Electromagnetic Radiation (EMR)

It is kind of energy with wave character (exactly as sea waves) that can be characterized by :

Wavelength (λ) : The distance between two identical points on the wave. nm=10A°=$10^{'3}$pm=$10^{'7}$cm=$10^{'9}$m

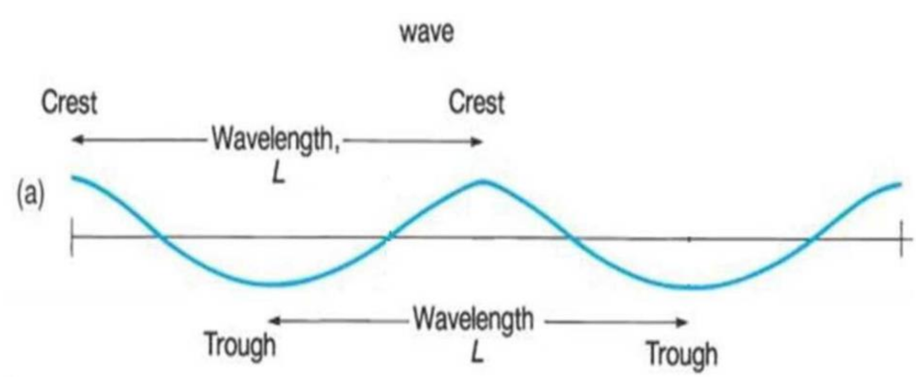
frequency (v) : The number of wavelengths that pass a point in a set period of time.

Energy (E) : in units of measure called electron volts (eV).

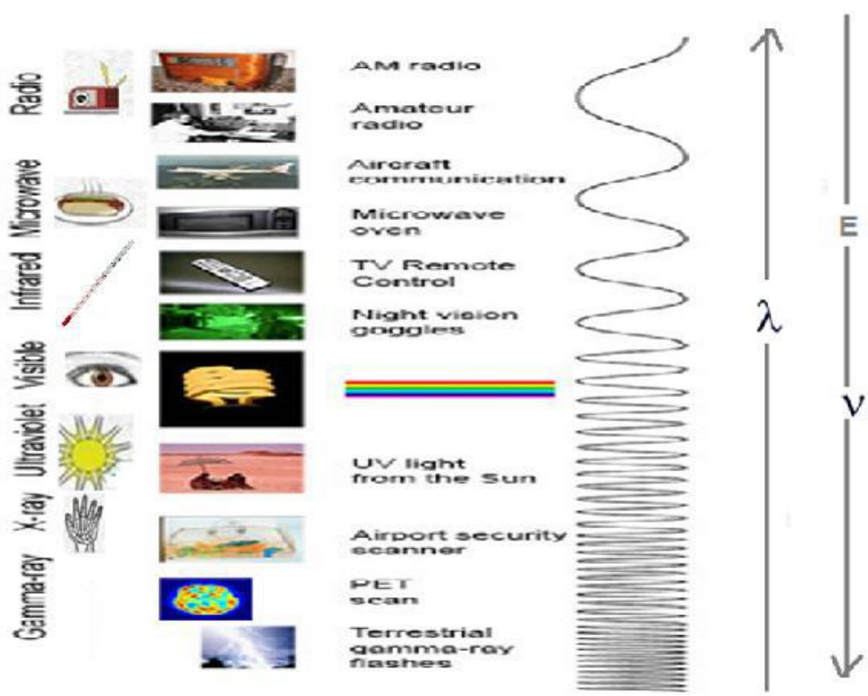
The speed (c) of all EMR waves is the speed of light (300,000 km/s).

Crest : The highest point of the wave.

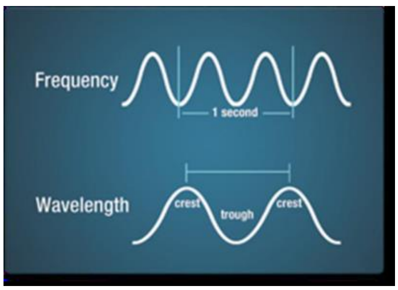
Trough : The lowest point of the wave :

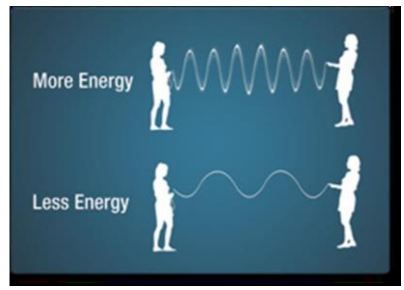


Electromagnetic radiation requires no supporting medium for its transmission and passes readily through a vacuum. Electromagnetic radiation is a stream of wave packets of energy called **photons**.
The EMR spectrum is the entire range of EMR waves in order of increasing frequency and decreasing wavelength.
Look at the following figure and notice that as you go from down to up, the wavelengths get longer and the frequencies and energies get lower .



