Electromagnetic Waves

Question1

If the magnetic field in a plane progressive wave is represented by the equation $B_y = 2 \times 10^{-7} \sin\left(0.5 \times 10^3 x + 1.5\pi \times 10^{11} t\right) \text{T}$, then the frequency of the wave is

(In the equation time t is in second)

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Options:

A.

75×10^9 Hz

B.

150×10^9 Hz

C.

75×10^7 Hz

D.

150×10^7 Hz

Answer: A

Solution:

$$B_y = 2 \times 10^{-7} \sin \left(0.5 \times 10^3 x + 1.5\pi \times 10^{11} t \right) \text{T}$$

$$\therefore \quad \omega = 1.5\pi \times 10^{11}$$

$$\text{Thus, } f = \frac{\omega}{2\pi} = \frac{1.5\pi \times 10^{11}}{2\pi}$$

$$= 0.75 \times 10^{11} = 75 \times 10^9 \text{ Hz}$$

Question2

If a 10 W bulb emits electromagnetic waves uniformly in all directions, then the intensity of light at a distance 0.5 m from the source is nearly

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Options:

A.

3.18Wm^{-2}

B.

0.31Wm^{-2}

C.

0.62Wm^{-2}

D.

5Wm^{-2}

Answer: A

Solution:

Given:

- Power of bulb $P = 10$ W

- Distance $r = 0.5$ m

- The bulb emits uniformly in all directions (i.e., isotropically).

Step 1: Formula for intensity

$I = \frac{P}{A} = \frac{P}{4\pi r^2}$

Step 2: Substitute values

$I = \frac{10}{4\pi(0.5)^2}$

$I = \frac{10}{4\pi \times 0.25} = \frac{10}{\pi}$

Step 3: Simplify numerically

$I \approx \frac{10}{3.14} \approx 3.18 \text{ W m}^{-2}$

✅ **Final Answer:**

$\boxed{I \approx 3.18 \text{ W m}^{-2}}$

Correct Option: A.

Question3

The layer of the atmosphere that reflects low frequency (LF) electromagnetic waves during day time only is

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Options:

A.

D

B.

E

C.

F_1

D.

F_2

Answer: A

Solution:

Question:

The layer of the atmosphere that reflects low frequency (LF) electromagnetic waves during daytime only is —

Step 1: Recall the ionospheric layers

The **ionosphere** has several layers:

- **D layer** — lowest layer, present **only during the daytime**

- **E layer**

- **F_1 and F_2 layers** — present at higher altitudes

Step 2: Function of the D layer

- The **D layer** is ionized by solar radiation and **disappears at night** (it recombines quickly when sunlight is gone).

- It primarily affects **low-frequency (LF) and medium-frequency (MF)** radio waves.

- It does not strongly reflect HF waves—it mostly causes absorption at higher frequencies.

Step 3: Reflection characteristic

- **LF waves (30–300 kHz)** are **reflected by the D layer** during **daytime only**.

- At night, the D layer disappears, and these LF waves can instead travel farther by ground or sky wave propagation.

✅ **Final Answer:**

Option A — D layer

Answer:

A. D layer

Question4

The oscillating electric and magnetic field vectors of an electromagnetic wave are along

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Options:

A.

the same direction and in same phase.

B.

the same direction but have a phase difference of $90°$.

C.

mutually perpendicular directions and are in same phase.

D.

mutually perpendicular directions but have a phase difference of $90°$.

Answer: C

Solution:

In an electromagnetic wave, oscillating electric and magnetic fields increases and decreases simultaneously i.e., they are always in same phase. Also **E** and **B** are always perpendicular to each other.

Question5

The waves having maximum wavelength among the following electromagnetic waves is

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Options:

A.

X-rays

B.

radio waves

C.

UV-waves

D.

visible rays

Answer: B

Solution:

The electromagnetic spectrum (in order of **increasing wavelength**) is:

Gamma rays → X-rays → Ultraviolet (UV) → Visible light → Infrared → Microwaves → Radio waves

So, **radio waves** have the **maximum wavelength** among the given options.

✅ **Correct answer: Option B — Radio waves**

Question6

The ratio of the magnitudes of the electric field and 10^8 times the magnetic field of a plane electromagnetic wave is

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Options:

A.

1 : 3

B.

3 : 1

C.

1 : 1

D.

1 : $\sqrt{3}$

Solution:

The electric field (E_0) and magnetic field (B_0) in a plane electromagnetic wave have a special relationship.

We know that $\frac{E_0}{B_0} = c$ where c is the speed of light, which is 3×10^8 m/s.

