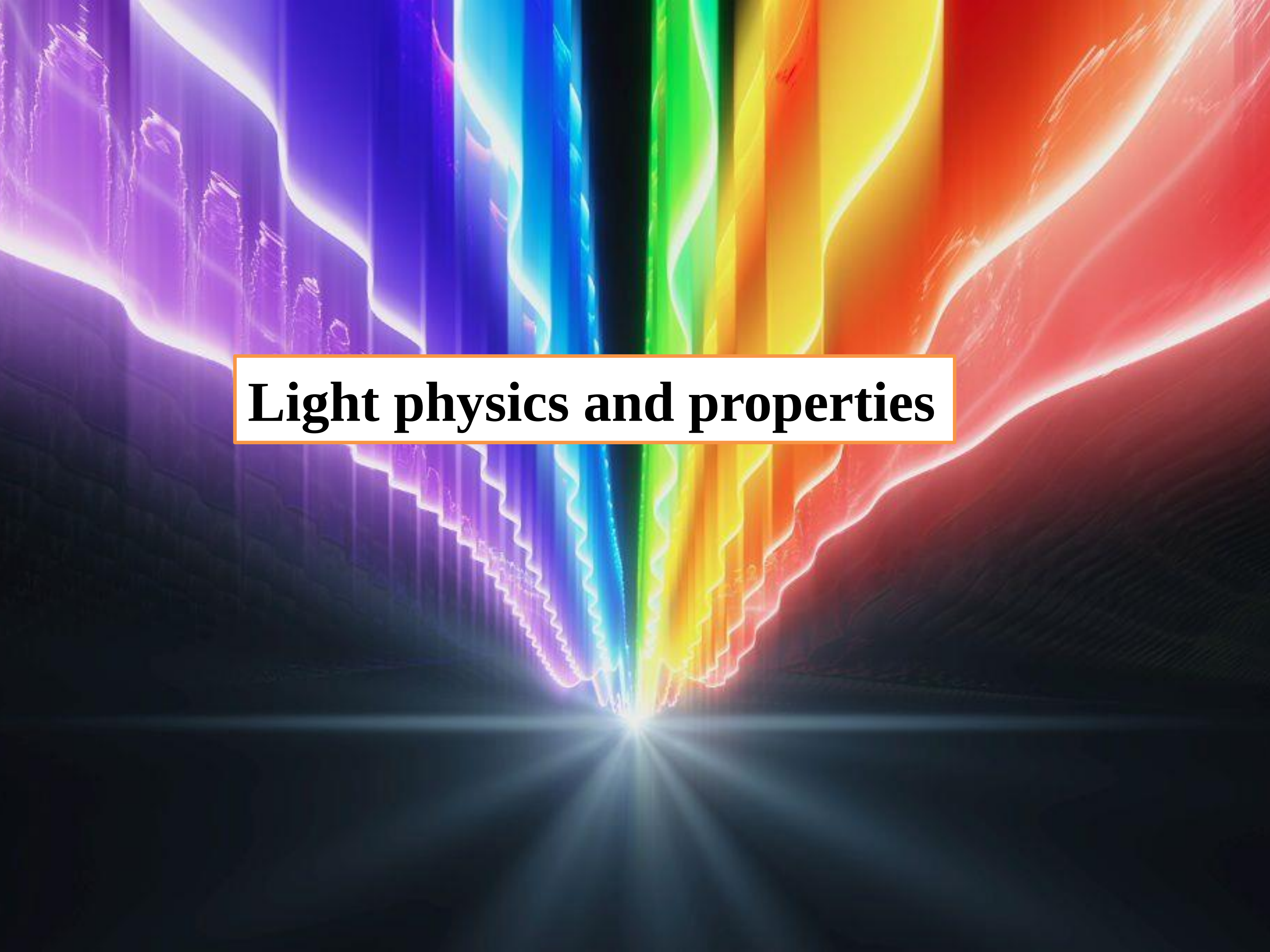
Dr. Siham Jasim Al-Faris

Department of Physics

2nd stage

University of Al Hamdanyah

Light physics and properties



Light physics

Wave

, light is represented as a ray that travels in a straight path، the direction of which can be changed only by placing an obstruction in the path