As we mentioned energy and frequency increase as the wavelength shorten . Consider a jump rope with its ends being pulled up and down. More energy is needed to make the rope have more waves with short wavelength .





Each of the three quantities for describing EM radiation are related to each other in a precise mathematical way called :

Planck's Equation

The relationship between frequency v of light and energy E,

$$E = hv$$

where,h=Planck's constant=6.6×10^{-34} joule . sec In vacuum, velocity of light : $c = v\lambda = 3 \times 10^{10}$cm/s which gives, $v = c/\lambda$

$$E = h\,(c/\lambda)$$

Energy directly proportional to frequency and Inversely proportional to wavelength .

$$E \propto \nu$$

$$E \propto \frac{1}{\lambda}$$

Example :

The wavelength of the sodium D line is 589 nm. What is the frequency for this line?

Solution :

The frequency of the sodium D line is

$$\nu = \frac{c}{\lambda} = \frac{3X10^{8}\, m/s}{589X10^{-9}\, m} = 5.09X10^{14}\, s^{-1}$$

Example :

What is the energy of a photon from the sodium D line at 589 nm?

Solution :

The photon's energy is

$$E = \frac{hc}{\lambda} = \frac{(6.626X10^{-34}\, J.s)(3X10^{8} m/s}{589\ X\ 10^{-9}\, m} = 3.37X10^{-19}\ J$$

Example :

What is the wavelength of a photon with an energy of $3,37X10''^{19}$ J ?

Solution :

$E = h (c/ \lambda)$, then $X = (h X c) / E$

$X = (6.626x10^{-34} J . s X 3X10^{8} m/s) / 3,37X10'^{19} J = 589x10^{-7}$

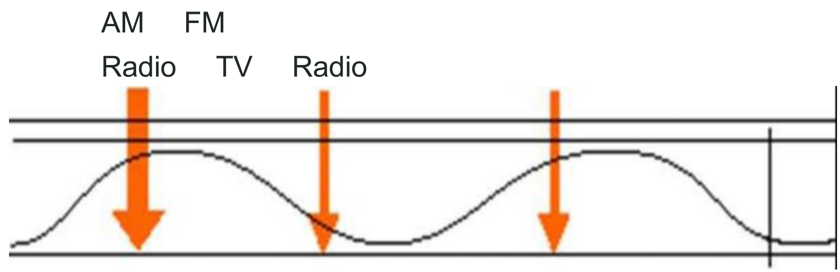
Radio Waves

They have the longest wavelengths(A range from thousands of meters to 0.001 meter) and the lowest frequencies .

Used in: radar , cooking food, satellite transmissions (TV and FM radio (short wavelength)



This radar image seen on TV weather forecasting



i-1-1-1-1—

3km 300m 30m_ 3m_30cm

Radio Wave Region of the Electro magnetic Spectrum

Microwaves : Microwaves are basically extremely short wavelength radio waves (**their wavelength is usually a couple of centimetres).**

Microwaves are not just used for cooking food, but for many other things :

Medicine:

It can be used to treat health problems better than drugs. Microwaves are primarily used in medical cases as an alternative to surgery. For example an enlarged prostate. Instead of surgically removing the problematic organ, doctors can use microwaves to heat up the enlarging tissue of the prostate and in turn decreasing the size of the enlarged prostate.

Industry:

used for clean up. to decrease air pollutants, sanitize hospital waste, ... etc.

Communication:

Microwaves are also used in telephones, telegraphs, television, and satellites. They are useful in communication because they easily penetrate the earth's atmosphere. Recent research indicates that microwaves from mobile phones can affect parts of your brain

Some uses of microwaves

Infrared waves (heat)

Have a shorter wavelength, from .001 m to 700 nm, and therefore, a higher frequency.
Used for finding people in the dark and in TV remote control devices and in toasters

