The electromagnetic wave is an important topic that is **Air Force Group X & Y Exams**. This topic is also asked in the **Indian Navy SSR AA Exam**. We are sharing important notes for you

Notes on Electromagnetic Waves

Displacement Current

While charging a capacitor, Maxwell found an inconsistency in the Ampere's law.

Maxwell suggested the existence of an additional current, called displacement current, to remove this inconsistency.

This displacement current is due to the time-varying electric field and is given by

$i_d = \varepsilon_o (d\phi_E/dt)$

and acts as a source of the magnetic field in exactly the same way as conduction current.

Maxwell's Equations

1. $\oint \mathbf{E} \cdot d\mathbf{A} = Q/\varepsilon_0$	(Gauss's Law for electricity)
2. $\oint \mathbf{B} \cdot d\mathbf{A} = 0$	(Gauss's Law for magnetism)
3. $\oint \mathbf{E} \cdot d\mathbf{l} = \frac{-d\Phi_B}{dt}$	(Faraday's Law)
4. $\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 i_c + \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$	(Ampere – Maxwell Law)

Electromagnetic Waves

Electromagnetic waves are those waves in which there are sinusoidal variations of electric and magnetic field vectors at right angles to each other as well as at right angles to the direction of wave propagation.

Sources of electromagnetic waves

Accelerated charges radiate electromagnetic waves. An oscillating charge is an example of accelerating charge. Electromagnetic waves are also produced when fast moving electrons are suddenly stopped by a metallic surface of high atomic number.

Nature of Electromagnetic Waves

Electric and magnetic fields oscillate sinusoidally in space and time in an electromagnetic wave. The oscillating electric and magnetic fields, E and B are perpendicular to each other, and to the direction of propagation of the electromagnetic wave. For a wave of frequency ν, wavelength λ, propagating along z-direction, we have

$$E = E_x(t) = E_0 \sin(kz - \omega t)$$

$$= E_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \nu t\right)\right] = E_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \frac{t}{T}\right)\right]$$

$$B = B_y(t) = B_0 \sin(kz - \omega t)$$

$$= B_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \nu t\right)\right] = B_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \frac{t}{T}\right)\right]$$

Note: $E_o/B_o = c$, where c is the velocity of light.

Speed of Electromagnetic Wave

The speed c of the electromagnetic wave in vacuum is related to μ and ε (the free space permeability and permittivity constants) as follows:

$$c = 1/\sqrt{\mu_o \varepsilon_o}$$

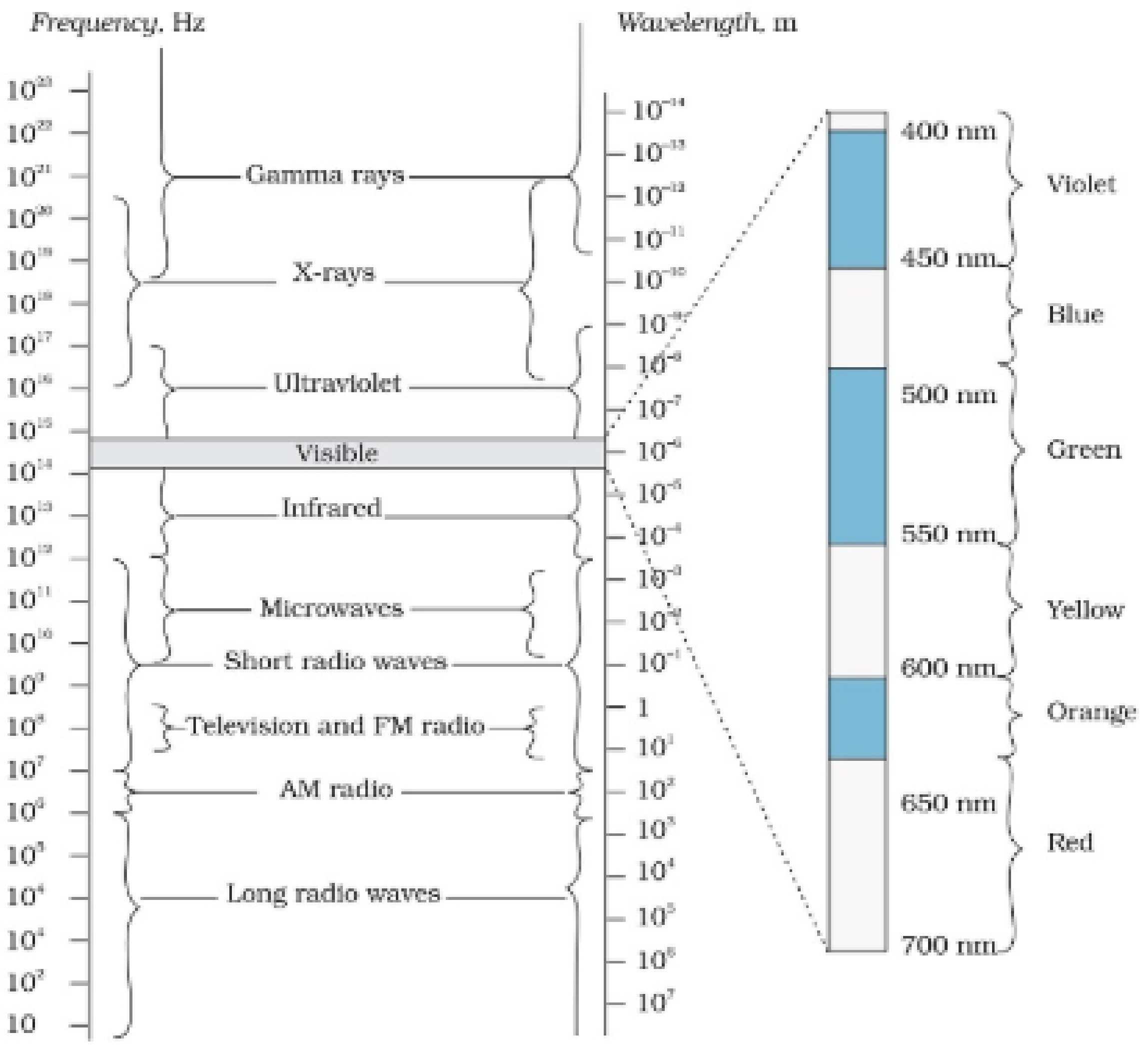
Electromagnetic waves other than light also have the same velocity c in free space.