particles

light is a stream of fast-moving particles

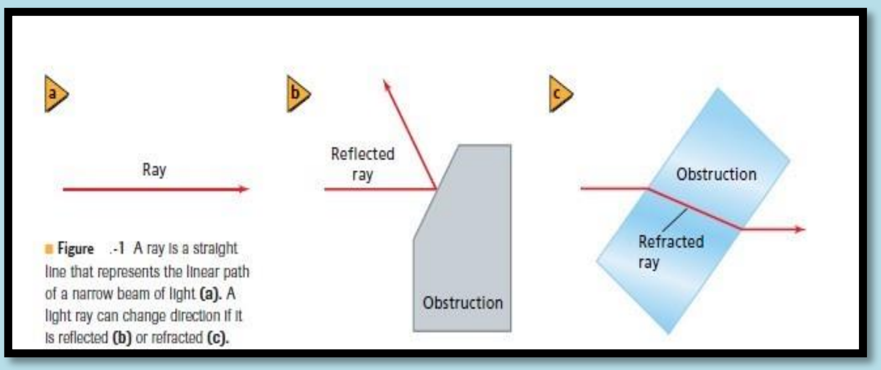
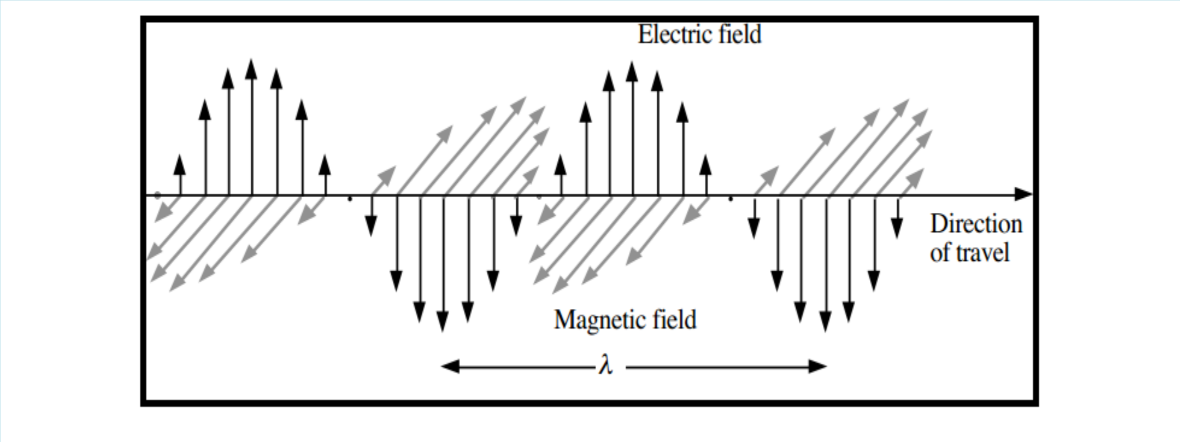


Figure .-1 A ray is a straight line that represents the linear path of a narrow beam of light **(a)**. A light ray can change direction if it is reflected **(b)** or refracted **(c)**.

Light waves

In the wave model light is viewed as electromagnetic waves. Since these waves consist of oscillating *electric* and *magnetic* fields which can exist in empty space, light can travel through a vacuum.

