University of Salahaddin
College of science
Department of Environmental science

Chapter One

Radiation

Class: 2^{nd} - Environmental science

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Radiation

- ***Radiation*** *is defined as energy that travels through space or matter in the form of a particle or wave.*
- ***Electromagnetic spectrum*** *all of the frequencies or wavelengths of electromagnetic radiation.*

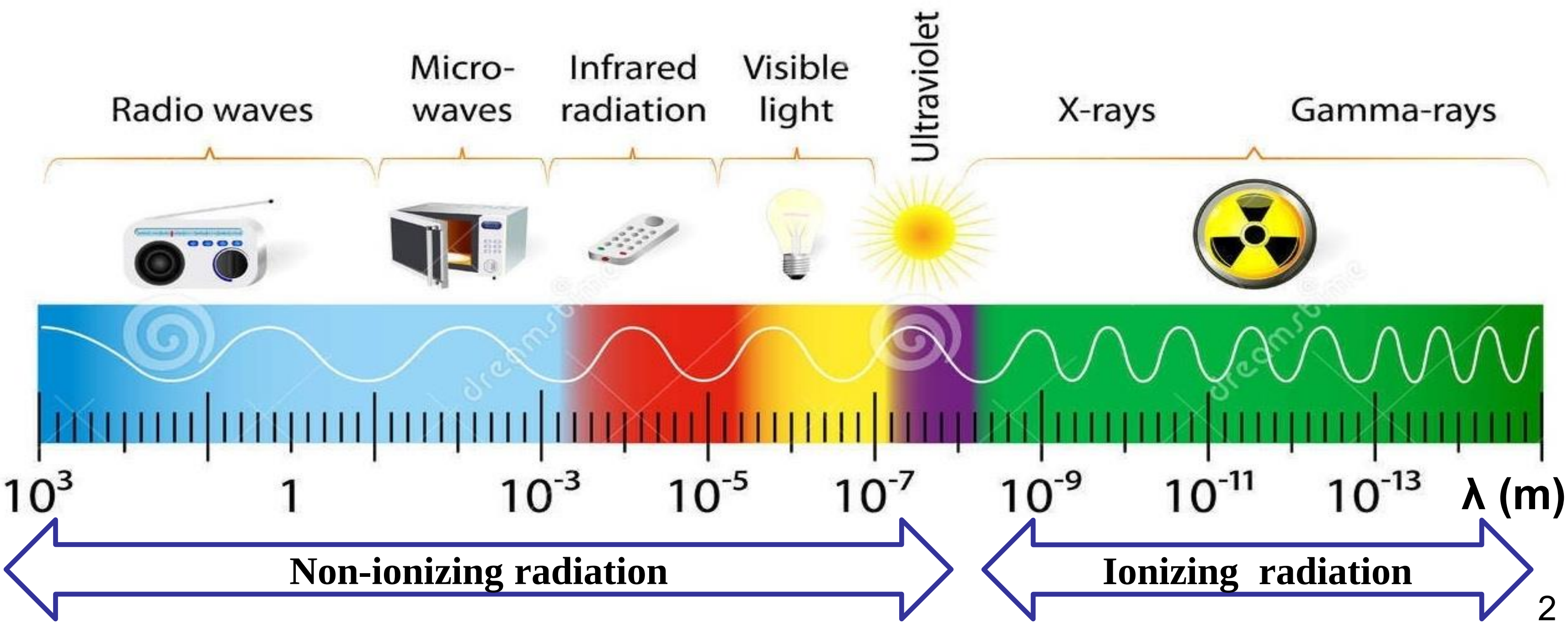


Fig.(1) The spectrum of electromagnetic radiation.

Electromagnetic Wave

Electromagnetic wave *is a wave that consists of electric and magnetic fields that vibrate at right angles to each other.*

