

ELECTROMAGNETIC WAVES

1. Region of electromagnetic spectrum

The electromagnetic spectrum, in simple terms, is defined as the range of all types of electromagnetic radiation. We shall learn about the concept in detail and understand all its underlying aspects in this lesson.

2. What Is the Electromagnetic Spectrum?

- The electromagnetic spectrum is a range of frequencies, wavelengths, and photon energies covering frequencies from below 1 Hz to above 10^{25} Hz.
- Electromagnetic waves tend to travel at speeds similar to that of light.
- The electromagnetic spectrum consists of a span of all electromagnetic radiation
- An electromagnetic region can be further classified by its wavelength, frequency, and photon energy into distinct regions like radio waves, microwaves, infrared, visible, ultraviolet (UV), X-rays, and gamma rays.

Q/ Which electromagnetic spectrum has the highest wavelength?

A/ An electromagnetic spectrum is a collection of a range of waves in sequential order. Radio waves have the highest frequency, and gamma rays have the shortest wavelength.

3. Electromagnetic Waves in the Electromagnetic Spectrum

The entire range (electromagnetic spectrum) is given by radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays, gamma rays, and cosmic rays in the increasing order of frequency and decreasing order of wavelength. The type of radiation and its frequency, and wavelength ranges are as follows:

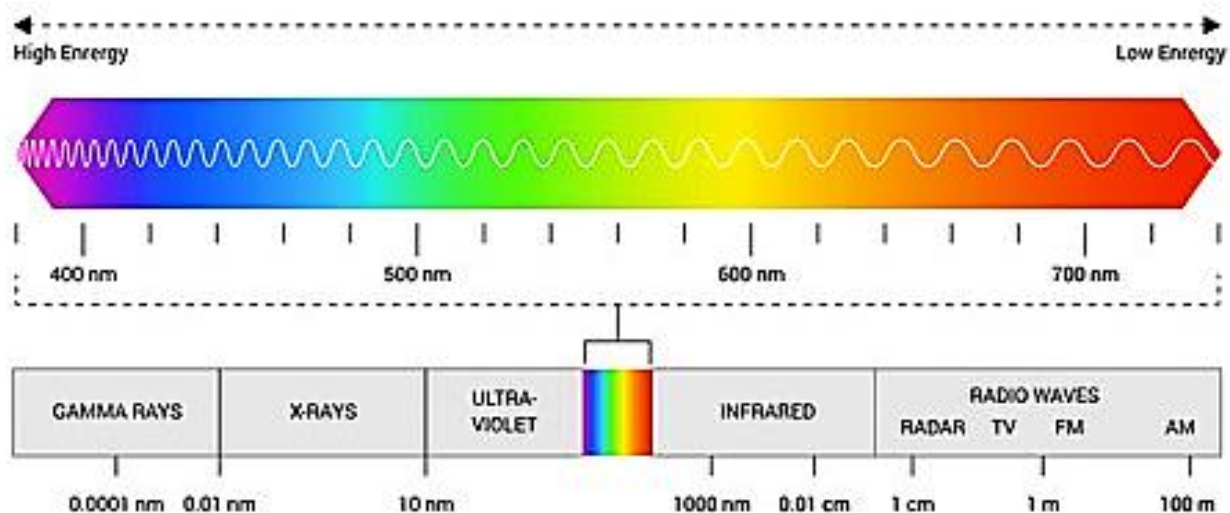


Fig (1) Electromagnetic Waves in the Electromagnetic Spectrum

Type of Radiation	Frequency Range (Hz)	Wavelength Range
Gamma-rays	$10^{20} - 10^{24}$	$< 10^{-12} \text{ m}$
X-rays	$10^{17} - 10^{20}$	1 nm – 1 pm
Ultraviolet	$10^{15} - 10^{17}$	400 nm – 1 nm
Visible	$4 \times 10^{14} - 7.5 \times 10^{14}$	750 nm – 400 nm
Near-infrared	$1 \times 10^{14} - 4 \times 10^{14}$	2.5 μm – 750 nm
Infrared	$10^{13} - 10^{14}$	25 μm – 2.5 μm
Microwaves	$3 \times 10^{11} - 10^{13}$	1 mm – 25 μm
Radio waves	$< 3 \times 10^{11}$	$> 1 \text{ mm}$

A- RADIO WAVES :

1. Radio waves are produced by the accelerated motion of charges in conducting wires.
2. They are used in radio and television communication systems.
3. Cellular phones use radio waves to transmit voice communication in the ultrahigh frequency (UHF) band.

