**Unit: 6.1**

**Introduction to Spectroscopy**

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**1.2. The Region of Spectrum:**

**What Is Electromagnetic Radiation ?**

Electromagnetic (EM) radiation is a form of energy that is all around us and takes many forms, such as radio waves, microwaves, X-rays and gamma rays. Sunlight is also a form of EM energy, but visible light is only a small portion of the EM spectrum, which contains a broad range of electromagnetic wavelengths.

**What Is Electromagnetic theory ?**

Electricity and magnetism were once thought to be separate forces. However, in 1873, Scottish physicist James Clerk Maxwell developed a unified theory of electromagnetism. The study of electromagnetism deals with how electrically charged particles interact with each other and with magnetic fields.

There are four main electromagnetic interactions:

* The force of attraction or repulsion between electric charges is inversely proportional to the square of the distance between them.
* Magnetic poles come in pairs that attract and repel each other, much as electric charges do.
* An electric current in a wire produces a magnetic field whose direction depends on the direction of the current.
* A moving electric field produces a magnetic field, and vice versa.

Maxwell also developed a set of formulas, called Maxwell's equations, to describe these phenomena.

**What Is Waves and fields ?**

EM radiation is created when an atomic particle, such as an electron, is accelerated by an electric field, causing it to move. The movement produces oscillating electric and magnetic fields, which travel at right angles to each other in a bundle of light energy called a photon. Photons travel in harmonic waves at the fastest speed possible in the universe: 186,282 miles per second (299,792,458 meters per second) in a vacuum, also known as the speed of light. The waves have certain characteristics, given as **frequency, wavelength or energy**.



Electromagnetic waves are formed when an electric field (shown in blue arrows) couples with a magnetic field (shown in red arrows). Magnetic and electric fields of an electromagnetic wave are perpendicular to each other and to the direction of the wave.

A **wavelength (λ)** is the distance between two consecutive peaks of a wave. **Frequency (ν)** is the number of waves that form in a given length of time. It is usually measured as the number of wave cycles per second. A short wavelength means that the frequency will be higher because one cycle can pass in a shorter amount of time

**What Is The EM Spectrum ?**

EM radiation spans an enormous range of wavelengths and frequencies. This range is known as the electromagnetic spectrum. The EM spectrum is generally divided into **Seven Regions**, in order of decreasing wavelength and increasing energy and frequency. The common designations are-

1. Radio waves
2. Microwaves
3. Infrared (IR)
4. Visible light
5. Ultraviolet (UV)
6. X-rays and
7. Gamma rays.

Typically, lower-energy radiation, such as radio waves, is expressed as frequency; microwaves, infrared, visible and UV light are usually expressed as wavelength; and higher-energy radiation, such as X-rays and gamma rays, is expressed in terms of energy per photon.

**Radio waves:**

Radio waves are at the lowest range of the EM spectrum, with frequencies of up to about 30 billion hertz, or 30 gigahertz (GHz), and wavelengths greater than about 10 millimeters (0.4 inches). Radio is used primarily for communications including voice, data and entertainment media.

**Microwaves:**

Microwaves fall in the range of the EM spectrum between Radio and IR. They have frequencies from about 3 GHz up to about 30 trillion hertz, or 30 terahertz (THz), and wavelengths of about 10 mm (0.4 inches) to 100 micrometers (μm), or 0.004 inches. Microwaves are used for high-bandwidth communications, radar and as a heat source for microwave ovens and industrial applications.

**Infrared:**

Infrared is in the range of the EM spectrum between microwaves and visible light. IR has frequencies from about 30 THz up to about 400 THz and wavelengths of about 100 μm (0.004 inches) to 740 nanometers (nm), or 0.00003 inches. IR light is invisible to human eyes, but we can feel it as heat if the intensity is sufficient.

**Visible light:**

Visible light is found in the middle of the EM spectrum, between IR and UV. It has frequencies of about 400 THz to 800 THz and wavelengths of about 740 nm (0.00003 inches) to 380 nm (.000015 inches). More generally, visible light is defined as the wavelengths that are visible to most human eyes.

**Ultraviolet:**

Ultraviolet light is in the range of the EM spectrum between visible light and X-rays. It has frequencies of about 8 × 1014 to 3 × 1016 Hz and wavelengths of about 380 nm (.000015 inches) to about 10 nm (0.0000004 inches). UV light is a component of sunlight; however, it is invisible to the human eye. It has numerous medical and industrial applications, but it can damage living tissue.

**X-rays:**

[X-rays](https://www.livescience.com/32344-what-are-x-rays.html) are roughly classified into two types: soft X-rays and hard X-rays. Soft X-rays comprise the range of the EM spectrum between UV and gamma rays. Soft X-rays have frequencies of about 3 × 1016 to about 1018 Hz and wavelengths of about 10 nm (4 × 10−7inches) to about 100 picometers (pm), or 4 × 10−8inches. Hard X-rays occupy the same region of the EM spectrum as gamma rays. The only difference between them is their source: X-rays are produced by accelerating electrons, while gamma rays are produced by atomic nuclei.

**Gamma-rays:**

Gamma-rays are in the range of the spectrum above soft X-rays. Gamma-rays have frequencies greater than about 1018 Hz and wavelengths of less than 100 pm (4 × 10−9inches). Gamma radiation causes damage to living tissue, which makes it useful for killing cancer cells when applied in carefully measured doses to small regions. Uncontrolled exposure, though, is extremely dangerous to humans.

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