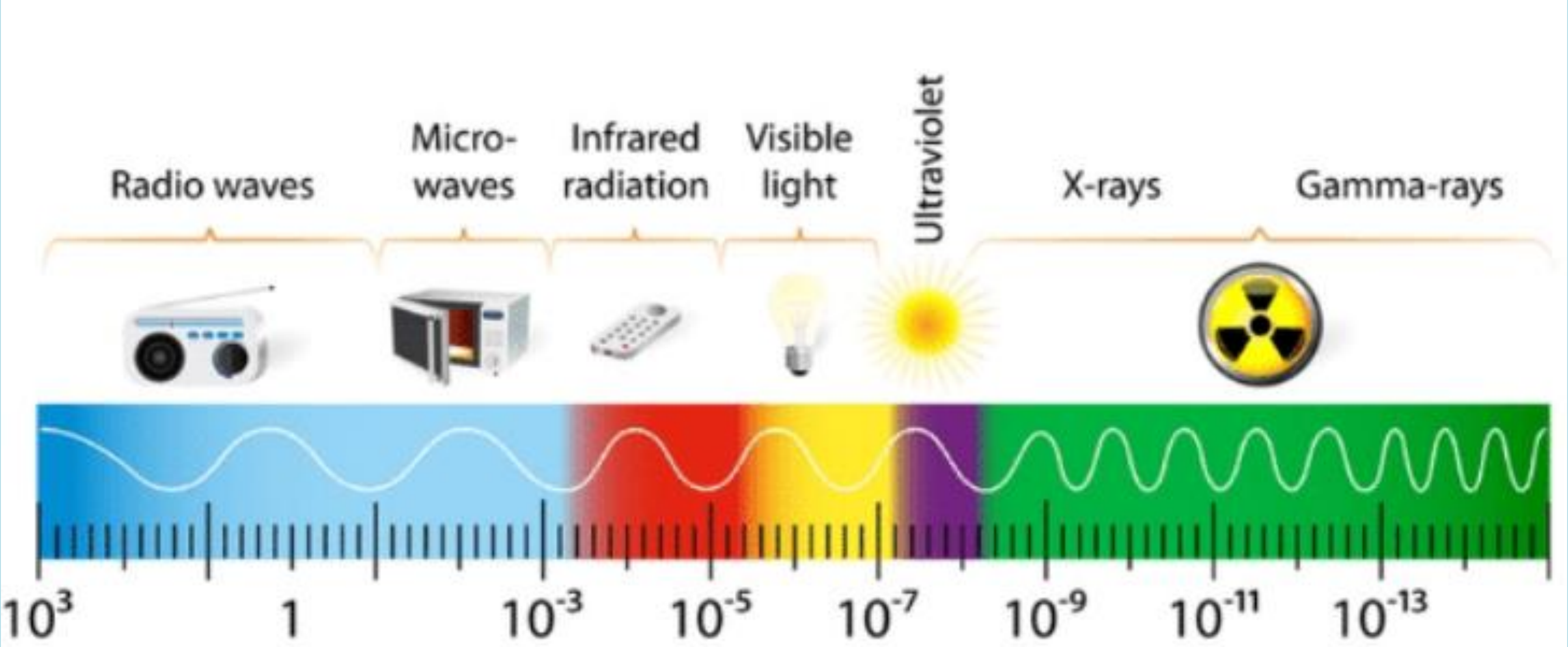


Since light can be analyzed as a complex mixture of a huge number of individual electromagnetic waves, the important properties of light and other electromagnetic waves can therefore be understood in terms of the properties of these simple elementary waves.

Properties of Light

- Waves, particles and EM spectrum
- Interaction with matter
- Absorption
- Reflection, refraction and scattering
- Polarization and diffraction

Electromagnetic wave, E.M spectrum



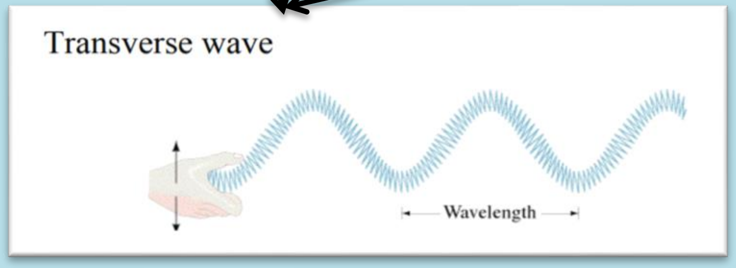
Waves

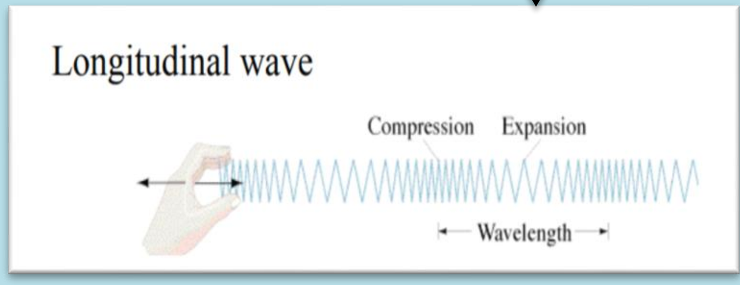
Electromagnetic

- Transverse
  - Ex: Radio wave

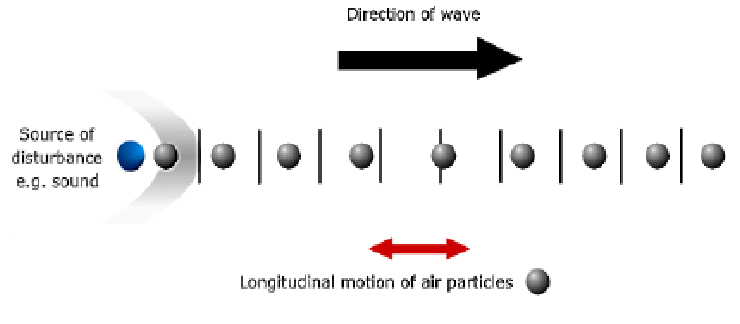
Mechanical waves

- Transverse
  - Ex: Water wave
- Longitudinal
  - Ex: Sound wave

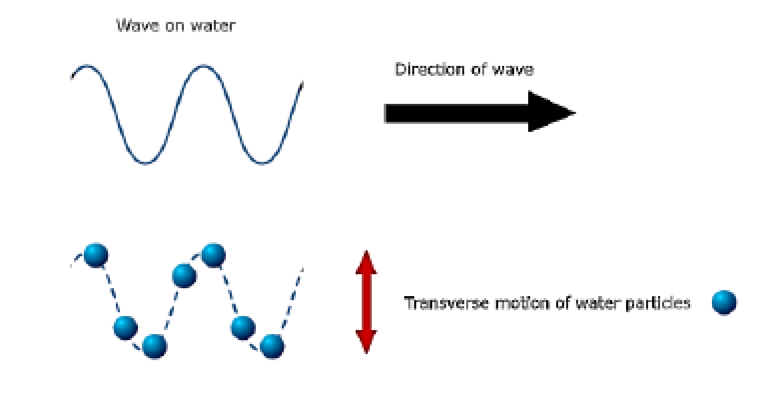




Longitudinal waves : In this type of wave, the movement of the particle are parallel to the motion of the energy i.e. the displacement of the medium is in the same direction to which the wave is moving.