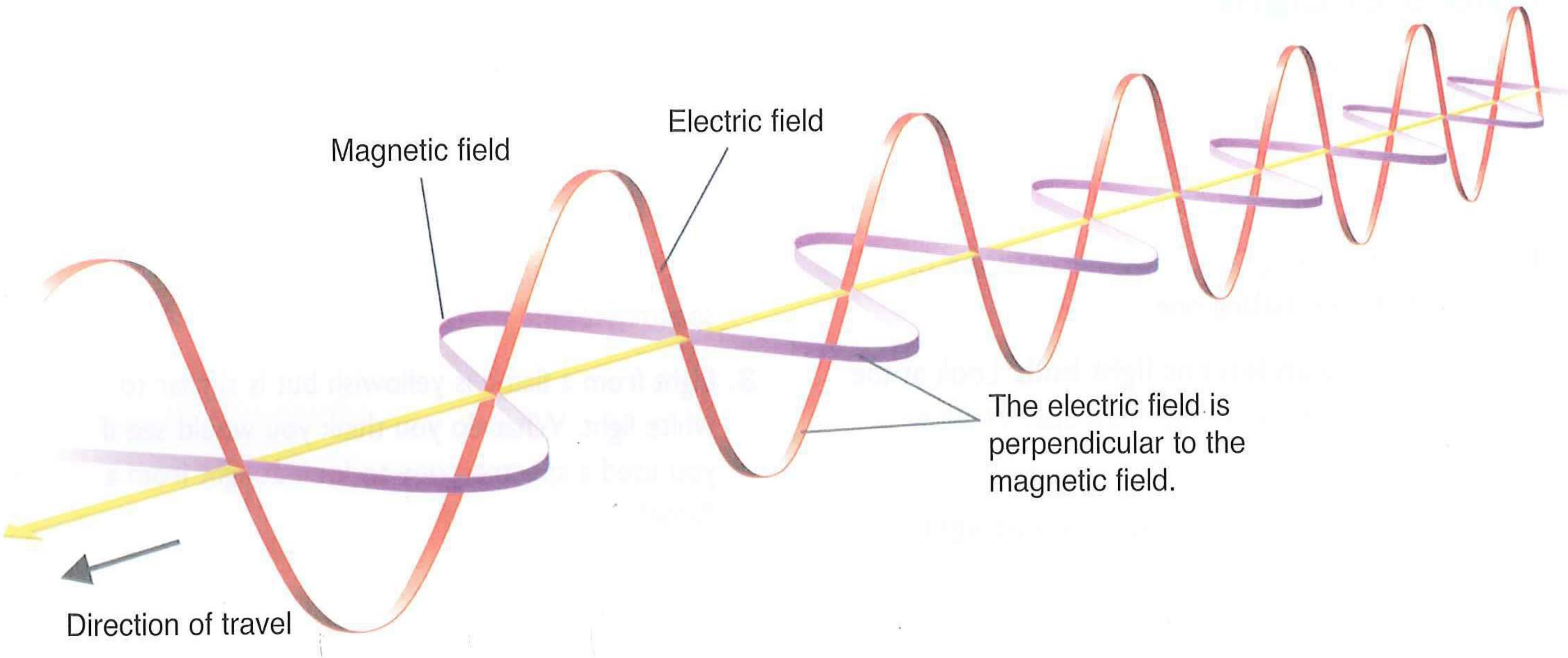


Fig.(2) Electromagnetic waves are made of vibrating electric and magnetic field.

Electromagnetic spectrum

- ***Radio waves*** are a type of electromagnetic radiation. Radio waves have some of the longest wavelengths and the lowest frequencies of all electromagnetic waves and travel at the speed of light. In fact, radio waves are any electromagnetic waves that have wavelengths longer than 30 cm. Radio waves are used for broadcasting radio and television signals.

Electromagnetic spectrum

- *Microwaves* have shorter wavelengths and higher frequencies than radio waves do. Microwaves have wavelengths between 1 mm and 30 cm. You are probably familiar with microwaves they are created in a microwave oven, such as the one shown in fig.(3).

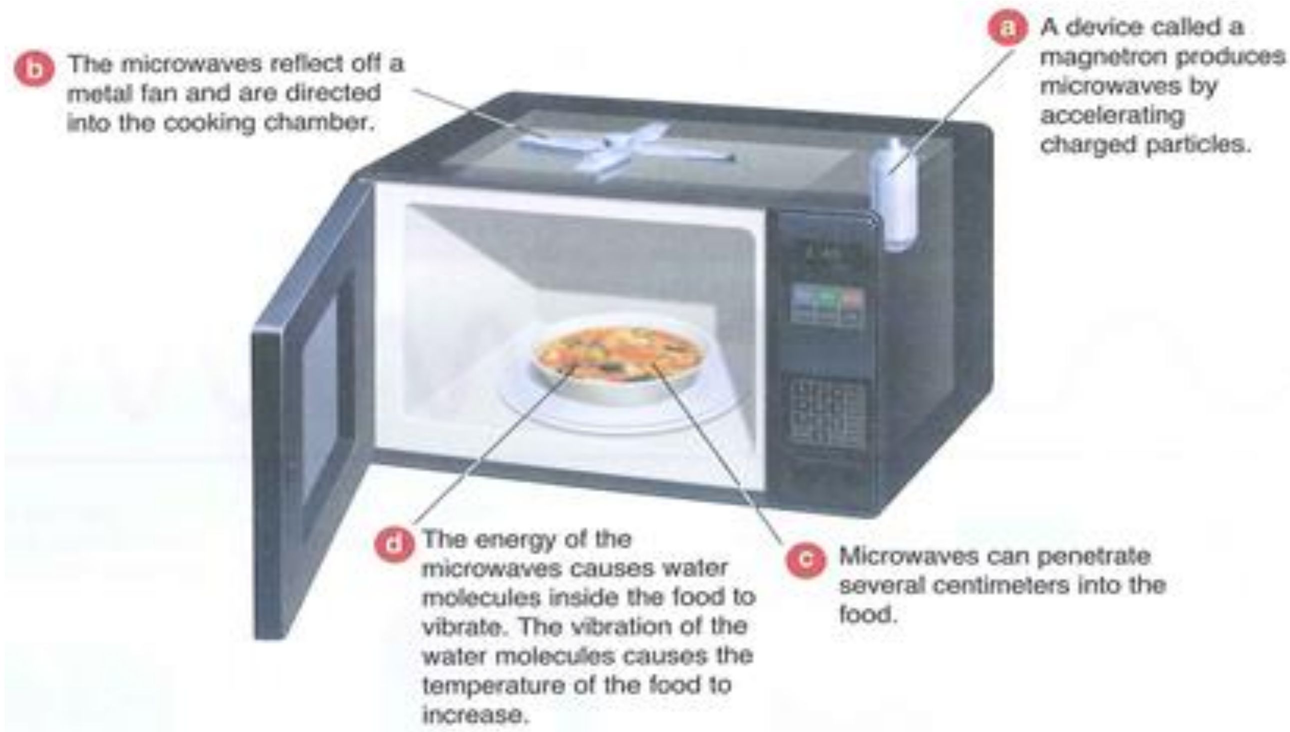


Fig.(3) How a microwaves oven works.