The speed of light, or of electromagnetic waves in a material medium is given by

$$v = 1/\sqrt{\mu \varepsilon}$$

where μ is the permeability of the medium and ε its permittivity.

Electromagnetic Spectrum



Different Types of Electromagnetic Waves

Type (Wavelength)	Production	Detection
Radio (> 0.1 m)	Rapid acceleration and decelerations of electrons in aerials	Receiver's aerials
Microwave (0.1m to 1 mm)	Klystron valve or magnetron valve	Point contact diodes
Infra-red (1 mm to 700 nm)	Vibration of atoms and molecules	Thermopiles Bolometer, Infrared photographic film
Visible light (700 nm to 400 nm)	700 nm to 400 nm	Electrons in atoms emit light when they move from one energy level to a lower energy level
Ultraviolet (400 nm to 1nm)	Inner shell electrons in atoms moving from one energy level to a lower level	Photocells, Photographic film

X-rays (1nm to 10–3 nm)	X-ray tubes or inner shell electrons	Photographic film, Geiger tubes, Ionisation chamber
Gamma rays (< 10–3 nm)	Radioactive decay of the nucleus	

Radio waves

Radio waves are produced by the accelerated motion of charges in conducting wires.

They are used in radio and television communication systems.

They are generally in the frequency range from 500 kHz to about 1000 MHz.

Microwaves

Microwaves (short-wavelength radio waves), with frequencies in the gigahertz (GHz) range.

They are produced by special vacuum tubes (called klystrons, magnetrons and Gunn diodes).

Due to their short wavelengths, they are suitable for the radar systems used in aircraft navigation.

Infrared waves

Infrared waves are sometimes referred to as heat waves.

Infrared waves are produced by hot bodies and molecules.

Infrared radiation plays an important role in maintaining the earth's warmth or average temperature through the greenhouse effect.

Visible rays

It is the part of the spectrum that is detected by the human eye.

It runs from about

4 × 1014 Hz to about 7 × 1014 Hz or a wavelength range of about 700 – 400 nm.

Visible light emitted or reflected from objects around us provides us information about the world.

Ultraviolet rays

It covers wavelengths ranging from about 4 × 10–7 m (400 nm) down to 6 × 10–10 m (0.6 nm).

Ultraviolet (UV) radiation is produced by special lamps and very hot bodies.

The sun is an important source of ultraviolet light.

Ultraviolet radiations can be focussed into very narrow beams for high precision applications such as LASIK (Laser assisted in situ keratomileusis) eye surgery.

Ultraviolet lamps are used to kill germs in water purifiers

X-rays

It covers wavelengths from about 10–8 m (10 nm) down to 10–13 m (10–4 nm).

One common way to generate X-rays is to bombard a metal target by high energy electrons.

X-rays are used as a diagnostic tool in medicine and as a treatment for certain forms of cancer.

Gamma rays

The wavelengths of Gamma rays are from about 10–10 m to less than 10–14 m.

Gamma rays are produced in nuclear reactions and also emitted by radioactive nuclei.

They are used in medicine to destroy cancer cells.