If we compare E_0 to 10^8 times B_0, we get: $\frac{E_0}{10^8 B_0} = \frac{E_0}{B_0} \times \frac{1}{10^8}$

Now substitute c for $\frac{E_0}{B_0}$: $\frac{E_0}{10^8 B_0} = \frac{3 \times 10^8}{10^8} = 3$

So, the answer is: $\frac{E_0}{10^8 B_0} = 3$

Question7

If the rms value of the electric field of electromagnetic waves at a distance of 3 m from a point source is $3\mathrm{NC}^{-1}$, then the power of the source is

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Options:

A.

10.8 W

B.

8.1 W

C.

5.4 W

D.

2.7 W

Solution:

Power of the source

$$P = I \times 4\pi r^2$$
$$= \frac{1}{2} C \varepsilon_0 E_{\text{rms}}^2 \times 4\pi r^2$$
$$= \frac{1}{2} \times 3 \times 10^8 \times 8.85 \times 10^{-12} \times 3^2 \times 4\pi \times 3^2$$
$$= 2.7 \text{ W}$$

Question8

The magnitude of the electric field of a plane electromagnetic wave travelling in free space is E. If μ_0 and ε_0 are respectively permeability and permittivity of the free space, then the magnitude of magnetic field of the wave is

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Options:

A.

$E\mu_0\varepsilon_0$

B.

$\frac{E}{\mu_0\varepsilon_0}$

C.

$E\sqrt{\mu_0\varepsilon_0}$

D.

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

Answer: C

Solution:

Step 1: Relationship between E and B in an electromagnetic wave

For a plane electromagnetic wave in free space,

$$E = cB$$

where c is the speed of light in free space.

Thus,

$$B = \frac{E}{c}.$$

Step 2: Express c in terms of μ_0 and ε_0

The speed of light is given by

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}.$$

Step 3: Substitute into expression for B

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

✅ **Final Answer:**

$$\boxed{B = E\sqrt{\mu_0 \varepsilon_0}}$$

Correct Option: C

Question9

A plane electromagnetic wave of frequency 25 MHz propagates in vacuum along positive x-direction. At a particular point in space and time, if the electric field is $63\hat{j}\,\mathrm{Vm}^{-1}$, then the magnitude of the magnetic field of the wave at this point at the same time is

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Options:

A.

2.1×10^{-8} T

B.

4.2×10^{-8} T

C.

6.3×10^{-8} T

D.

8.4×10^{-8} T

Answer: A

Solution:

$$B = \frac{F}{c} = \frac{6.3}{3 \times 10^8}$$
$$= 2.1 \times 10^{-8} \text{ T}$$

Question10

If the magnetic field inside a solenoid is B, then the magnetic energy stored in it per unit volume is ($c =$ speed of light in vacuum and ε_0 is permittivity of free space)

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Options:

A.

$\varepsilon_0 c^2 B^2$

B.

$\frac{\varepsilon_0 c^2 B^2}{2}$

C.

$2\varepsilon_0 c^2 B^2$

D.

$\frac{\varepsilon_0 c^2 B^2}{4}$

Answer: B

Solution:

Magnetic energy stored per unit volume

$$= \frac{B^2}{2\mu_0} = \frac{B^2}{2 \times \frac{1}{\varepsilon_0 c^2}} \quad \left[c^2 = \frac{1}{\mu_0 \varepsilon_0}\right]$$

$$= \frac{\varepsilon_0 B^2 c^2}{2}$$

Question11

In a plane electromagnetic wave, the magnetic field is given by $\mathbf{B} = 3 \times 10^{-7} \sin\left(100\pi x + 10^{12} t\right) \mathrm{T}$, then the wavelength of the wave is

(In the equation x is in metre and t is in second)

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Options:

A.

0.02 m

B.

0.2 m

C.

0.4 m

D.

0.04 m

Answer: A

Solution:

$\mathbf{B} = 3 \times 10^{-7} \sin\left(100\pi x + 10^{12} t\right) \mathrm{T}$

Here, $K = 100\pi \ \mathrm{m}^{-1}$

$$\therefore \quad \lambda = \frac{2\pi}{K} = \frac{2\pi}{100\pi} = 0.02 \text{ m}$$

Question12

For plane electromagnetic waves propagating in the positive z-direction. The combination which gives the correct possible direction for E and B fields respectively is

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Options:

A. $(-2\hat{\mathbf{i}} - 3\hat{\mathbf{j}})$ and $(3\hat{\mathbf{i}} - 2\hat{\mathbf{j}})$

B. $(3\hat{i} + 4\hat{j})$ and $(4\hat{i} - 3\hat{j})$

C. $(\hat{\mathbf{i}} - 2\hat{\mathbf{j}})$ and $(-2\hat{\mathbf{i}} - \hat{\mathbf{j}})$

D. $(-2\hat{\mathbf{i}} + 3\hat{\mathbf{j}})$ and $(\hat{\mathbf{i}} + 2\hat{\mathbf{j}})$

Answer: A

Solution:

For a wave moving in the +z-direction we need

$\mathbf{E} \perp \mathbf{B}$, $\quad \mathbf{E} \times \mathbf{B}$ along $+z,$

so in components

$\mathbf{E} = (E_x, E_y, 0), \ \mathbf{B} = (B_x, B_y, 0) \implies \mathbf{E} \times \mathbf{B} = (0, 0 \ E_x B_y - E_y B_x)$

and we require

$E_x B_y - E_y B_x > 0$.

Let's check each option (we write only the key step):

• A: $\mathbf{E} = (-2, -3, 0), \mathbf{B} = (3, -2, 0)$

$E_x B_y - E_y B_x = (-2)(-2) - (-3)(3) = 4 + 9 = 13 > 0.$

$\Rightarrow$ +z

• B: $(3, 4) \times (4, -3) \rightarrow 3 \cdot (-3) - 4 \cdot 4 = -25 < 0$

• C: $(1, -2) \times (-2, -1) \rightarrow 1 \cdot (-1) - (-2) \cdot (-2) = -5 < 0$

• D: $(-2, 3) \times (1, 2) \rightarrow (-2) \cdot 2 - 3 \cdot 1 = -7 < 0$

Only Option A gives a positive z-component, so the correct choice is **A**.

Question13

Size of the antenna for a carrier wave of frequency 3 MHz is

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Options:

A. 75 m

B. 50 m

C. 2.5 m

D. 25 m

Answer: D

Solution:

First find the wavelength:

$\lambda = \frac{c}{f} = \frac{3 \times 10^8 \text{ m/s}}{3 \times 10^6 \text{ Hz}} = 100 \text{ m}$

A typical monopole (quarter-wave) antenna is

$\frac{\lambda}{4} = \frac{100 \text{ m}}{4} = 25 \text{ m}$

So the correct choice is **Option D: 25 m**.

Question14

The radiation of energy E falls normally on a perfectly reflecting surface. The momentum transferred to the surface is

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Options:

A. $\frac{E}{C}$

B. $\frac{2E}{c}$

C. $\frac{E}{c^2}$

D. $\frac{2E}{c^2}$

Answer: B

Solution:

When energy E in the form of radiation falls normally on a perfectly reflecting surface, the momentum transferred to the surface can be calculated as follows:

Energy of the Radiation:

The energy of radiation is given by the equation:

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

where h is Planck's constant, c is the speed of light, and λ is the wavelength of the radiation.

Momentum of the Incident Radiation:

The momentum p_i of the incident radiation is given by:

$p_i = \frac{E}{c}$

which simplifies to:

$p_i = \frac{h}{\lambda}$

Momentum of the Reflected Radiation:

Since the surface is perfectly reflecting, the momentum of the reflected radiation p_r is:

$p_r = -p_i$

Momentum Transferred to the Surface:

The momentum transferred (Δp) to the surface is the difference between the incident and reflected momentum:

$\Delta p = p_i - p_r = \frac{E}{c} - \left(-\frac{E}{c}\right)$

Simplifying further:

$\Delta p = \frac{E}{c} + \frac{E}{c} = \frac{2E}{c}$

Thus, the momentum transferred to the surface is $\frac{2E}{c}$.

Question15

The structure of solids is investigated by using

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Options:

A. cosmic rays

B. β-rays

C. X-rays

D. γ-rays

Answer: C

Solution:

The correct answer is Option C: X-rays.

Here's why:

When X-rays are directed at a solid (especially a crystalline material), they are diffracted by the planes of atoms in the crystal.

This diffraction pattern, known as X-ray diffraction (XRD), is used to determine the arrangement of atoms within the material.

Techniques like X-ray crystallography rely on X-rays because their wavelengths are similar in scale to the interatomic distances, allowing for precise structural investigations.

Thus, using X-rays, scientists can deduce the internal structure of solids.