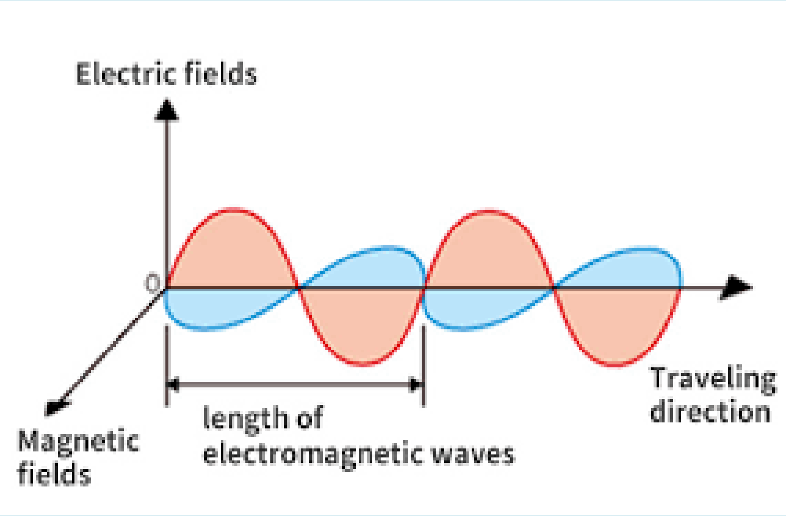


Transverse waves : When the movement of the particles is at right angles or perpendicular to the motion of the energy, then this type of wave is known as Transverse wave.



Electromagnetic waves

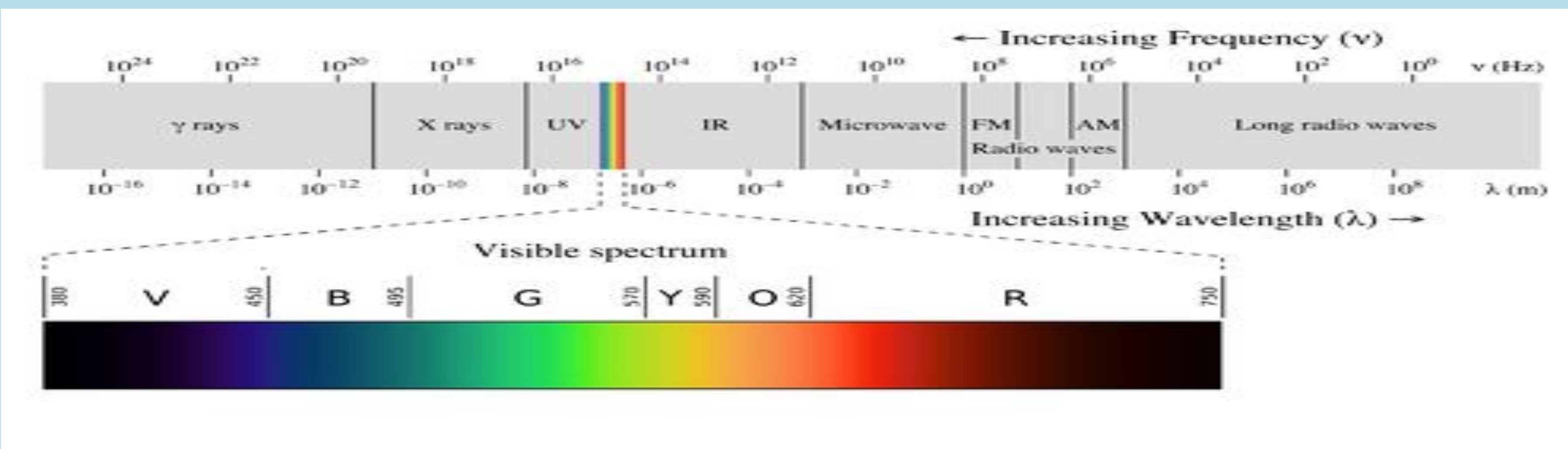
- Electromagnetic waves (or electromagnetic radiation) are waves made of oscillating magnetic and electric fields.
- Electromagnetic waves are waves that are capable of traveling through a vacuum.
- capable of transporting energy through the vacuum of outer space.