SEEING THROUGH DUST

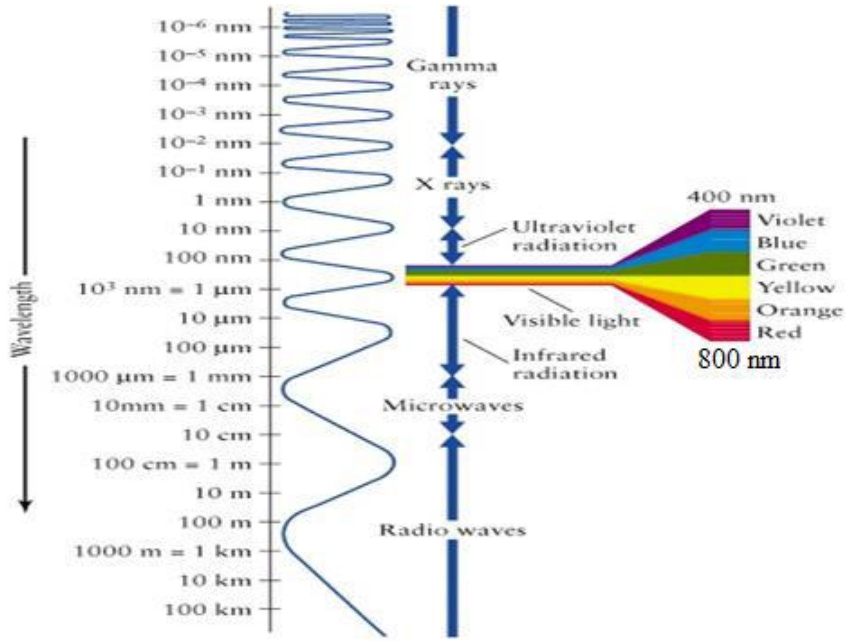
- Any object that radiates heat radiates Infrared Radiation.
- Infrared Radiation is absorbed by all materials and causes heating.
- Infrared Radiation is visible in daytime or night-time.
- Police use it to catch criminals, army use it to detect enemy.
- Dangers: damage to cells (burns)

Visible light

Wavelengths range from 800 nm (red light) to 400 nm (violet light) with frequencies higher than infrared waves .

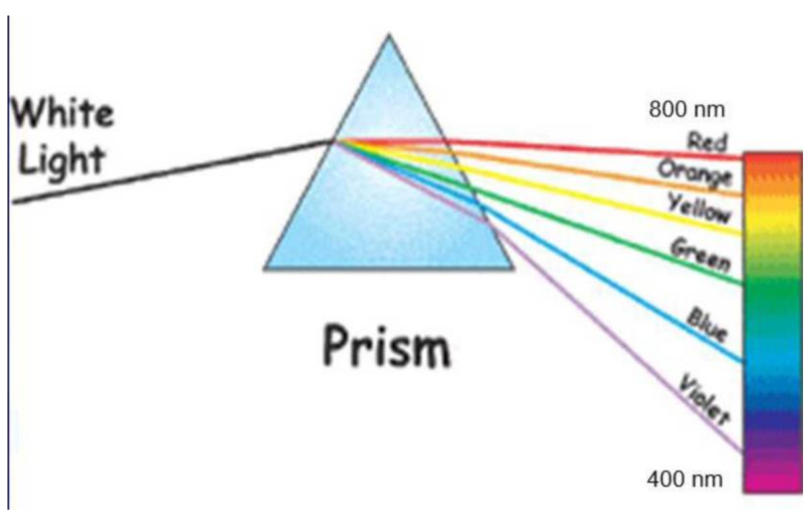
- These are the waves in the EM spectrum that humans can see.

- Visible light waves are a very small part of the EM spectrum!



Visible Light

Remembering the Order



Visible spectrum

Wavelength (nm)

390 450 520 590 620 780

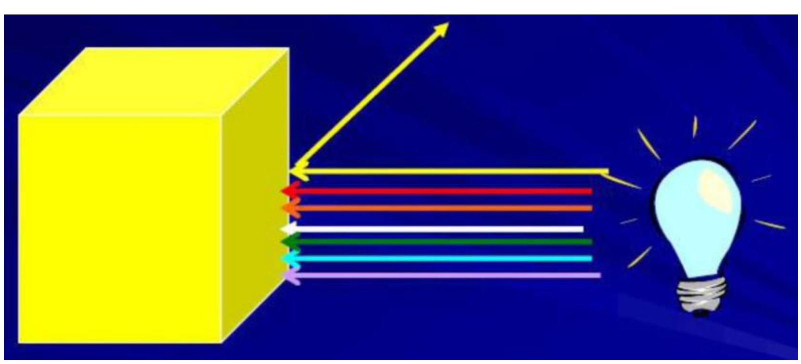
← UV IR →

← Increasing Energy

Increasing Wavelength →

But why is the Box yellow?

Yellow molecules are yellow because they reflect or transmit yellow light while absorbs the other colors .