Electromagnetic spectrum

Microwaves are also used in radar. Radar is used to detect the speed and location of objects as in fig.(4). The radar gun sends out microwaves that reflect off the car and return to the gun. The reflected waves are used to calculate the speed of the car.

Fig.(4) We use radar to detect cars going faster than the speed limit.

Electromagnetic spectrum

- *Infrared waves have shorter wavelengths and higher frequencies than microwaves do.* The wavelengths of infrared waves vary between 700 nm and 1 mm.

- *A nanometer* (nm) is equal to 1×10^{-9} m.

- The amount of infrared waves an object gives off depends on the objects temperature.

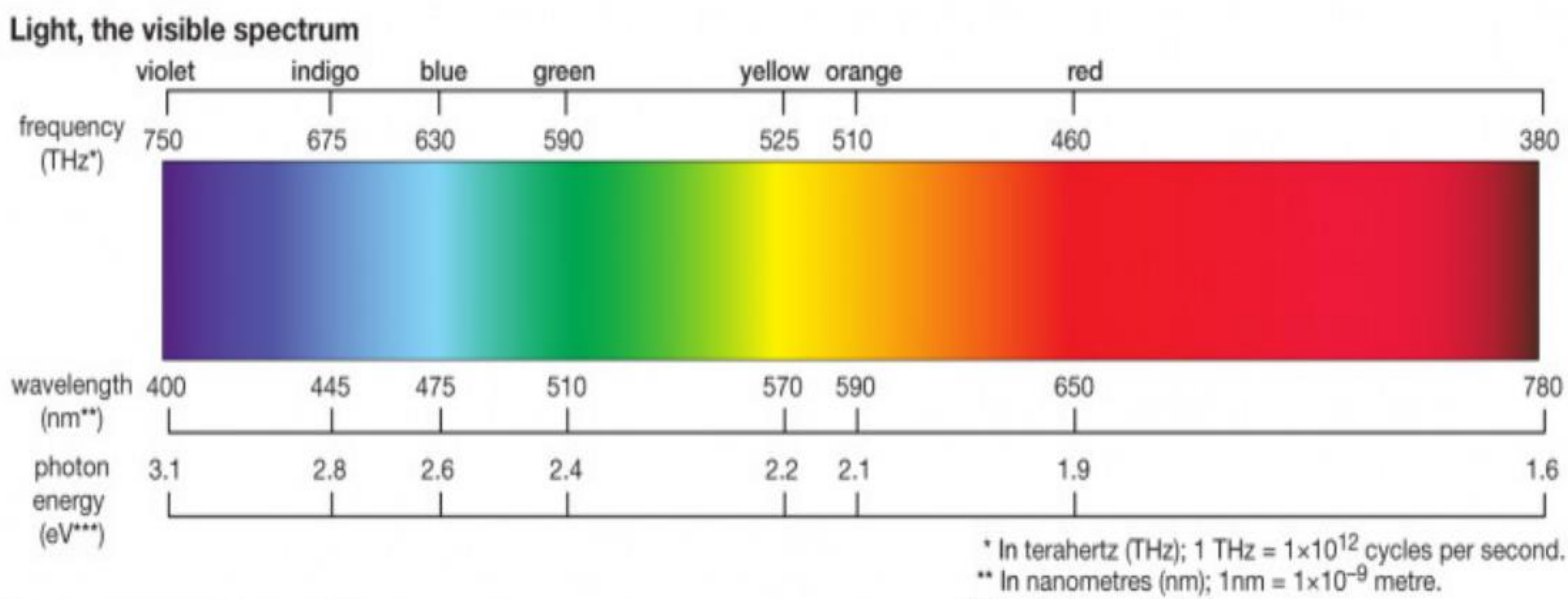
- Warmer objects give off more infrared waves than cooler objects do.

- You cannot see infrared waves, but some devices can detect infrared waves. For exp. infrared binoculars can be used to watch animals at night.

Fig.(5) In this photograph, brighter colors indicate higher temperatures.

Electromagnetic spectrum

Visible light is the very narrow range of wavelengths and frequencies in the electromagnetic spectrum that humans can see. Visible light waves have shorter wavelengths and higher frequencies than infrared waves do. Visible light waves have wavelengths between 400 nm and 780 nm.



Electromagnetic spectrum

Ultraviolet light is another type of electromagnetic wave produced by the sun. Ultraviolet waves have shorter wavelengths and higher frequencies than visible light does. The wavelengths of ultraviolet light waves vary between 60 nm and 400 nm.

- Ultraviolet light affects your body in both bad and good ways.

- ***Bad Effects***

On the bad side, too much ultraviolet light can cause painful sunburn, as you can see in Fig.(6). Too much ultraviolet light can also cause skin cancer, wrinkles, and damage to the eyes.

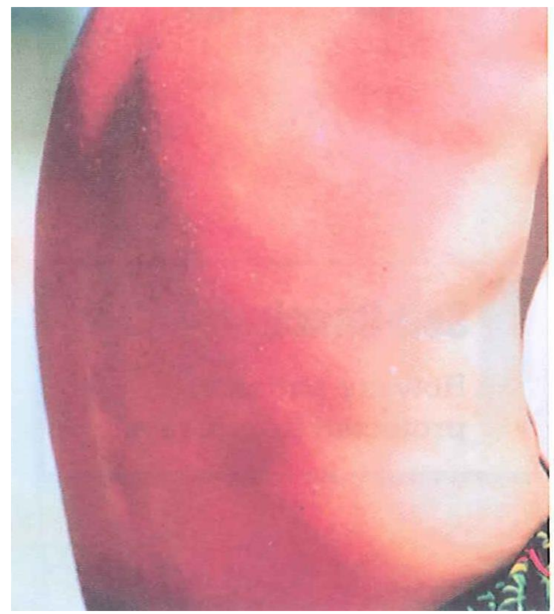


Fig.(6) Too much exposure to ultraviolet light can lead to a painful sunburn.