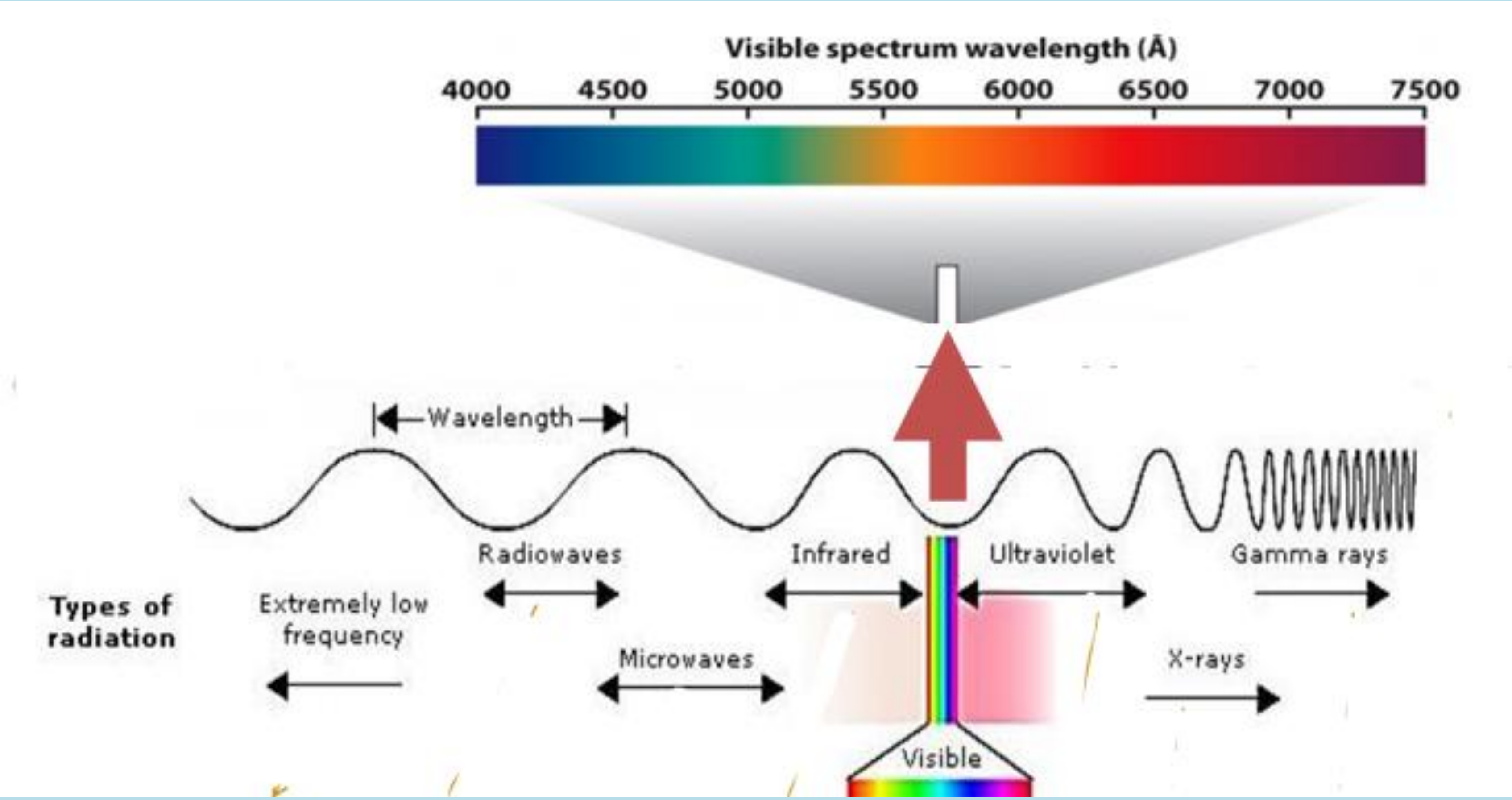
The Electromagnetic Spectra

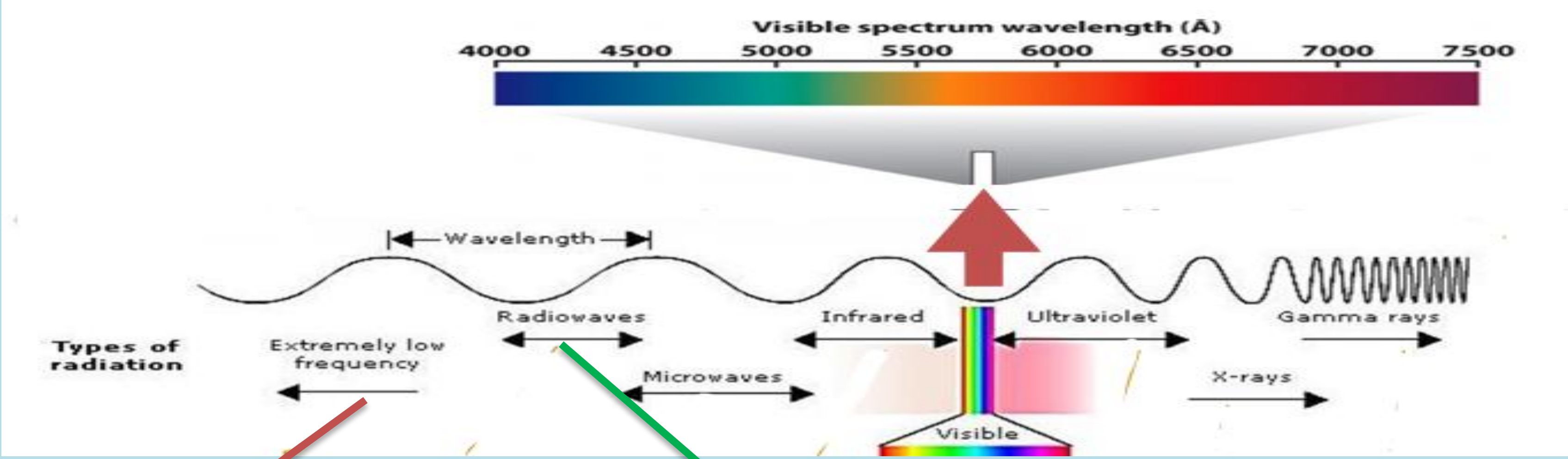
Electromagnetic waves exist with a large range of frequencies. This continuous range of frequencies is known as the electromagnetic spectrum.

The subdividing of the entire spectrum into smaller spectra is done mostly on the basis of how each region of electromagnetic waves interacts with matter.



The diagram below depicts the electromagnetic spectrum and its various regions.





Extremely low frequency

Source: power lines, electrical appliances

