JEE Main Physics

Short Notes

Electromagnetic Wave

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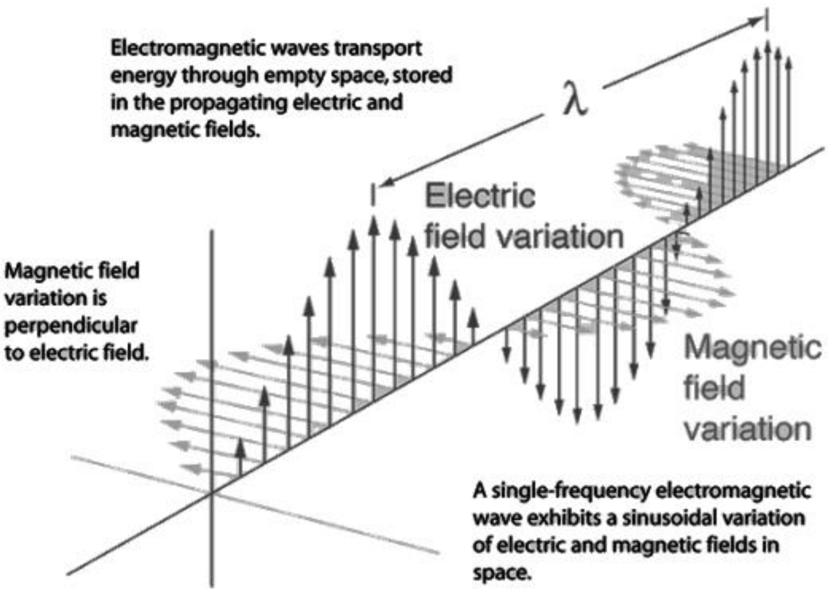
Electromagnetic Wave is an important topic from JEE Main / JEE Advanced Exam Point of view. Every year there are 1-2 questions asked from this topic. This short notes on Alternating Current and EM Wave will help you in revising the topic before the JEE Main & IIT JEE Advanced Exam.

Electromagnetic Wave

An electromagnetic wave which radiated by an accelerated charge propagates through space as coupled electric and magnetic field, oscillating perpendicular to each other and to the direction of propagation of the wave.



Electric and magnetic field oscillate sinusoidally in space and time in an electromagnetic wave.

Oscillating electric and magnetic field are perpendicular to each other. The electric and magnetic field have the same frequency of oscillation and are in same phase.

Equation of electric field is, $E = E_o \sin(kz - \omega t)$

Equation of magnetic field is, $B = B_o \sin(kz - \omega t)$

where $k = \frac{2\pi}{\lambda}$

Points to remember

(1) The amplitude of electric and magnetic field in an electromagnetic wave are related to each other, $B_o = \frac{E_o}{c}$

(2) The speed of an electromagnetic wave in free space, $c = \frac{1}{\mu_o \in_o}$

(3) The speed of an electromagnetic wave in a material medium is $\upsilon = \frac{1}{\sqrt{\mu \in}}$, where are permeability and permittivity of the medium.

(4) Electromagnetic waves are transverse in nature, hence can be polarized.

Energy density of electromagnetic waves

In an electromagnetic wave, the energy density of the electric field is, $\mu_E = \frac{1}{2} \in_0 E^2$

The energy density of the magnetic field is, $\mu_B = \frac{1}{2} \frac{B^2}{\mu_o}$

The total average density of electromagnetic wave, $\mu = \in_o E^2 = \frac{B^2}{\mu_0}$

Radiation pressure

The pressure exerted by an electromagnetic wave on a surface is known as the radiation pressure.

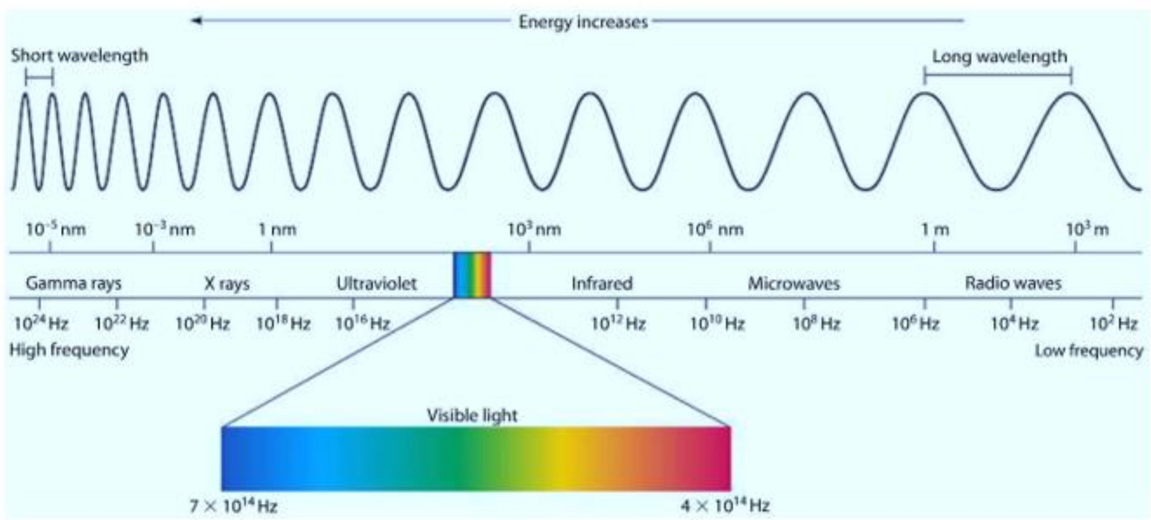
$P = \frac{I}{c}$ (perfectly absorbing surface)

$P = \frac{2I}{c}$ (Perfectly reflecting surface)

Where I, is the intensity of electromagnetic wave, $I = \frac{1}{2}\epsilon_o E_o^2 c = \frac{1}{2}\frac{B_o^2 c}{\mu_o}$

Electromagnetic Spectrum

The distribution of electromagnetic radiations according to their wavelength or frequency is known as the electromagnetic spectrum.



Displacement Current

According to Ampere's circuital law, the line integral of the magnetic field B around and a closed circuit is equal to N_o times the total current I passing through the closed circuit. $\oint \vec{B}.d\vec{\ell} = \mu_o I$

Ampere's circuital law is only valid for closed surface through which an electric field does not change with time. But if the electric field is changing with time then this law doesn't work at all and the other quantity is added know as displacement current.

$$\oint \vec{B}.d\vec{\ell} = \mu_o I + \epsilon_o \frac{d}{dt}\int_s \vec{E}.\hat{n}da$$

$$\oint \vec{B}.d\vec{\ell} = \mu_o I + I_D$$

where I_D is the displacement current

Displacement current is caused due to moving the electric field.

Maxwell's equation

Maxwell describes the fundamental equation of the electric and magnetic field these equation is known as Maxwell's equation. These equations describe the relation between electric and magnetic field and their influence.

$$\oint E.dA = \frac{Q}{\varepsilon_o} \qquad (\text{Gauss's Law for electricity})$$

$$\oint B.dA = 0 \qquad (\text{Gauss's Law for magnetism})$$

$$\oint E.dl = -\frac{d\phi_B}{\varepsilon_o dt} \qquad (\text{Faraday's Law})$$

$$\oint B.dl = \mu_o i_C + \mu_o \varepsilon_o \frac{d\phi_E}{\varepsilon_o dt} \qquad (\text{Ampere - Maxwell Law})$$

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