Electromagnetic spectrum

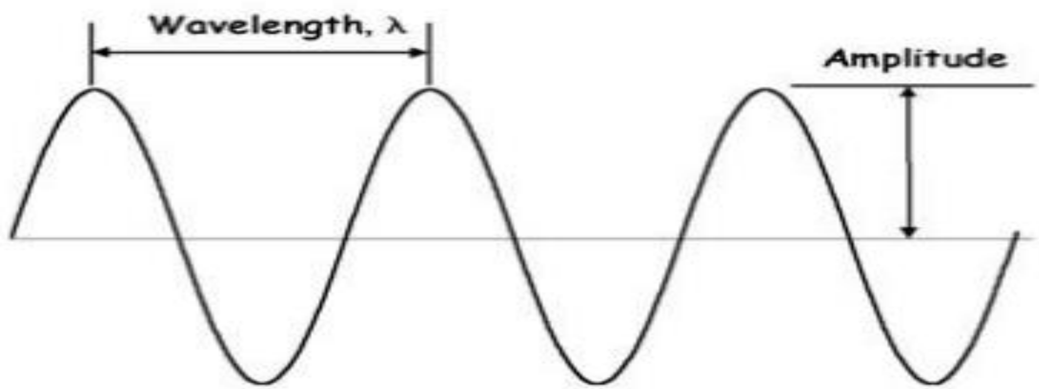
- ***Good Effects***

On the good side, ultraviolet waves produced by ultraviolet lamps are used to kill bacteria on food and surgical tools. In addition, small amounts of ultraviolet light are beneficial to your body. When exposed to ultraviolet light, skin cells produce vitamin D. This vitamin allows the intestines to absorbed calcium. Without calcium, your teeth and bones would be very weak.

Electromagnetic Wave

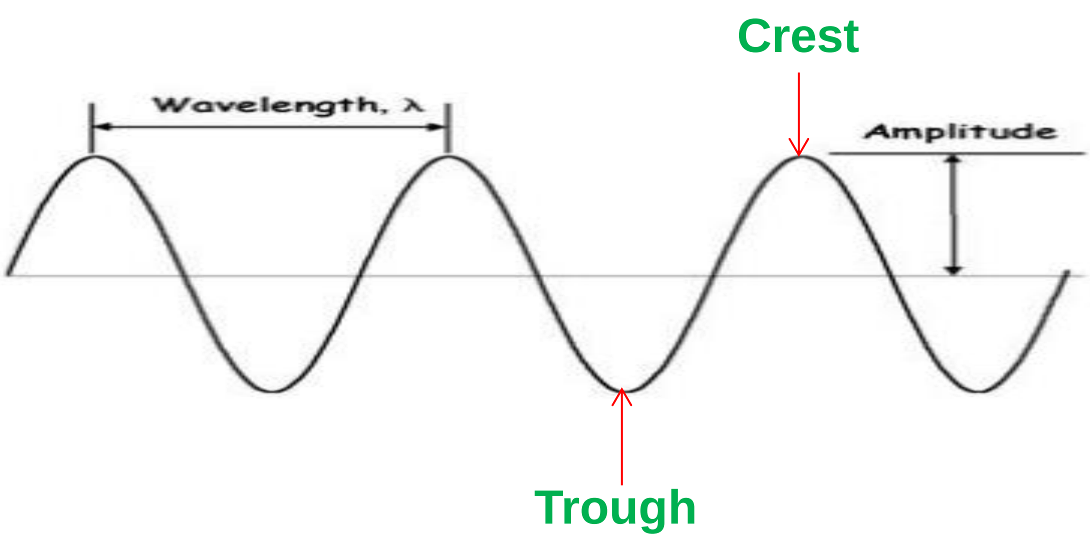
- Long-wavelength EM waves : Radio & Microwave
- Medium-wavelength EM waves :IR , Visible, UV light
- Short-wavelength EM waves : X-ray & Gamma-ray

- *Wavelength is the liner measurement of a wave.*



Electromagnetic Wave

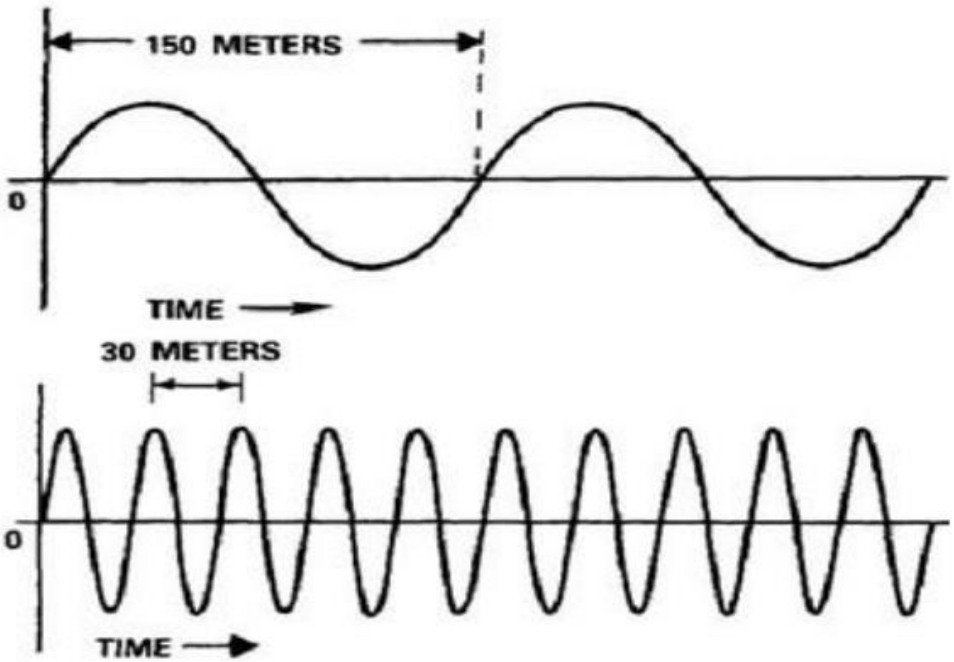
- A Cycle is one complete vibration.
- Crest is the highest part of the wave.
- Trough is the lowest part of the wave.