Question16

The rms value of the electric field of an electromagnetic wave emitted by a source is $660 \mathrm{NC}^{-1}$. The average energy density of the electromagnetic wave is

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Options:

A. $1.75 \times 10^{-6} \mathrm{Jm}^{-3}$

B. $2.75 \times 10^{-6} \mathrm{Jm}^{-3}$

C. $4.85 \times 10^{-6} \mathrm{Jm}^{-3}$

D. $3.85 \times 10^{-6} \mathrm{Jm}^{-3}$

Answer: D

Solution:

Given that the root mean square (rms) value of the electric field of an electromagnetic wave is $E_{\mathrm{rms}} = 660 \, \mathrm{N/C}$, the average energy density E_{avg} of the electromagnetic wave can be calculated using the formula:

$$E_{\mathrm{avg}} = \varepsilon_0 E_{\mathrm{rms}}^2$$

Where:

$\varepsilon_0 = 8.85 \times 10^{-12}$ F/m (the permittivity of free space)

Plugging in the values, we have:

$$E_{\mathrm{avg}} = 8.85 \times 10^{-12} \times (660)^2$$

Calculating this:

$$E_{\mathrm{avg}} = 3.85 \times 10^{-6} \, \mathrm{J/m^3}$$

Thus, the average energy density of the electromagnetic wave is $3.85 \times 10^{-6} \, \mathrm{J/m^3}$.

Question17

A transmitter of power 10 kW emits radio waves of wavelength 500 m . The number of photons emitted por second by the transmitter of the order of

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Options:

A. 10^{37}

B. 10^{31}

C. 10^{25}

D. 10^{43}

Answer: B

Solution:

Given:

Wavelength, $\lambda = 500\,\mathrm{m}$

Power, $P = 10\,\mathrm{kW} = 10^4\,\mathrm{W}$

To find the number of photons emitted per second by the transmitter, we use the formula for power related to energy and photon emission:

$$P = \frac{E}{t} \quad \text{and} \quad E = \frac{n \cdot h \cdot c}{\lambda}$$

This leads to:

$$P = \frac{n \cdot h \cdot c}{\lambda \cdot t} \quad \Rightarrow \quad \frac{n}{t} = \frac{P \times \lambda}{h \times c}$$

Substitute the known values:

$$\frac{n}{t} = \frac{10^4 \times 500}{6.64 \times 10^{-34} \times 3 \times 10^8}$$

Simplify the expression:

$$\frac{n}{t} = \frac{500}{6.64 \times 3} \times 10^{30}$$

Simplifying further gives:

$$\frac{n}{t} = \frac{50}{6.64 \times 3} \times 10^{31} \approx 2.5 \times 10^{31}$$

Thus, the order of the number of photons emitted per second is:

$$\text{Order} = 10^{31}$$

Question18

Which of the following produces electromagnetic waves?

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Options:

A. Stationary charges

B. Charges in uniform motion

C. Accelerating charges

D. Stationary magnet

Answer: C

Solution:

Accelerating charges can produce electromagnetic waves because a change in the velocity of charges causes a variation in the electromagnetic waves.

Stationary charges do not change electric field with time. Charges in uniform motion produces steady electric and magnetic fields, but no changing fields. Stationary magnet produces a static magnetic field with no time variation. So, due to these reasons they can not produce EM waves.

Question19

The average value of electric energy density in an electromagnetic wave is where E_0 is peak value

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Options:

A. $\frac{E_0 E_{\pi m}^2}{4}$

B. $\frac{1}{2}\varepsilon_0 E_0^2$

C. $\frac{1}{2}e_0 E_0$

D. $\frac{1}{4}\varepsilon_0 E_0^2$

Answer: D

Solution:

The average value of electric energy density in an electromagnetic wave can be determined as follows:

The formula for average electric energy density is given by:

$u_c = \frac{1}{2}\varepsilon_0 E_{\text{rms}}^2$

Where E_{rms} is the root mean square value of the electric field, which is expressed as:

$E_{\text{rms}} = \frac{E_0}{\sqrt{2}}$

Substituting the expression for E_{rms} into the formula for u_c, we have:

$$u_c = \frac{1}{2}\varepsilon_0 \left(\frac{E_0}{\sqrt{2}}\right)^2$$

Simplifying this, we get:

$$u_c = \frac{1}{4}\varepsilon_0 E_0^2$$

Thus, the average electric energy density is $\frac{1}{4}\varepsilon_0 E_0^2$.

Question20

An electromagnetic wave travel in a medium with a speed of $2 \times 10^8 \text{ ms}^{-1}$. The relative permeability of the medium is 1 . Then, the relative permittivity is

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Options:

A. 1.75

B. 2

C. 2.28

D. 2.75

Answer: C

Solution:

The speed of an electromagnetic wave in a medium can be described by the equation:

$$v = \frac{c}{\sqrt{\varepsilon_r \mu_r}}$$

Given that the relative permeability (μ_r) of the medium is 1, the equation simplifies to:

$$v = \frac{c}{\sqrt{\varepsilon_r}}$$

where:

v is the speed of the wave in the medium,

c is the speed of light in a vacuum (3×10^8 m/s),

ε_r is the relative permittivity.