Wavelength: Kilometers

Frequency :30-300 Hz

Photon energy: Pico eV($10^{-12}\ eV$)

Radio waves

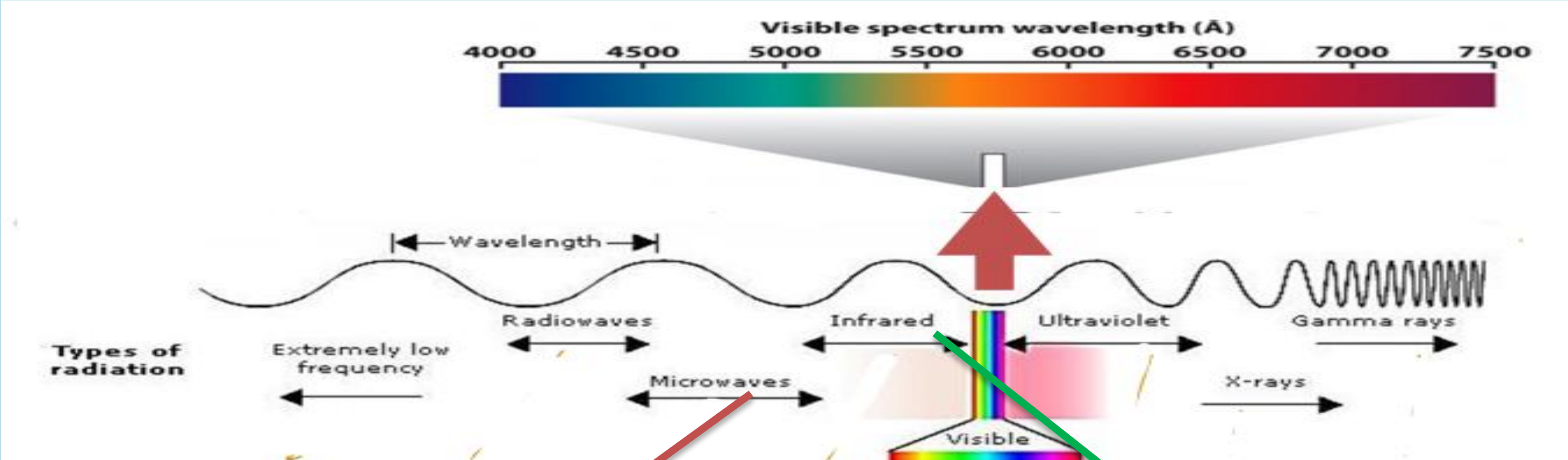
Source: AM and FM radio, TV

Wavelength: Centimeters to Kilometers

Frequency :30 kHz to 30 MHz

Photon energy: Nano to micro eV($10^{-9}\ to\ 10^{-6}\ eV$)

- **lowest energy**
- **lowest frequency and**
- **the longest wavelength**
- **used in communications**



Microwaves

Source: Microwave oven

Wavelength: millimeters to meters

Frequency :300 MHz-300 GHz

Photon energy: Micro to milli eV($10^{-6}\ to\ 10^{-3}\ eV$)

