

Electromagnetic spectrum properties

Electromagnetic Spectrum – Short Notes

The electromagnetic (EM) spectrum represents the range of all possible electromagnetic radiation, arranged by wavelength (λ) or frequency (ν). It spans from long-wavelength, low-frequency radio waves to short-wavelength, high-frequency gamma rays. All EM waves travel at the speed of light ($c = 3 \times 10^8$ m/s) in vacuum.

1. Radio Waves

- **Wavelength:** > 0.1 m
 - **Frequency:** $< 3 \times 10^9$ Hz
 - **Properties:**
 - Longest wavelength, lowest energy.
 - Used in radio, TV, radar, mobile communication.
 - Can diffract around obstacles and follow Earth's curvature.
 - Harmless to human body.
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2. Microwaves

- **Wavelength:** 1 mm – 0.1 m
 - **Frequency:** 3×10^9 – 3×10^{11} Hz
 - **Properties:**
 - Used in radar, satellite communication, Wi-Fi, microwave ovens.
 - Causes water molecules to vibrate → heating effect.
 - Limited penetration, absorbed by water vapor.
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3. Infrared (IR) Waves

- **Wavelength:** 700 nm – 1 mm
 - **Frequency:** 3×10^{11} – 4×10^{14} Hz
 - **Properties:**
 - Felt as heat radiation.
 - Used in remote controls, night vision, thermal imaging, medical therapy.
 - Excessive exposure causes skin burns.
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4. Visible Rays

- **Wavelength:** 400 – 700 nm
 - **Frequency:** 4×10^{14} – 7.5×10^{14} Hz
 - **Properties:**
 - Only part visible to human eye (VIBGYOR spectrum).
 - Enables vision, photosynthesis.
 - Used in optics, photography, fiber optics.
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5. Ultraviolet (UV) Rays

- **Wavelength:** 10 – 400 nm
 - **Frequency:** 7.5×10^{14} – 3×10^{16} Hz
 - **Properties:**
 - High energy, causes fluorescence and ionization.
 - Kills bacteria and germs (sterilization).
 - Causes skin tanning, sunburn, DNA damage → cancer risk.
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6. X-Rays

- **Wavelength:** 0.01 – 10 nm
 - **Frequency:** 3×10^{16} – 3×10^{19} Hz
 - **Properties:**
 - Highly penetrating, passes through soft tissues but absorbed by bones.
 - Used in medical imaging, airport security, crystallography.
 - Overexposure harmful, can damage living tissues.
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7. Gamma Rays

- **Wavelength:** < 0.01 nm
 - **Frequency:** $> 3 \times 10^{19}$ Hz
 - **Properties:**
 - Highest energy, most penetrating EM radiation.
 - Produced in nuclear reactions, radioactive decay, cosmic sources.
 - Used in cancer therapy, sterilizing medical equipment, food preservation.
 - Highly dangerous to living cells, causes mutations.
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Summary:

- Energy ↑ and wavelength ↓ as we move from **Radio** → **Gamma**.

- Applications vary from communication (radio) to medicine (X-rays, gamma rays).
- Biological effects become increasingly harmful at higher frequencies.

| Type of Radiation | Frequency Range (Hz) | Wavelength Range |
|-------------------|-------------------------------------|--------------------------|
| gamma-rays | $10^{20} - 10^{24}$ | $< 10^{-12}$ m |
| x-rays | $10^{17} - 10^{20}$ | 1 nm - 1 pm |
| ultraviolet | $10^{15} - 10^{17}$ | 400 nm - 1 nm |
| visible | $4 - 7.5 \cdot 10^{14}$ | 750 nm - 400 nm |
| near-infrared | $1 \cdot 10^{14} - 4 \cdot 10^{14}$ | 2.5 μ m - 750 nm |
| infrared | $10^{13} - 10^{14}$ | 25 μ m - 2.5 μ m |
| microwaves | $3 \cdot 10^{11} - 10^{13}$ | 1 mm - 25 μ m |
| radio waves | $< 3 \cdot 10^{11}$ | > 1 mm |