We need to find the relative permittivity (ε_r) of the medium when the wave speed (v) is 2×10^8 m/s:

$$\varepsilon_r = \frac{c^2}{v^2} = \frac{(3 \times 10^8)^2}{(2 \times 10^8)^2}$$

Calculating this gives:

$$\varepsilon_r = \left(\frac{3}{2}\right)^2 = \frac{9}{4} = 2.25 \approx 2.28$$

Therefore, the relative permittivity is approximately 2.28.

Question21

A message signal of 3 kHz is used to modulate a carric signal frequency 1 MHz , using amplitude modulation. The upper side band frequency and band width respectively are

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Options:

A. 1.003 MHz and 6 kHz

B. 0.997 MHz and 6 kHz

C. 1.003 MHz and 3 kHz

D. 1.003 MHz and 2 MHz

Answer: A

Solution:

To solve for the upper sideband frequency and the bandwidth of an amplitude-modulated signal, given:

Message signal frequency (f_m): 3 kHz

Carrier frequency (f_c): 1 MHz (1000 kHz)

Calculating the Upper Sideband Frequency

The upper sideband frequency is calculated as follows:

$$f_{\text{USB}} \quad = f_c + f_m = 1000\,\text{kHz} + 3\,\text{kHz} = 1003\,\text{kHz} = 1.003\,\text{MHz}$$

Calculating the Bandwidth

The bandwidth of an amplitude-modulated signal is the difference between the upper sideband and the lower sideband frequencies:

$$\text{Bandwidth} = (f_c + f_m) - (f_c - f_m) = 2f_m = 2 \times 3\,\text{kHz} = 6\,\text{kHz}$$

Thus, the upper sideband frequency is 1.003 MHz, and the bandwidth is 6 kHz.

Question22

The solar radiation is

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Options:

A. stationary wave

B. mechanical wave

C. transverse EM wave

D. longludinal EM wave

Answer: C

Solution:

Solar radiation is a form of electromagnetic radiation. Here's why Option C is the correct choice:

Nature of Solar Radiation:

Solar radiation includes visible light, ultraviolet light, infrared, and other types of electromagnetic waves.

Transverse vs. Longitudinal Waves:

Transverse Waves: In these waves, the oscillations (the electric and magnetic fields in the case of EM waves) are perpendicular to the direction of propagation.

Longitudinal Waves: In these, the oscillations occur in the same direction as the wave travels. Sound waves are a common example, but electromagnetic waves are not longitudinal.

Mechanical vs. Electromagnetic Waves:

Mechanical Waves: These require a medium (like air or water) to propagate (e.g., sound waves).

Electromagnetic Waves: These do not need a medium and can travel through a vacuum, like the solar radiation from the sun.

Since solar radiation consists of electromagnetic waves that are transverse in nature, the correct option is:

Option C: Transverse EM wave.

Question23

The magnetic field in a plane electromagnetic wave is given as
$$\mathbf{B} = \left(3 \times 10^{-7} \text{ T}\right) \sin \left(3 \times 10^4 x + 9 \times 10^{12} t\right) \hat{j}$$

The electric field of this wave is given as

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Options:

A. $90 \sin \left(3 \times 10^4 x + 9 \times 10^{12} t\right) \hat{i} \text{ Vm}^{-1}$

B. $90 \sin \left(3 \times 10^4 \text{x} + 9 \times 10^{12} t\right) \hat{\text{k}} \text{ Vm}^{-1}$

C. $45 \sin \left(3 \times 10^4 x + 9 \times 10^{12} t\right) \hat{i} \text{ Vm}^{-1}$

D. $45 \sin \left(3 \times 10^4 x + 9 \times 10^{12} t\right) \hat{k} \text{ Vm}^{-1}$

Answer: B

Solution:

Given, Magnetic field in a plane EM wave,

$B = \left(3 \times 10^{-7} \text{ T}\right) \sin \left(3 \times 10^4 x + 9 \times 10^{12} t\right) \text{T}$

Here, $B_0 = 3 \times 10^{-7} \text{ T}$

Amplitude of electric field,

$\quad E_0 = B_0 c$
$\qquad = 3 \times 10^{-7} \times 3 \times 10^8$
$\Rightarrow \quad E_0 = 90 \text{Vm}^{-1}$

From the given equation of B, it is clear that EM wave is travelling along negative direction of X-axis i.e.