Yellow molecules absorb the other colors of visible light

Colors of visible light

Wavelength of maximum absorption (nm)	Color absorbed	Color observed
380—420	Violet	Green-yellow
420—440	Violet-blue	Yellow
440—470	Blue	Orange
470—500	Blue-green	Red
500—520	Green	Purple
520—550	Yellow-green	Violet
550—580	Yellow	Violet-blue
580—620	Orange	Blue
620—680	Red	Blue-green
680—780	Red	Green

Ultraviolet Light

Wavelengths range from 400 nm to 10 nm; the frequency (and therefore the energy) is high enough with UV rays to penetrate living cells and cause them damage. The useful rang in chemical analysis is 200 -380 nm .

- Although we cannot see UV light, bees, bats, butterflies, and some birds can.

- Ultraviolet radiation is emitted by the Sun.
- UV on our skin produces vitamin D . Too much UV can lead to sunburn and skin cancer. UV rays are easily blocked by clothing.
- Used for sterilization because they kill bacteria.
- Detecting forged bank notes .

X-Rays

Wavelengths from 10 nm to .001 nm. These rays have enough energy to penetrate deep into tissues and cause damage to cells (cancer) ; are stopped by dense materials, such as bone.
Used to look at solid structures, such as bones and bridges (for cracks), and for treatment of cancer.

Gamma Rays

Carry the most energy and have the shortest wavelengths, less than one trillionth of a meter (10-12 m).
□- Gamma rays have enough energy to go through most materials easily; you would need a 3-4 ft thick concrete wall to stop them!

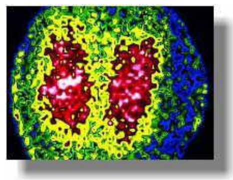
□- Gamma rays are released by nuclear reactions in nuclear power plants, by nuclear bombs, and by naturally occurring elements on Earth.

□- Gamma Rays cause and treat cancers

Gamma Rays

Doctors use gamma-ray imaging to see inside your body.

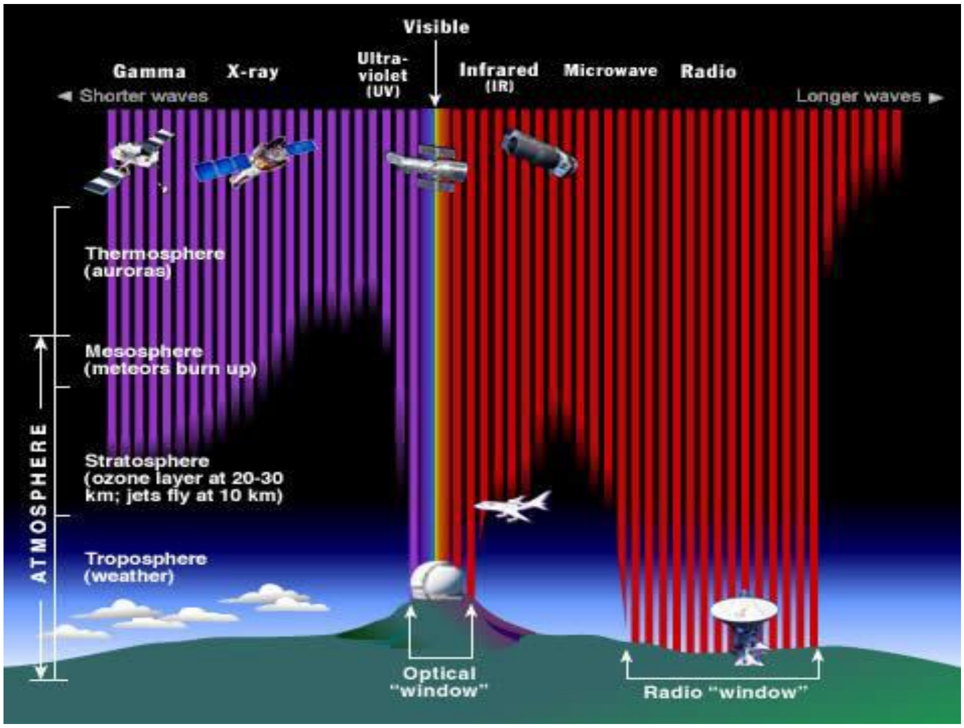
- This picture shows an asthmatic person's lungs.

