

# 8. ELECTROMAGNETIC WAVES

## Single Page Simple Synopsis

**Electromagnetic waves** are electric and magnetic field waves that propagate at the speed of light through space as transverse waves without needing a material medium. In this chapter, we study how EM waves are generated, their physical characteristics, and the structure of the electromagnetic spectrum.

### 1. Key Characteristics of EM Waves:

- **Transverse Nature:** The oscillating electric and magnetic fields are perpendicular to each other, and both are at right angles to the direction in which the wave is propagating.

- **No Medium Required:** Unlike mechanical waves, they can travel through a vacuum.

**Wave Equation:** Speed of EM wave is  $c = f\lambda$ . Here  $f$  is frequency,  $\lambda$  is wavelength.

- **Source:** An oscillating or accelerating charge produces an oscillating electric field, which in turn produces an oscillating magnetic field.

### 2. Properties of the Fields

The electric field ( $\vec{E}$ ) and magnetic field ( $\vec{B}$ ) vary sinusoidally. If the electric field oscillates along the Y-axis and the magnetic field along the Z-axis, the wave will propagate along the X-axis.  $\vec{E}$ ,  $\vec{B}$  and the direction of propagation of the waves are mutually perpendicular.

### 3. The Electromagnetic Spectrum is the orderly arrangement of the complete range of electromagnetic radiation in increasing frequency or decreasing wavelength.

- i) **Radio waves:** Lowest frequency, highest wavelength; used in radio and TV communication.
- ii) **Microwaves:** Used in radar, satellite communication, and microwave ovens.
- iii) **Infrared rays:** Emitted by hot bodies and molecules. Used in remote controls and physical therapy.
- iv) **Visible light:** The only part of the spectrum detectable by the human eye.
- v) **Ultraviolet (UV) rays:** Produced by the Sun and special lamps. Used in water purification
- vi) **X-rays:** Used in medicine for detecting bone fractures and airport security.
- vii) **Gamma rays:** Lowest wavelength and highest frequency, produced by radioactive nuclei; used in cancer treatment and sterilization.

☞ **Memory Tip:** Rich Men In Vizag Use X-ray Glasses.

### Real Life Examples

- **Global communication network,** Internet, Wifi, bluetooth, GPS Navigation, TV, Radio, Water purifiers, Scanners, Radars, Satellite communication

### IMP. IPE POINTS

1. An **electromagnetic wave** consists of electric and magnetic fields that are perpendicular to each other and perpendicular to the direction of wave propagation. Thus electromagnetic waves are transverse waves.

2. An **accelerating charged particle** emits electromagnetic waves.

3. The relation between amplitudes of electric and magnetic fields in an electromagnetic wave is  $c = \frac{E_0}{B_0}$

4. The **velocity** of electromagnetic wave in **vacuum** is given by  $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$

5. The **velocity** of electromagnetic wave in a **medium** is given by  $c = \frac{1}{\sqrt{\mu \epsilon}}$

6. Electromagnetic waves carry energy and momentum.

7. The momentum of electromagnetic wave is given by  $p = U/c$

8. The displacement current is equal to conduction current at every instant.

9. Electromagnetic waves of frequency range from **500 kHz to about 1000 MHz** are called radio waves. Radio waves are used in communication systems.

10. **Short wavelength radio waves** with frequencies in GHz are called **microwaves**. Micro waves are used in medicine, air-craft communication and microwave ovens.

11. Electromagnetic waves of lower frequencies **adjacent to visible light** are called infrared rays. They are also called **heat waves**. Infrared rays are used in photography, greenhouse effect for heating the atmosphere and in remote control systems of TV, VCR etc.

12. Electromagnetic waves with wavelengths from 400 nm to 700 nm are called **visible light**. Visible light enables us to see the world.

13. Electromagnetic waves of higher frequencies adjacent to visible light are called **ultraviolet rays**. Ultraviolet rays are used in eye surgery, water purifiers etc. Ultraviolet rays can harm human eyes & skin.

14. The **Ozone layer** of the atmosphere protects human life from the ultraviolet rays of the sun.

15. Electromagnetic waves of wavelengths from  **$10^{-3}$  nm to 10 nm** are called **X-rays**. X-rays are used in medicine for curing cancer and taking the photographs of bones. They are also used in research to study the molecular structure of matter.

16. Electromagnetic waves of wavelength less than  $10^{-3}$  nm are called **gamma rays**. They are used in medicine to destroy cancer cells.