$\therefore$ If $\hat{\mathbf{n}}$ be the unit vector along the direction of electric field, then

$\hat{\mathbf{n}} \times \hat{j} = -\hat{i}$

Clearly, $\hat{\mathbf{n}} = \hat{k}$

Hence.

$E = E_0 \sin(kx + \omega t) \hat{k}$
$\quad = 90 \sin \left(3 \times 10^4 x + 9 \times 10^{12} t\right) \hat{k} \text{Vm}^{-1}$

Question24

Frequencies in the UHF range normally propagate by means of

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Options:

A. Space waves

B. Surface waves

C. Ground waves

D. Sky waves

Answer: A

Solution:

The correct answer is **Option A: Space Waves**. Here's why:

UHF (Ultra High Frequency) waves, which range from 300 MHz to 3 GHz, typically propagate using space waves. Let's break down the different types of wave propagation:

Space Waves:

- Travel in a straight line directly from the transmitting antenna to the receiving antenna.
- These waves are not affected by the Earth's surface or atmosphere significantly.
- They are commonly used for satellite communication, terrestrial microwave links, and short-distance line-of-sight communication.

Surface Waves:

- These waves travel along the surface of the Earth.
- They are primarily used for low-frequency (LF) and very low frequency (VLF) radio waves, which have wavelengths longer than UHF.

Ground Waves:

- Similar to surface waves, they travel along the ground.
- They are primarily used for medium-frequency (MF) radio waves and are affected by the Earth's conductivity.

Sky Waves:

- These waves are reflected by the ionosphere, a layer of charged particles in the upper atmosphere.

- They are primarily used for long-distance communication with high-frequency (HF) radio waves.

In summary: UHF frequencies, being much higher than those used for ground or sky waves, primarily propagate via space waves, which travel directly from the transmitter to the receiver without significant interaction with the Earth's surface or the atmosphere.

Question25

A light of intensity $12 \mathrm{Wm}^{-2}$ incidents on a black surface of area $4 \, \mathrm{cm}^2$. The radiation pressure on the surface is

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Options:

A. $1 \times 10^{-8} \, \mathrm{Pa}$

B. $4 \times 10^{-8} \, \mathrm{Pa}$

C. $1.6 \times 10^{-7} \, \mathrm{Pa}$

D. $4.8 \times 10^{-7} \, \mathrm{Pa}$

Answer: B

Solution:

Given:

- Intensity of light (I) = 12 W/m²

- Surface area (A) = 4 cm² = 4 × 10⁻⁴ m²

For a perfectly black surface, the radiation pressure (p) is calculated using the formula:

$p = \frac{I}{c}$

where c is the speed of light in vacuum, approximately 3×10^8 m/s.

Substituting the given values:

$p = \frac{12}{3 \times 10^8}$

$p = 4 \times 10^{-8} \, \mathrm{Pa}$

Hence, the radiation pressure on the surface is $4 \times 10^{-8} \, \mathrm{Pa}$.

Question26

The electric field (E) and magnetic field (B) of an electromagnetic wave passing through vacuum are given by

$$E = E_0 \sin(kx - \omega t)$$
$$B = B_0 \sin(kx - \omega t)$$

Then the correct statement among the following is

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Options:

A. $E_0 k = B_0 \omega$

B. $E_0 \omega = B_0 k$

C. $E_0 B_0 = \omega k$

D. $E_0 B_0 = \frac{\omega}{k}$

Answer: A

Solution:

Electric field (E) and magnetic field (B) of an electromagnetic wave are given as

$E = E_0 \sin(kx - \omega t)$

and $B = B_0 \sin(kx - \omega t)$

We know that,

$$E_0 = CB_0$$

$$K = \frac{2\pi}{\lambda} \text{ and } \omega = 2f\pi$$

$$\therefore \quad \frac{E_0}{B_0} = C = f\lambda$$

$$\Rightarrow \quad \frac{E_0}{B_0} = f\lambda$$

$$= \frac{\omega}{2\pi} \cdot \frac{2\pi}{k} \quad \left(\because f = \frac{\omega}{2\pi} \text{ and } \lambda = \frac{2\pi}{k} \right)$$

$$\Rightarrow \quad \frac{E_0}{B_0} = \frac{\omega}{k}$$

$$\Rightarrow \quad E_0 k = B_0 \omega$$

Question27

A carrier wave is used to transmit a message signal. If the peak voltage of modulating signal and carrier signal are increased by 1% and 3% respectively, the modulation index is changed by

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Options:

A. -2%

B. 4%

C. 2%

D. -4%

Answer: A

Solution:

We know that, Modulation index,

$\mu = \frac{A_m}{A_c}$ .... (i)

Where, $A_m =$ amplitude of message signal $A_c =$ amplitude of carrier signal When A_m is increased by 1% then, new,

$A'_m = A_m + \frac{A_m}{100} = \frac{101 A_m}{100}$

Similarly, A_c is increased by 3%.