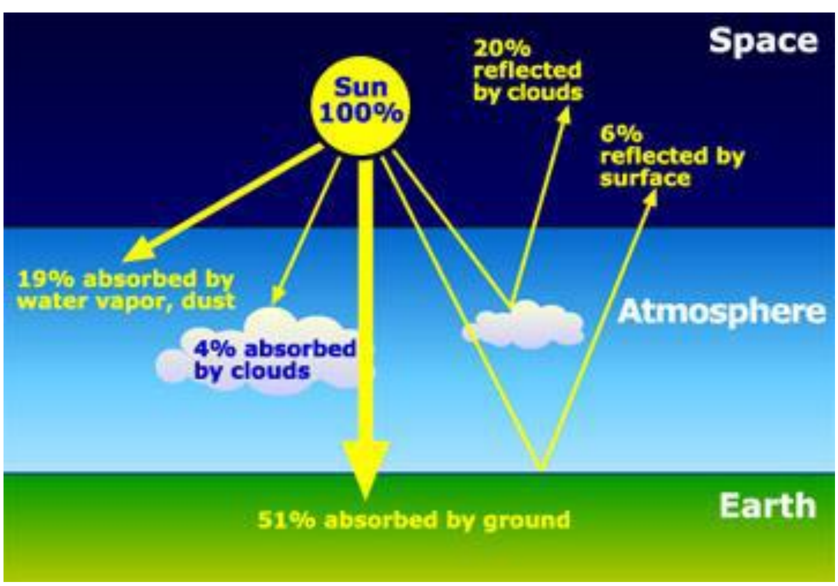


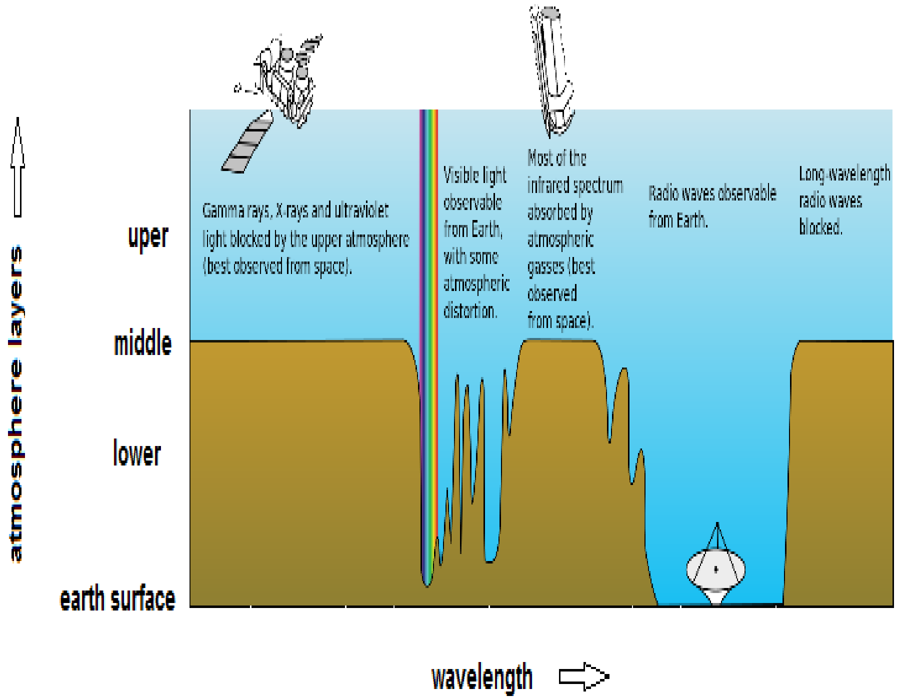
- The patient was given a slightly radioactive gas to breath, and the picture was taken using a gamma camera to detect the radiation.
- The colors show the air flow in the lungs.

EMR from Space

The Earth's atmosphere stops most types of electromagnetic radiation from space from reaching Earth's surface. The following illustration shows how far into the atmosphere different parts of the EM spectrum can go before being absorbed. Only portions of radio and visible light reach the Earth's surface)


Visible
Gamma
X-ray
Ultra-violet (UV)
Infrared (IR)
Microwave
Radio
◄ Shorter waves
Longer waves ►
Thermosphere (auroras)
Mesosphere (meteors burn up)
Stratosphere (ozone layer at 20-30 km; jets fly at 10 km)
Troposphere (weather)
ATMOSPHERE
Optical "window"
Radio "window"


Space
Sun 100%
20% reflected by clouds
6% reflected by surface
19% absorbed by water vapor, dust
4% absorbed by clouds
Atmosphere
51% absorbed by ground
Earth


atmosphere layers
uper
middle
lower
earth surface
Gamma rays, X-rays and ultraviolet light blocked by the upper atmosphere (best observed from space).
Visible light observable from Earth, with some atmospheric distortion.
Most of the infrared spectrum absorbed by atmospheric gasses (best observed from space).
Radio waves observable from Earth.
Long-wavelength radio waves blocked.
wavelength