- **high energy**
- **used in our kitchen microwaves to cook your food**

Infrared waves

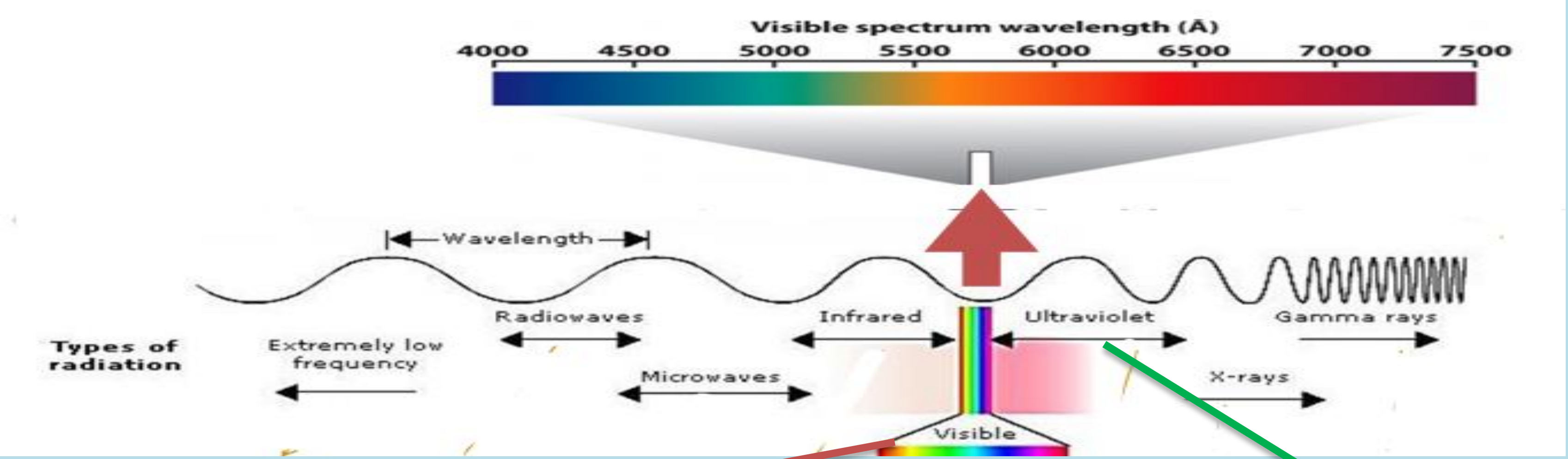
Source: Radiant heat

Wavelength: Microns to millimeters

Frequency :300 GHz to 300 THz

Photon energy: Milli eV to eV ($10^{-3}eV$)

- **has a wavelength just a little longer than what our eyes can detect.**
- The human body has a temperature that produces radiation in this part of the spectrum
- **used in night-vision cameras and remote controls**



Visible

Source: Sun

Wavelength: 400 to 700 nanometers

Frequency : 430 to 750 THz

Photon energy: 1.8 to 3 eV

- **is the part of the electromagnetic spectrum that our eyes can detect and so is the part we are most familiar with in our everyday lives.**