$\because$ New value of amplitude of carrier wave,

$A'_c = A_c + 3\%$ of A_c
$\quad = A_c + \dfrac{3A_c}{100}$
$\quad = \dfrac{103A_c}{100}$

New modulation index,

$\mu' = \dfrac{A'_m}{A'_c} = \dfrac{101A_m/100}{103A_c/100}$
$\quad = \dfrac{101}{103} \cdot \dfrac{A_m}{A_c}$
$\quad = \dfrac{101}{103}\mu \quad$ [From Eq. (i)]

% change in modulation index $= \dfrac{\mu' - \mu}{\mu} \times 100$
$$= \dfrac{\frac{101}{103}\mu - \mu}{\mu} \times 100$$
$$= -2\%$$

Question28

A plane electromagnetic wave travels in free space along Z-axis. At a particular point in space, the electric field along X-axis is 8.7 Vm^{-1}. The magnetic field along Y-axis is

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Options:

A. 2.9×10^{-8} T

B. 3×10^{-6} T

C. 8.7×10^{-6} T

D. 3×10^{-5} T

Answer: A

Solution:

Given, Electric field along X-axis

$E = 8.7 \ \text{Vm}^{-1}$

$\therefore$ Magnetic field along Y - axis,

$B = \dfrac{E}{c} \quad [\because E = cB]$

$\quad = \dfrac{8.7}{3 \times 10^8} = 29 \times 10^{-8} \ \text{T}$

Question29

If the average power per unit area delivered by an electromagnetic wave is $9240 \ \text{Wm}^{-2}$. then the amplitude of the oscillating magnetic field in EM wave is

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Options:

A. 4.4 μT

B. 6.6 μT

C. 8.8 μT

D. 102 μT

Answer: C

Solution:

Given, Average power per unit area,

$I = 9240 \text{Wm}^{-2}$

We know that, average power per unit area delivered by an electromagnetic wave is known as intensity of EM wave which is given as

$$I = \frac{CB^2}{2\mu_0}$$

$$\Rightarrow \quad B = \sqrt{\frac{2\mu_0 I}{c}} = \sqrt{\frac{2 \times 4\pi \times 10^{-7} \times 9240}{3 \times 10^8}}$$

$$= 87.98 \times 10^{-7} \text{ T} = 8.798 \times 10^{-6} \text{ T}$$

$$= 8.798\mu\text{T} \approx 8.8\mu\text{T}$$

Question30

A beam of light with intensity 10^{-3} Nm^{-2} and cross-sectional area 20 cm^2 is incident on a fully reflective surface at angle $45°$. Then, the force exerted by the beam on the surface is

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Options:

A. 2.3×10^{-15} N

B. 1.33×10^{-14} N

C. 6.67×10^{-15} N

D. 9.4×10^{-15} N

Answer: D

Solution:

Given, Intensity of light beam,

$I = 10^{-3}$ N/m^2

Area,

$A = 20$ cm$^2 = 2 \times 10^{-3}$ m^2
$\alpha = 45°$

For a fully reflecting surface, force exerted by the beam on the surface, is given as

$$F = \frac{2IA\cos\alpha}{c}$$

$$= \frac{2 \times 10^{-3} \times 2 \times 10^{-3}\cos 45°}{3 \times 10^8}$$

$$= \frac{4 \times 10^{-6}}{3 \times 10^8} \times \frac{1}{\sqrt{2}} = 9.42 \times 10^{-15} \text{ N}$$

$$\simeq 9.4 \times 10^{-15} \text{ N}$$

Question31

The maximum number of TV signals, that can be transmitted along a co-axial cable is

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Options:

A. 100

B. 125

C. 140

D. 90

Answer: B

Solution:

The maximum number of TV signals, that can transmitted along a co-axial cable is 125.

Question32

The electric and the magnetic fields associated with an electromagnetic wave propagating along the z-axis, can be represented by

Options:

A. $\left[E = E_0\hat{i}, B = B_0\hat{j} \right]$

B. $\left[E = E_0\hat{k}, B = B_0\hat{i} \right]$

C. $\left[E = E_0\hat{j}, B = B_0\hat{i} \right]$

D. $\left[E = E_0\hat{j}, B = B_0\hat{k} \right]$

Answer: A

Solution:

Given, wave is propagating along z-axis.