This diagram actually shows 3 cycles.

Electromagnetic Wave

- Frequency is number of cycles per second.
- Hertz is a measurement of frequency. Usually measured in kilohertz or megahertz.



When wavelength increases
Then frequency decreases

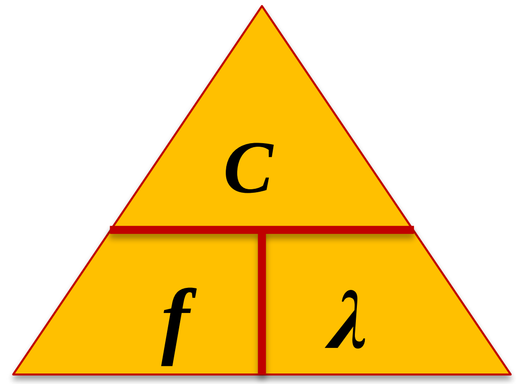
or

When wavelength decreases
Then frequency increases

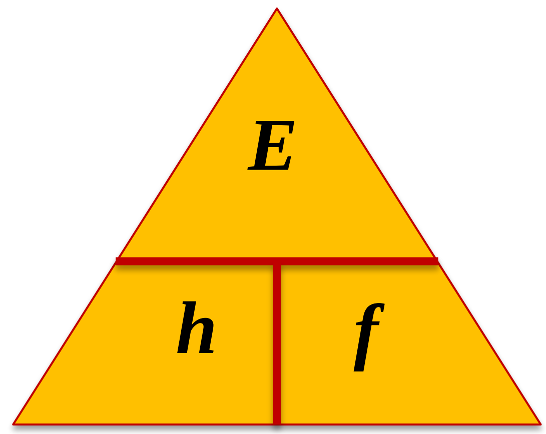
Electromagnetic Wave

- Relationship between frequency, speed , wavelength and Energy

$$f . \lambda = c$$



$$E = h f$$



where

f is frequency (S^{-1} or Hz)

λ is wavelength (in m)

c is speed of light ($3*10^{8}$ m/s)

E is energy (J or ev)

h is plank constant ($6.63*10^{-34}$ J.S)

Units of Energy

- *One electron volt* is defined as the amount of energy acquired (gained) by an electron when accelerated through a potential difference of *one volt*.
- Since the charge carried by one electron is 1.602×10^{-19} C.
- 1 ev = 1.6×10^{-19} coulomb ×1 volt=1.6×10^{-19} Joule.

  1 ev =1.6×10^{-19} Joule.
- 1MeV= 10^6 eV
- ∴ 1 MeV= 1.6×10^{-13} Joule

Example

What is the frequency of violet light with wavelength 400 nm?

$$c = \lambda\nu$$

$$\nu = \frac{c}{\lambda}$$

$c = 2.998 \times 10^{8}\ \mathrm{ms^{-1}}$
$\lambda = 400\ \mathrm{nm} = 400 \times 10^{-9}\ \mathrm{m}$

$$= \frac{2.998 \times 10^{8}\ \cancel{\mathrm{m}}\mathrm{s^{-1}}}{400 \times 10^{-9}\ \cancel{\mathrm{m}}}$$

$$= 7.50 \times 10^{14}\ \mathrm{Hz}$$

Electromagnetic Wave

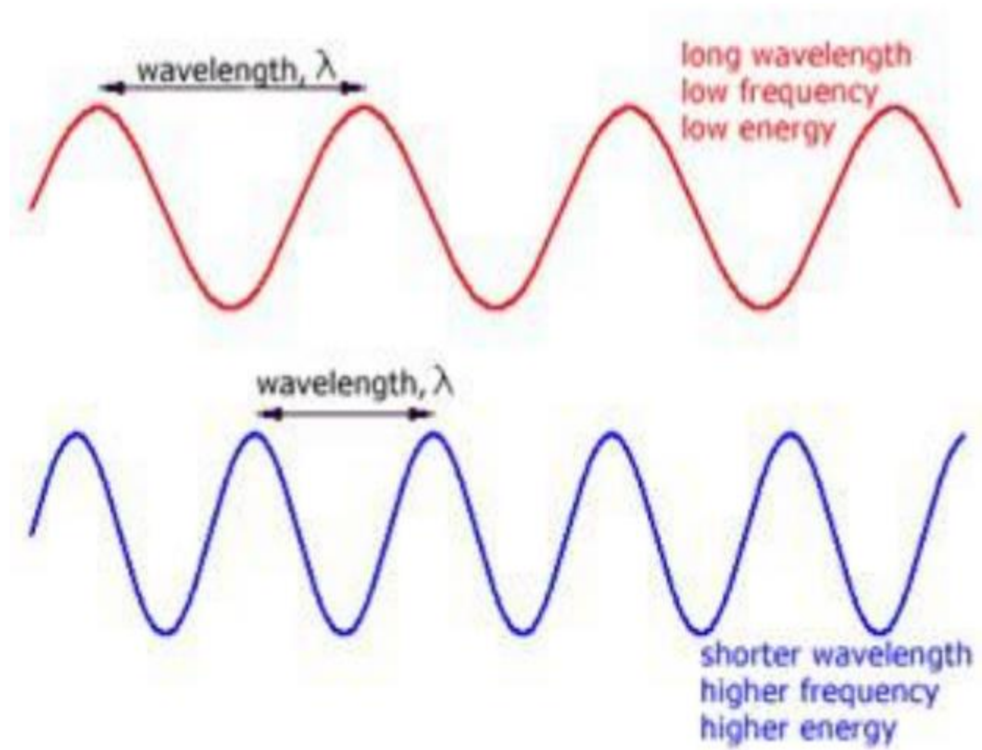
- Describe the relationship between frequency and wavelength

