Electromagnetic Waves JEE Main PYQ - 2

Total Time: 1 Hour : 15 Minute **Total Marks:** 120

Instructions

Instructions

1. Test will auto submit when the Time is up.
2. The Test comprises of multiple choice questions (MCQ) with one or more correct answers.
3. The clock in the top right corner will display the remaining time available for you to complete the examination.

Navigating & Answering a Question

1. The answer will be saved automatically upon clicking on an option amongst the given choices of answer.
2. To deselect your chosen answer, click on the clear response button.
3. The marking scheme will be displayed for each question on the top right corner of the test window.

Electromagnetic Waves

1. A plane electromagnetic wave of frequency 20 MHz travels in free space along the +x direction. At a particular point in space and time, the electric field vector of the wave is $E_y = 9.3\,\mathrm{V/m}$. Then, the magnetic field vector of the wave at that point is: (+4, -1)

a. $B_z = 9.3 \times 10^{-8}\,\mathrm{T}$

b. $B_z = 1.55 \times 10^{-8}\,\mathrm{T}$

c. $B_z = 6.2 \times 10^{-8}\,\mathrm{T}$

d. $B_z = 3.1 \times 10^{-8}\,\mathrm{T}$

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2. The magnetic field of an E.M. wave is given by: (+4, -1)

$$\vec{B} = \left(\frac{\sqrt{3}}{2}\hat{i} + \frac{1}{2}\hat{j}\right) 30 \sin\left(\omega\left(t - \frac{z}{c}\right)\right)$$

The corresponding electric field in S.I. units is:

a. $\vec{E} = \left(\frac{1}{2}\hat{i} + \frac{\sqrt{3}}{2}\hat{j}\right) 30c \sin\left(\omega\left(t + \frac{z}{c}\right)\right)$

b. $\vec{E} = \left(\frac{3}{4}\hat{i} + \frac{1}{4}\hat{j}\right) 30c \cos\left(\omega\left(t - \frac{z}{c}\right)\right)$

c. $\vec{E} = \left(\frac{\sqrt{3}}{2}\hat{i} - \frac{1}{2}\hat{j}\right) 30c \sin\left(\omega\left(t + \frac{z}{c}\right)\right)$

d. $\vec{E} = \left(\frac{1}{2}\hat{i} - \frac{\sqrt{3}}{2}\hat{j}\right) 30c \sin\left(\omega\left(t - \frac{z}{c}\right)\right)$

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3. Monochromatic light of frequency 6×10^{14} Hz is produced by a laser. The power emitted is 2×10^{-3} W. How many photons per second on average are emitted by the source.(Given $h = 6.63 \times 10^{-34}\,\mathrm{Js}$) (+4, -1)

a. 9×10^{18}

b. 6×10^{15}

c. 5×10^{15}

d. 7×10^{16}

---

4. If frequency of electromagnetic wave is 60 MHz and it travels in air along z direction then the corresponding electric and magnetic field vectors will be mutually perpendicular to each other and the wavelength of the wave (in m) is : **(+4, -1)**

a. 2.5

b. 10

c. 5

d. 2

---

5. Electromagnetic waves travel in a medium with a speed of $1.5 \times 10^8 \text{ ms}^{-1}$. The relative permeability of the medium is 2.0. The relative permittivity will be: **(+4, -1)**

a. 5

b. 4

c. 1

d. 2

---

6. In the given electromagnetic wave **(+4, -1)**

$$E_y = 600 \sin(\omega t - kx) \text{ V/m},$$

intensity of the associated light beam is (in W/m^2); (Given $\epsilon_0 = 9 \times 10^{-12} \text{ C}^2\text{N}^{-1}\text{m}^{-2}$).

a. 486

b. 243

c. 729

d. 972

7. Match List-I with List-II :- **(+4, -1)**

List-I EM-Wave	List-II Wavelength Range
(A) Infra-red	(III) 1 mm to 700 nm
(B) Ultraviolet	(II) 400 nm to 1 nm
(C) X-rays	(IV) 1 nm to 10^{-3} nm
(D) Gamma rays	(I) $< 10^{-3}$ nm

Choose the correct answer from the options given below :