As we know that, electric field **E**, magnetic field **B** and propagation **k** all are mutually perpendicular to each other.

So, $\mathbf{E} = E_0\hat{i}$ and $\mathbf{B} = B_0\hat{j}$

Question33

The magnetic field of a plane electromagnetic wave is given by $B = (400 \propto \text{T}) \sin\left[\left(4.0 \times 10^{15} \text{ s}^{-1}\right)\left(t - \frac{x}{c}\right)\right]$. Average energy density corresponding to the electric field is

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Options:

A. $8 \times 10^{-3} \text{Jm}^{-3}$

B. $31.8 \times 10^{-3} \text{Jm}^{-3}$

C. $80 \times 10^{-3} \, \mathrm{Jm^{-3}}$

D. $3.18 \times 10^{-3} \, \mathrm{Jm^{-3}}$

Answer: A

Solution:

Step 1: Relate magnetic and electric field amplitudes

For electromagnetic waves in free space:

$$E_0 = cB_0$$

where $c = 3 \times 10^8 \, \mathrm{m/s}$ and $B_0 = 400 \, \mathrm{nT} = 4.0 \times 10^{-7} \, \mathrm{T}$.

$$E_0 = (3 \times 10^8)(4.0 \times 10^{-7}) = 120 \, \mathrm{V/m}$$

Step 2: Energy density of the electric field

The instantaneous energy density due to the electric field is:

$$u_E = \frac{1}{2} \varepsilon_0 E^2$$

and the average over time is:

$$\langle u_E \rangle = \frac{1}{2} \varepsilon_0 \langle E^2 \rangle$$

For a sinusoidal wave, $\langle E^2 \rangle = \frac{E_0^2}{2}$.

So:

$$\langle u_E \rangle = \frac{1}{4} \varepsilon_0 E_0^2$$

Step 3: Substitute values

$$\varepsilon_0 = 8.85 \times 10^{-12} \, \mathrm{F/m}, \quad E_0 = 120 \, \mathrm{V/m}$$

$$\langle u_E \rangle = \frac{1}{4} (8.85 \times 10^{-12})(120)^2$$

$$\langle u_E \rangle = \frac{1}{4} (8.85 \times 10^{-12})(1.44 \times 10^4)$$

$$\langle u_E \rangle = 3.2 \times 10^{-8} \, \mathrm{J/m^3}$$

Wait — that's too small because $B_0 = 400 \, \mathrm{nT} = 4 \times 10^{-7} \, \mathrm{T}$; recheck:

$$E_0 = cB_0 = 3 \times 10^8 \times 4 \times 10^{-7} = 120 \, \mathrm{V/m}$$

Let's compute carefully again:

$$\langle u_E \rangle = \frac{1}{4}(8.85 \times 10^{-12})(120)^2 = 0.25 \times 8.85 \times 10^{-12} \times 1.44 \times 10^4$$

$$= 0.25 \times 1.2744 \times 10^{-7} = 3.19 \times 10^{-8} \text{ J/m}^3$$

Wait — the given answer in the image is 8×10^{-3} J/m^3. That implies $B_0 = 400\,\mu$T, not $400\,$nT.

So likely it was $400\,\mu$T $= 4 \times 10^{-4}$ T.

Then:

$$E_0 = cB_0 = 3 \times 10^8 \times 4 \times 10^{-4} = 1.2 \times 10^5 \text{ V/m}$$

$$\langle u_E \rangle = \frac{1}{4}(8.85 \times 10^{-12})(1.2 \times 10^5)^2$$

$$= 0.25 \times 8.85 \times 10^{-12} \times 1.44 \times 10^{10} = 0.25 \times 127.4 \times 10^{-2} = 7.96 \times 10^{-3} \text{ J/m}^3$$

☑ Answer:

$$\boxed{8 \times 10^{-3} \text{ J/m}^3}$$

Question34

In an amplitude modulated signal, the maximum amplitude is 15 V and minimum amplitude is 5 V. The amplitude of modulating wave will be

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Options:

A. 5 V

B. 10 V

C. 20 V

D. 30 V

Answer: B

Solution:

Given, maximum amplitude of modulated signal,

$V_{\max} = 15 \text{ V} = V_m + V_c$ ..... (i)

Minimum amplitude of modulated signal,

$V_{\min} = 5 \text{ V} = V_m - V_c$ .... (ii)

where, V_c, V_m are carries wave and modulated wave voltage.

Now, from Eqs. (i) and (ii), we get

$20 = 2V_m \Rightarrow V_m = 10 \text{ V}$