inverse

wavelength ↑ frequency ↓

or

wavelength ↓ frequency ↑



Sources of Radiation

There are two main sources of radiation:

A. Naturally occurring (background radiation):

It is the naturally present radiation in our environment, since the birth of this planet, it includes:

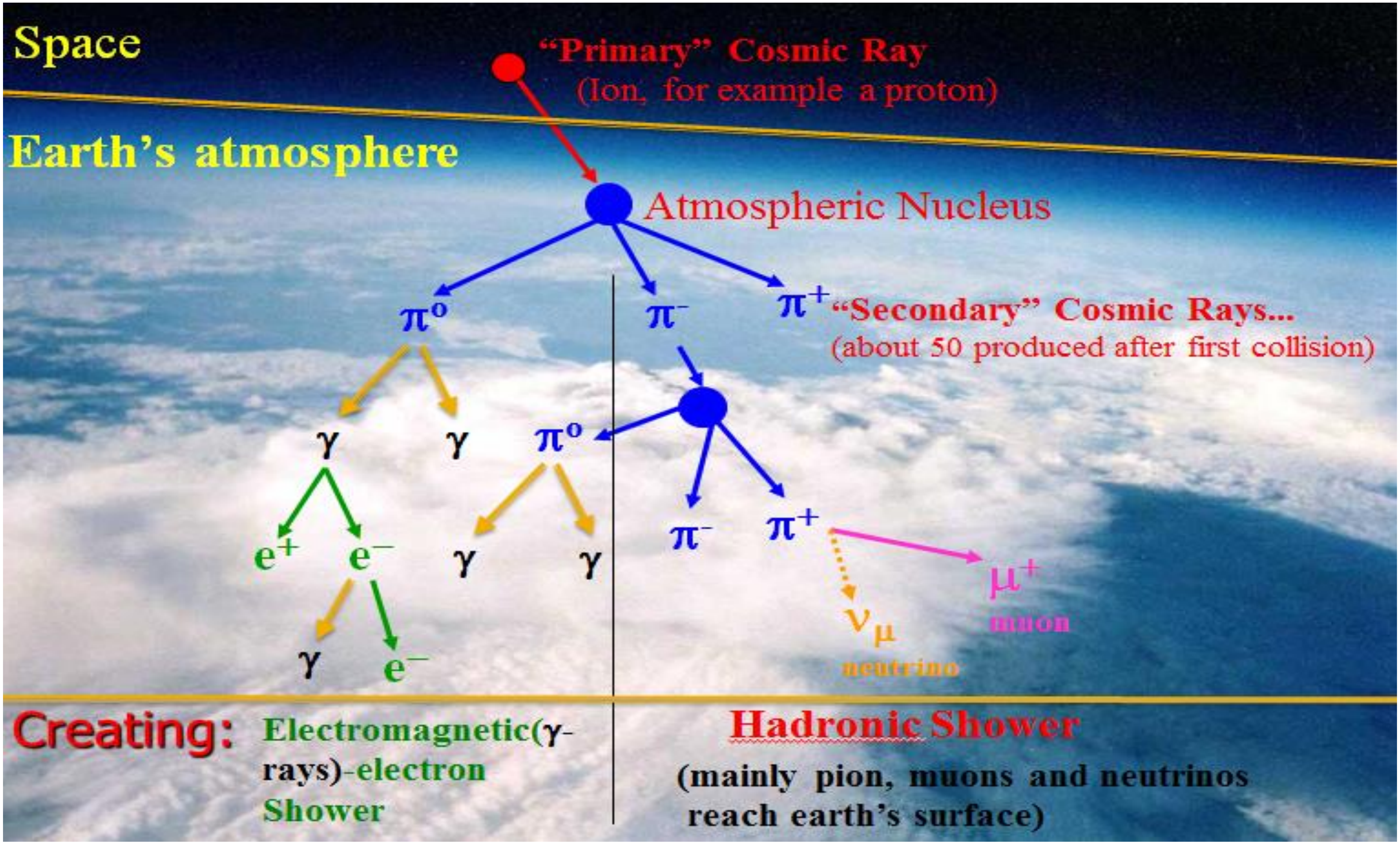
1. Cosmic radiation:

- The earth, and all living things on it, are bombarded by radiation from space (sun and stars), this radiation interact with the Earth's atmosphere and magnetic field (typically beta and gamma).
- The dose from cosmic radiation varies in different parts of the world due to differences in elevation and the effects of the earth's magnetic field.

