TOPIC : ELECTROMAGNETIC WAVES
EXERCISE # 1

32. Velocity of light waves in material is

$v = n\lambda$ ...(i)

Refractive index of material is

$\mu = \frac{c}{v}$ ...(ii)

where c is speed of light in vacuum or air.

or $\mu = \frac{c}{n\lambda}$ ...(iii)

Given, $n = 2 \times 10^{14}$ Hz

$\lambda = 5000$ Å $= 5000 \times 10^{-10}$ m,

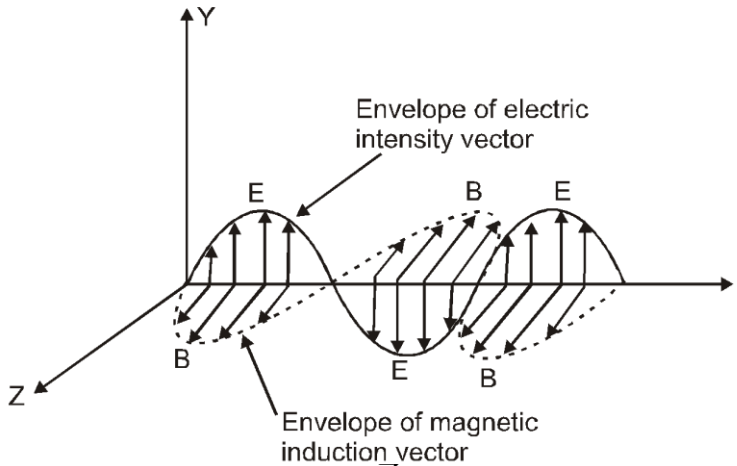
$c = 3 \times 10^{8}$ m/s

Hence, from Eq. (iii), we get

$$\mu = \frac{3 \times 10^8}{2 \times 10^{14} \times 5000 \times 10^{-10}} = 3.00$$

33. The amplitudes of the electric and magnetic fields in free space are related by

$\frac{E_0}{B_0} = c$



In figure, electric field vector $(\vec{E})$ and magnetic field vector $(\vec{B})$ are vibrating along Y and Z directions and propagation of electromagnetic wave is shown in X-direction.

Hence, electric and magnetic fields are in phase and perpendicular to each other.

34. Velocity of electromagnetic radiation is the velocity of light (3), ie,

$$\frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

where μ_0 is the permeability and ε_0 is the permittivity of free space.

74. For electron to pass undeflected,

electric force on electron **=** magnetic force on electron

i.e., $eE = evB$ or $v = \frac{E}{B}$ or $v = \frac{|\vec{E}|}{|\vec{B}|}$

82. Electromagnetic wave require no medium for their propagation.

EXERCISE # 2

3. The wavelength order of waves are given below :

	Waves	**Wavelength (in Å)**
(1)	X- rays	1 Å to 100 Å
(2)	Ultraviolet rays	100 Å to 4000 Å
(3)	γ- rays	0.001 Å to 1 Å
(4)	Cosmic rays	upto 4×10^{-4} Å

Thus, Cosmic rays have the minimum wavelength

4. Velocity = $\frac{c}{\mu}$ and μ decreases as wavelength increases i.e., $\mu_r < \mu_v$

⇒ $\mu_r < \mu_v$

5. Here: Velocity of electromagnetic waves in free space and wavelength

$v = 3 \times 10^8$ ms and $\lambda = 150$ m

Using the relation for the frequency of radio waves is given by

$v = \frac{v}{\lambda}\frac{3\times10^8}{150} = 2 \times 10^6$ Hz - 2 MHz

6. As velocity of light is perpendicular to the wavefront and light is travelling is vacuum along the y-axis, therefrore, the wavefront is represented by y = constant.

7. Energy $E \propto E = hv = \frac{hc}{\lambda} \propto \frac{L}{\lambda}$

we know that $\lambda_{infrared} > \lambda_{visible}$

∴ $E_{infrared} < E_{visible}$

9. $\vec{E} = 6.3\hat{j}$ (v/m) and f = 20 MHz

direction of propagation = $\hat{k} \parallel \left(\vec{E}\times\vec{B}\right)$

then $\vec{B} = \frac{E}{c}\left(-\hat{i}\right) = \left(-\hat{i}\right)\frac{6.3}{3\times10^8}T$ $= 2.1 \times 10^{-8}$ T $(-\hat{i})$

EXERCISE # 3
PART - I

1. Comparing the given equation

$E_y = 2.5\frac{N}{C}\cos\left[\left(2\pi\times10^6\ \frac{rad}{sec}\right)t - \left(\pi\times10^{-2}\ \frac{rad}{sec}\right)x\right]$

With the standard equation

$E_y = E_0\cos(\omega t - kx)$

we get

$\omega = 2\pi f = 2\pi \times 10^6$

∴ $f = 10^6$ Hz

Moreover, we know that

$\frac{2\pi}{\lambda} = k = \pi \times 10^{-2}\ m^{-1}$ ⇒ $\lambda = 200$m

2. Both electric and magnetic field vectors are perpendicular to each other perpendicular to the direction of propagation of wave.