B- MICRO WAVES:

1. Microwaves are short-wavelength radio waves.
2. They are produced by special vacuum tubes (called klystrons, magnetrons and Gunn diodes).
3. Micro waves are used in micro wave oven to cook food.
4. Micro waves are used in very long distance wireless communication through satellites.

Q / How we can use microwave to cook the food?

A/ When the oven is operated, the microwaves are generated, which in turn produce a non-uniform oscillating electric field. The water molecules in the food which are the electric dipoles are excited by an oscillating torque. Hence few bonds in the water molecules are broken, and heat energy is produced. This is used to cook food.

C- INFRA RED WAVES:

1. Infrared waves are produced by hot bodies and molecules.
2. Infrared lamps are used in physical therapy.
3. Infrared radiation also plays an important role in maintaining the earth's warmth or average temperature through the greenhouse effect.
4. Infrared detectors are used in Earth satellites, both for military purposes and to observe growth of crops.

D- VISIBLE RAYS:

1. It is the part of the spectrum that is detected by the human eye.
2. Visible light emitted or reflected from objects around us provides us information about the world.
3. It is produced by incandescent bodies.

E- ULTRA VIOLET RAYS:

1. The Sun is an important source of ultraviolet light.
2. UV radiation is produced by special lamps and very hot bodies.
3. UV light in large quantities has harmful effects on humans.
4. UV lamps are used to kill germs in water purifiers.

F- X-RAYS:

1. X-rays are used as a diagnostic tool in medicine and as a treatment for certain forms of cancer.
2. X-rays damage or destroy living tissues and organisms.
3. One common way to generate X-rays is to bombard a metal target by high energy electrons.

Q/ What are the uses of X-rays?

A/ X-rays can be used to detect medical ailments and bone deformities in medical diagnosis. They are useful for ionization purposes also.

G- GAMMA RAYS:

1. They lie in the upper frequency range of the electromagnetic spectrum and have wavelengths from about 10^{-10} m to less than 10^{-14} m.
2. They are the high frequency radiation produced in nuclear reactions and also emitted by radioactive nuclei.
3. They are used in medicine to destroy cancer cells.

Q/ Which part of the electromagnetic spectrum has the highest frequency?

A/ Gamma rays have the highest frequency and the shortest wavelength.

Q/ Can we use X-rays and gamma rays for broadcasting radio/TV/mobile signals?

A/ No, X-rays and gamma rays are short-range. Moreover, they are harmful and have penetrating power on the matter with which they interact and can damage the tissues of living bodies.

4. Formulas for the Electromagnetic Radiation

The frequency(f), speed(c), energy(E) and wavelength(λ) of electromagnetic waves are related as Formulas for Electromagnetic Radiation:

$$E = hf = \frac{hc}{\lambda}$$

Where,

$c \approx 3 \times 10^8 \text{ m/s}$ is the speed of light in a vacuum

$h \approx 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$ is Planck's constant.

Q/ Calculate the frequency and wave number of radiation with a wavelength of 480 nm.

A/

$$\lambda = 480 \text{ nm} \Rightarrow \lambda = 480 \times 10^{-9} \text{ m}$$

$$c \approx 3 \times 10^8 \text{ m/s}$$

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

$$f = \frac{3 \times 10^8}{480 \times 10^{-9}}$$

$$f = 8.9 \times 10^{15} \text{ Hz}$$

Q/ Find the wavelength of a photon with an energy of $2.88 \times 10^{-19} \text{ J}$.

A/

$$E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E}$$

$$h \approx 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$$

$$c \approx 3 \times 10^8 \text{ m/s}$$

$$\lambda = \frac{(6.63 \times 10^{-34})(3 \times 10^8)}{2.88 \times 10^{-19}}$$

$$\lambda = 690 \times 10^{-9} \text{ m}$$

$$\lambda = 690 \text{ nm}$$