Cosmic-Ray

- Cosmic rays are high energy charged particles (10^9 eV to 10^{21} eV), in outer space, that travel at nearly the speed of light and strike the Earth's atmosphere from all directions that could be affecting the Earth's climate.
- They can range from a single proton to the nucleus of an iron atom-or larger.
- 89% protons (hydrogen nuclei)
- 10% Alpha particle(Helium nuclei)
- 1 % Electrons and heavier elements such as (iron ,carbon ,nitrogen ,...)

Cosmic Ray "Showers"



Sources of Radiation

2. Terrestrial radiation:

- The major isotopes of terrestrial radiation are uranium and the decay products of uranium, such as thorium, radium.
- Low levels of these elements and their decay products are found everywhere, and ingested with food and water.
- The dose from terrestrial sources varies in different parts of the world. Locations with higher concentrations of uranium and thorium have the higher dose levels in their soil.

Sources of Radiation

3. Radon gas (Inhalation):

- It is the largest natural source of radiation exposure to humans, which exist on air, water and soil.
- Radon's pathway is from the earth, through the basements of houses and other buildings, and into the air that people breathe.
- Radon exposures can vary depending on the soil and rock structure beneath buildings.

Sources of Radiation

4. Natural internal radiation in the human body (Ingestion) :

- It is the internal radiation comes from the radioactive materials that occur naturally in the human body.
- Potassium and Carbon are the primary sources of internal radiation exposures.
- The Potassium ^{40}K isotope enters the human body through the food chain.
- The Carbon ^{14}C (represent 0.23 weight of the human body) enters the body both through the food chain and breathing.

Sources of Radiation

B. Artificial sources (man-made radiation):

Artificial radiation sources are identical to the natural radiation in their nature and effect. The most important sources are:

1. **Medical procedures:** such as diagnostic X-rays, nuclear medicine, and radiation therapy.

2. **Concern isotopes:** Cobalt (^{60}Co), Cesium (^{137}Cs), Americium (^{241}Am), and others.

Sources of Radiation

Table 2.1 : Annual effective dose equivalent.

Sources	Dose(mrem/yr)	Percent of total
Natural radiation		
Radon	200	55%
Cosmic	27	8%
Terrestrial(rocks and soil)	28	8%
Internal (inside human body	40	11%
Total natural	295	82%
Man-made radiation		
Medical X-ray	39	11%
Nuclear medicine	14	4%
Consumer products	10	3%
Other	-	-
Occupational	0.9	<0.3%
Nuclear fuel cycle	<1	<0.03%
Total artificial	65	18%
The total	360	100%

The types of radiation fall into two main categories

1. ***Particulate radiation*** consists of particles that have mass and energy, and may or may not have an electric charge (alpha particles, beta particles, protons and neutrons).

2. ***Electromagnetic radiation***, consists of photons that have energy, but no mass or charge (X- Ray and Gamma Ray).

- A photon, as described by quantum theory, is a "particle" or "quantum" that contains a discrete quantity of electromagnetic energy which travels at the speed of light, or 3×10^8 meters per second.

- A photon is sometimes described as a “packet of light”. Visible light, ultraviolet light, x-rays, and gamma rays are all photons.

Classification of Radiation

- Radiation
  - Ionizing
    - Directly ionizing (charged particles)
      electrons, protons, alpha particles
    - Indirectly ionizing (neutral particles)
      X- rays, gamma- rays, neutrons
  - Non-Ionizing
    - ultraviolet (UV), visible light, infrared

Classification of Radiation

Ionizing Radiation

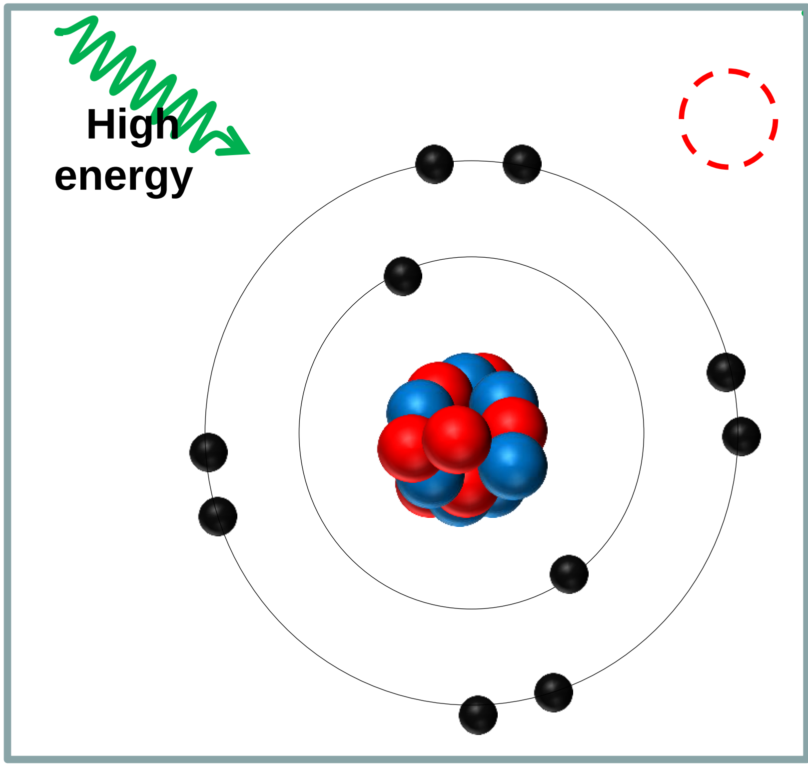
- Higher energy electromagnetic waves (gamma and X-ray) or Light and heavy particles (beta and alpha).
- High enough energy to eject electron from an atom.