Ultraviolet waves

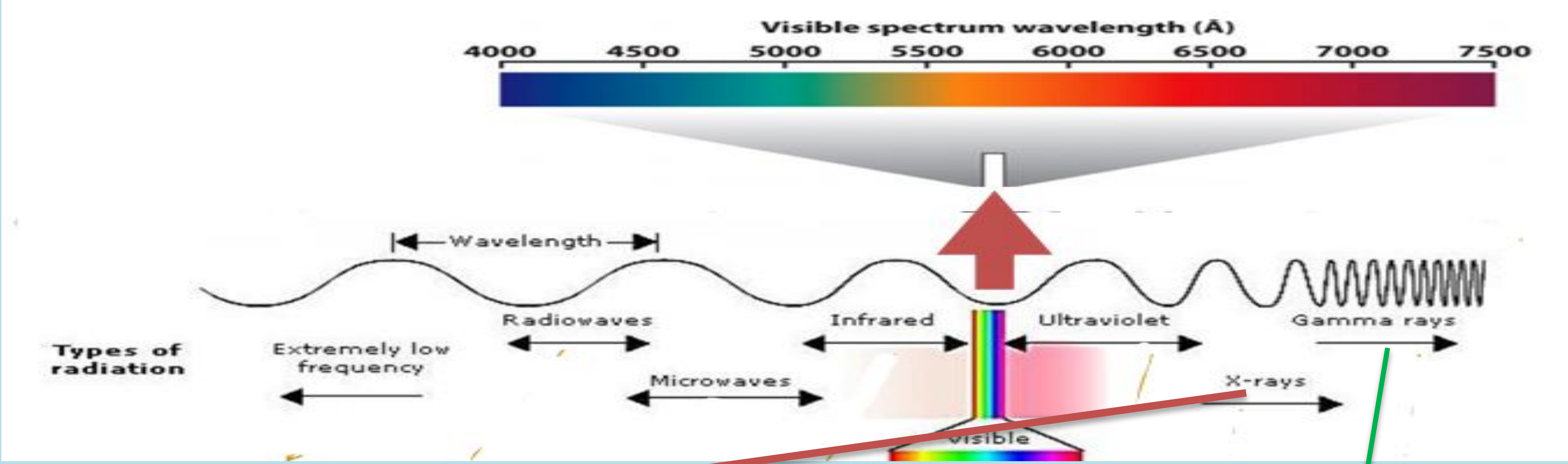
Source: Arc welding

Wavelength: 400 to 100 nanometers

Frequency :750 to 3000 THz

Photon energy: 3 to 12 eV

- high energy
- shorter wavelength
- are capable of ionizing atoms, breaking molecular bonds and even damaging DNA molecules.



X-rays

Source: X-ray tube, some radioactive source

Wavelength: 100 to 10^{-3} nanometers

Frequency : 3000 to 10^{20} THz

Photon energy: keV to MeV (10^3 *to* 10^6 eV)

- **very high energy and, like UV**
- **can ionize atoms in the body and cause damage**

Gamma rays

Source: Radioactive sources

Wavelength: 100 to less than 10^{-3} nanometers

Frequency : 3000 to above 10^{20} THz

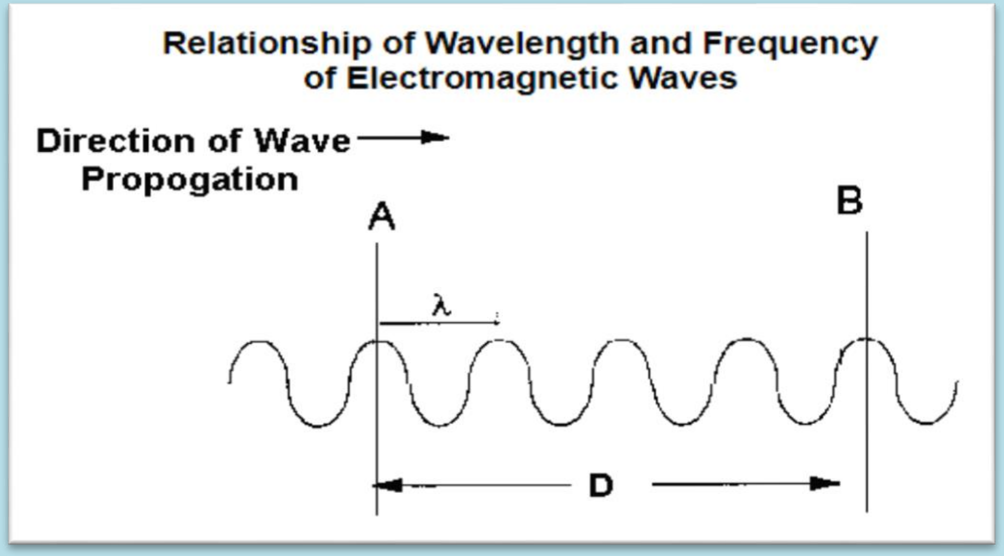
Photon energy: keV to above MeV (10^3 *to* 10^6 eV)

- the energy of this rays is greater than all the other rays in the electromagnetic spectrum, and it has lower wavelength.
- This rays emitted from a molecule which suffer translate in the inner of the molecule.

Wavelength: is defined as the distance between two successive crests or troughs of a wave. It is measured in the direction of the wave.

$$\lambda = \frac{2\pi}{k}$$

Where: *k*: propagation constant or wave number.



Frequency: The frequency of a wave measures the number of times a complete wave cycle will pass a given position. The relation between the frequency and the period T of a repeating event or oscillation is given by

$$f = \frac{1}{T}$$

Where

$$T = \frac{2\pi}{\omega} = \frac{1}{f}$$

where: ω is the angular frequency.

The equation that relates wavelength and frequency for electromagnetic waves is:

Speed of Light = Wavelength x Frequency

$$c = \lambda f$$

$$\text{Wavelength} = \frac{\text{Speed of Light}}{\text{Frequency}}$$

$$\text{Frequency} = \frac{\text{Speed of Light}}{\text{Wavelength}}$$

Where

λ: is the wavelength.

f: is the frequency and

c: is the speed of light.

Speed of Light and Refractive Index

The speed of light in a transparent material is always less than the speed, c, in vacuum. The ratio of the speed in a vacuum to the speed in the medium is called the refractive index (n) of the medium.

$$refractive\ index = \frac{speed\ of\ light\ in\ vacuum}{speed\ of\ light\ in\ medium}$$

$$n = \frac{c}{v}$$