3. As given E = $10\cos(10^7t + kx)$

Comparing it with standard equation of e.m. wave,

E = $E_0\cos(\omega t + kx)$

Amplitude E_0 =10V/m and $\omega = 10^7$ rad/s

$\because c = \nu\lambda = \frac{\omega\lambda}{2\pi}$ or $\lambda = \frac{2\pi c}{\omega} = \frac{2\pi \times 3 \times 10^8}{10^7}$ = 188.4 m

Also

$c = \frac{\omega}{k}$ or $k = \frac{\omega}{c} = \frac{10^7}{3 \times 10^8}$ = 0.033

The wave is propagating along –x direction. Since ($\omega t + kx$) remains constant so as t increases x must decrease so, wave is propagating in –x direction.

4. $\omega = 6 \times 10^{8z}$

$k = \frac{\omega}{v} = \frac{6 \times 10^8}{3 \times 10^8} = 2m^{-1}$

5. U = $\frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\frac{B^2}{\mu_0}$

$\varepsilon_0\mu_0 = \frac{B^2}{E^2}$

$\frac{B}{E} = \sqrt{\varepsilon_0\mu_0} = \frac{1}{c}$

6. Frequency of microwaves = Resonant frequency of H_2O molecules. So there is resonant absorption of microwave

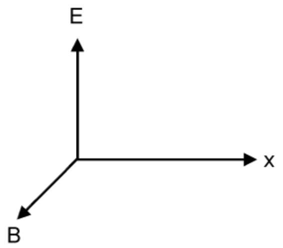
8. $E_0 = \sqrt{2}\, E_{rms} = \sqrt{2} \times 6$ V/m

$B_0 = \frac{E_0}{C} = \frac{\sqrt{2} \times 6}{3 \times 10^2}T = \sqrt{2} \times 10^{-8}$ T = $2 \times 1.414 \times 10^{-8}$ T = 2.828×10^{-8} T

9. $\hat{c} \rightarrow x$ direction

$\hat{E} \rightarrow y$ direction

$\hat{B} \rightarrow +z$ direction



10. Wavelength is maximum for red.

11. Q = CV

$\frac{dQ}{dt} = i = C\frac{dv}{dt} = 20\ \mu F \times \frac{3V}{s} = 60\ \mu A$

For circuit to be completed displacement current should be equal to conduction current.

12. $V = \frac{1}{\sqrt{\mu\varepsilon}} = \frac{1}{\sqrt{\mu_o\varepsilon_o\mu_r\varepsilon_r}} = \frac{3\times10}{\sqrt{1\times1.44}} = \frac{3\times10^8}{1.2}$

$V = 2.5 \times 10^8$ m/s

PART - III

1. Direction of polarization is the direction of electric field and wave propagation along $\vec{E}\times\vec{B}$ which is direction of propagation.

2. $\frac{|E|}{|B|} = c \Rightarrow E = |B|c$ $= 20 \times 10^{-9} \times 3 \times 10^{8} = 6$ V/m.

3. Both the energy densities are equal.

4. Option 4 Is Correct

5. Intensity $I = \frac{P}{4\pi r^2}$

$I = \frac{1}{2}\epsilon_0 E_0^2 \times c$

So $\frac{P}{4\pi r^2} = \frac{1}{2}\epsilon_0 E_0^2 \times c$

$E_0^2 = \frac{2P}{4\pi\epsilon_0 r^2 c} = \frac{2\times0.1\times9\times10^9}{1\times3\times10^8}$

$E_0 = \sqrt{6} = 2.45$ V/m

6. Y X U V I M R

X Rays VIBGVORX MW RW

→ λ λ increasing

Hence energy of radio wave will be minimum and maximum for X ray.

7. C = Speed in air

V = Speed in medium

$\frac{V}{C} = \frac{1}{2}$

$\mu_{r_2} = 1$ (Non-magnetic)

$\frac{V}{C} = \sqrt{\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}}} = \frac{1}{2} \Rightarrow \frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = \frac{1}{4}$

8. Energy is equally distributed in electric field & magnetic field

9. $\frac{E}{B} = C \Rightarrow E = B.C. = 10^{-4} \times 3 \times 10^8$ v / m $= 3 \times 10^4$ v/m

10. $V(t) = 10\,[1 + 0.3\cos(2.2\times10^4 t)\sin(5.5\times10^5 t)]$

$V(t) = 10 + 1.5\,[\sin(572\times10^3 t) + \sin(528\times10^3 t)]$

we get, $\omega_L + \omega_C = 572\times10^3 = 2\pi f_1$

$f_1 = 572\times10^3/2\pi = 91$ kHz

$\omega_L - \omega_C = 528\times10^3 = 2\pi f_2$

$f_2 = 572\times10^3/2\pi = 84$ kHz

11. In air $\frac{E_0}{B_0} = C$

In the medium of refractive index = n

$$\frac{E}{B} = \frac{C}{n}$$

It is possible if

$E = \frac{E_0}{\sqrt{n}}$ and $B = B_0\sqrt{n}$ $\therefore$ $\frac{B_0}{B} = \frac{1}{\sqrt{n}}, \frac{E_0}{E} = \sqrt{n}$