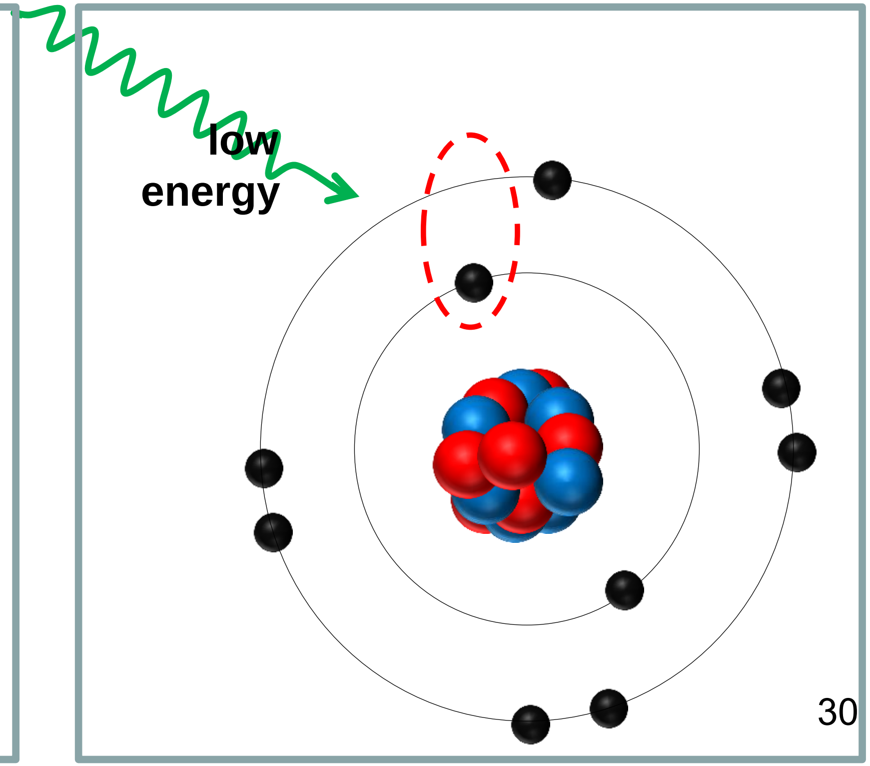
Non-ionizing Radiation

- Lower energy electromagnetic waves.
- Not enough energy to eject electron from an atom, but can excite the electron.

Classification of Radiation

Ionizing | Excitation





Directly ionizing radiation

- Deposits energy in the medium through direct coulomb interactions between the directly ionizing charged particle and orbital electrons of atoms in the medium.

Indirectly ionizing radiation

- Deposits energy in the medium through a two step process:

- *In the first step* a charged particle is released in the medium (photons release electrons or positrons, neutrons release protons or heavier ions);
- *In the second step* the released charged particles deposit energy to the medium through direct Coulomb interactions with orbital electrons of the atoms in the medium

Applications of Both directly and indirectly ionizing radiations

- The branch of medicine that uses radiation in the treatment of disease is called radiotherapy, therapeutic radiology or radiation oncology.

- Diagnostic radiology and nuclear medicine are branches of medicine that use ionizing radiation in the diagnosis of disease.

X-Ray Apparatus

- X-ray, discovered by Willhelm Roentgen in 1895, are high-energy photons (l-100keV) with wavelength of the order of 1 A°. They are usually produced by bombarding a target with a beam of high-energy electrons, as shown in Fig.(7).

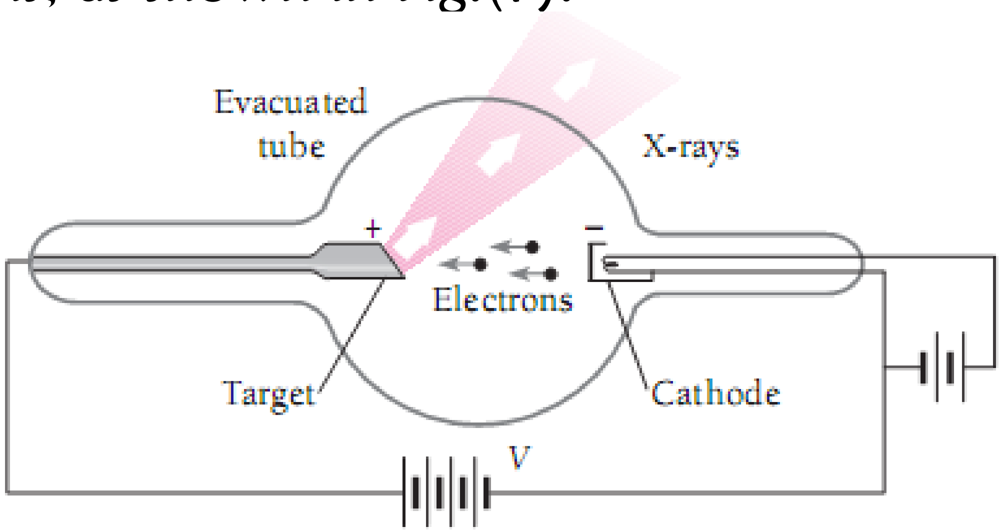


Fig.(7): An x-ray tube. The higher the accelerating voltage V, the faster the electrons and the shorter the wavelengths of the x-rays.

The X-ray have the following properties

- travel in straight lines
- unaffected by electric and magnetic fields
- pass readily through opaque materials
- cause phosphorescent substances to glow
- Expose photographic plates.