

#### Question 8.5:

A radio can tune in to any station in the 7.5 MHz to 12 MHz band. What is the corresponding wavelength band?

Answer

A radio can tune to minimum frequency,  $v_1$  = 7.5 MHz= 7.5 imes 10<sup>6</sup> Hz

Maximum frequency,  $v_2$  = 12 MHz = 12  $\times$  10<sup>6</sup> Hz

Speed of light,  $c = 3 \times 10^8$  m/s

Corresponding wavelength for  $v_1$  can be calculated as:

$$\lambda_1 = \frac{c}{v_1}$$

$$= \frac{3 \times 10^8}{7.5 \times 10^6} = 40 \text{ m}$$

Corresponding wavelength for  $v_2$  can be calculated as:

$$\lambda_2 = \frac{c}{v_2} = \frac{3 \times 10^8}{12 \times 10^6} = 25 \text{ m}$$

Thus, the wavelength band of the radio is 40 m to 25 m.

## Question 8.6:

A charged particle oscillates about its mean equilibrium position with a frequency of  $10^9$  Hz. What is the frequency of the electromagnetic waves produced by the oscillator?

Answer

The frequency of an electromagnetic wave produced by the oscillator is the same as that of a charged particle oscillating about its mean position i.e.,  $10^9$  Hz.

## Question 8.7:

The amplitude of the magnetic field part of a harmonic electromagnetic wave in vacuum is  $B_0 = 510$  nT. What is the amplitude of the electric field part of the wave?

Answer

Amplitude of magnetic field of an electromagnetic wave in a vacuum,

$$B_0 = 510 \text{ nT} = 510 \times 10^{-9} \text{ T}$$

Speed of light in a vacuum,  $c = 3 \times 10^8$  m/s

Amplitude of electric field of the electromagnetic wave is given by the relation,

$$E = cB_0$$

$$= 3 \times 10^8 \times 510 \times 10^{-9} = 153 \text{ N/C}$$

Therefore, the electric field part of the wave is 153 N/C.

#### Question 8.8:

Suppose that the electric field amplitude of an electromagnetic wave is  $E_0$  = 120 N/C and that its frequency is v = 50.0 MHz. (a) Determine,  $B_0$ ,  $\omega$ , k, and  $\lambda$ . (b) Find expressions for

## E and B.

Answer

Electric field amplitude,  $E_0 = 120 \text{ N/C}$ 

Frequency of source,  $v = 50.0 \text{ MHz} = 50 \times 10^6 \text{ Hz}$ 

Speed of light,  $c = 3 \times 10^8 \,\text{m/s}$ 

(a) Magnitude of magnetic field strength is given as:

$$B_0 = \frac{E_0}{c}$$
=\frac{120}{3\times 10^8}
= 4 \times 10^{-7} T = 400 nT

Angular frequency of source is given as:

$$\omega = 2\pi v$$

$$= 2n \times 50 \times 10^6$$

$$= 3.14 \times 10^8 \text{ rad/s}$$

Propagation constant is given as:

$$k = \frac{\omega}{c}$$
=  $\frac{3.14 \times 10^8}{3 \times 10^8}$  = 1.05 rad/m

Wavelength of wave is given as:

$$\lambda = \frac{c}{v} = \frac{3 \times 10^8}{50 \times 10^6} = 6.0 \text{ m}$$

**(b)** Suppose the wave is propagating in the positive x direction. Then, the electric field vector will be in the positive y direction and the magnetic field vector will be in the positive z direction. This is because all three vectors are mutually perpendicular.

Equation of electric field vector is given as:

$$\vec{E} = E_0 \sin(kx - \omega t) \hat{j}$$

$$= 120 \sin[1.05x - 3.14 \times 10^8 t] \hat{j}$$

And, magnetic field vector is given as:

$$\vec{B} = B_0 \sin(kx - \omega t) \hat{k}$$

$$\vec{B} = (4 \times 10^{-7}) \sin[1.05x - 3.14 \times 10^8 t] \hat{k}$$

# Question 8.9:

The terminology of different parts of the electromagnetic spectrum is given in the text. Use the formula E = hv (for energy of a quantum of radiation: photon) and obtain the photon energy in units of eV for different parts of the electromagnetic spectrum. In what way are the different scales of photon energies that you obtain related to the sources of electromagnetic radiation?

Answer

Energy of a photon is given as:

$$E = hv = \frac{hc}{\lambda}$$

Where,

 $h = Planck's constant = 6.6 \times 10^{-34} Js$ 

c = Speed of light = 3 × 10 $^8$  m/s

 $\lambda$  = Wavelength of radiation

$$\therefore E = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{\lambda} = \frac{19.8 \times 10^{-26}}{\lambda} \text{ J}$$
$$= \frac{19.8 \times 10^{-26}}{\lambda \times 1.6 \times 10^{-19}} = \frac{12.375 \times 10^{-7}}{\lambda} \text{ eV}$$

The given table lists the photon energies for different parts of an electromagnetic spectrum for different  $\!\lambda.$ 

λ (m)	10 <sup>3</sup>	1	10-3	10 <sup>-6</sup>	10-8	10 <sup>-10</sup>	10-12
	12.375 × 10 <sup>-10</sup>		12.375 × 10 <sup>-4</sup>	12.375 × 10 <sup>-1</sup>	12.375 × 10 <sup>1</sup>	12.375 × 10 <sup>3</sup>	12.375 × 10 <sup>5</sup>

The photon energies for the different parts of the spectrum of a source indicate the spacing of the relevant energy levels of the source.

## Question 8.10:

In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of  $2.0\times10^{10}$  Hz and amplitude 48 V m $^{-1}$ .

- (a) What is the wavelength of the wave?
- (b) What is the amplitude of the oscillating magnetic field?
- (c) Show that the average energy density of the **E** field equals the average energy density of the **B** field. [ $c = 3 \times 10^8$  m s<sup>-1</sup>.]

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