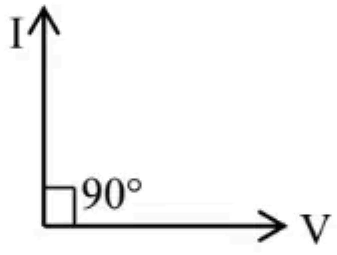
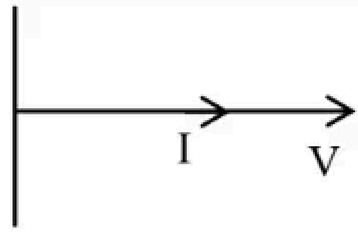
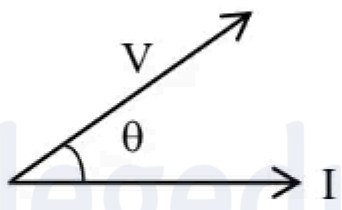
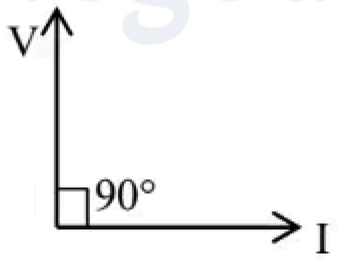
a. (A)-(II), (B)-(I), (C)-(IV), (D)-(III)

b. (A)-(III), (B)-(II), (C)-(IV), (D)-(I)

c. (A)-(IV), (B)-(III), (C)-(II), (D)-(I)

d. (A)-(I), (B)-(III), (C)-(II), (D)-(IV)

8. Match List I with List II **(+4, -1)**

	List–I		List–II
A.	Purely capacitive circuit	I.	
B.	Purely inductive circuit	II.	
C.	LCR series at resonance	III.	
D.	LCR series circuit	IV.	

Choose the correct answer from the options given below :

a. A-I, B-IV, C-III, D-II

b. A-IV, B-I, C-III, D-II

c. A-IV, B-I, C-II, D-III

d. A-I, B-IV, C-II, D-III

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9. A plane EM wave is propagating along x direction. It has a wavelength of 4 mm. If electric field is in y direction with the maximum magnitude of 60 V m^{-1}, **(+4, -1)**

the equation for magnetic field is:

a. $B_z = 60 \sin\left[\frac{\pi}{2}\left(x - 3 \times 10^8 t\right)\right] \hat{k}\,\mathrm{T}$

b. $B_z = 2 \times 10^{-7} \sin\left[\frac{\pi}{2} \times 10^3 \left(x - 3 \times 10^8 t\right)\right] \hat{k}\,\mathrm{T}$

c. $B_x = 60 \sin\left[\frac{\pi}{2}\left(x - 3 \times 10^8 t\right)\right] \hat{i}\,\mathrm{T}$

d. $B_z = 2 \times 10^{-7} \sin\left[\frac{\pi}{2}\left(x - 3 \times 10^8 t\right)\right] \hat{k}\,\mathrm{T}$

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10. The electric field in an electromagnetic wave is given by **(+4, -1)**

$$\vec{E} = \hat{i} 40 \cos\omega\left(t - \frac{z}{c}\right)\ \mathrm{NC^{-1}}.$$

The magnetic field induction of this wave is (in SI unit):

a. $\vec{B} = \hat{i}\frac{40}{c}\cos\omega\left(t - \frac{z}{c}\right)$

b. $\vec{B} = \hat{j} 40 \cos\omega\left(t - \frac{z}{c}\right)$

c. $\vec{B} = \hat{k}\frac{40}{c}\cos\omega\left(t - \frac{z}{c}\right)$

d. $\vec{B} = \hat{j}\frac{40}{c}\cos\omega\left(t - \frac{z}{c}\right)$

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11. An electron is projected with uniform velocity along the axis inside a current carrying long solenoid. Then : **(+4, -1)**

a. the electron will be accelerated along the axis.

b. the electron will continue to move with uniform velocity along the axis of the solenoid.

c. the electron path will be circular about the axis.

d. the electron will experience a force at 45° to the axis and execute a helical path.

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12. Given below are two statements: **(+4, -1)**

Statement I: Electromagnetic waves carry energy as they travel through

space and this energy is equally shared by the electric and magnetic fields.
Statement II: When electromagnetic waves strike a surface, a pressure is exerted on the surface. In the light of the above statements.
Choose the most appropriate answer from the options given below:

a. Statement I is incorrect but Statement II is correct

b. Both Statement I and Statement II are correct.

c. Both Statement I and Statement II are incorrect.

d. Statement I is correct but Statement II is incorrect.

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13. The magnetic field in a plane electromagnetic wave is **(+4, -1)**

$$B_y = (3.5 \times 10^{-7}) \sin\left(1.5 \times 10^3 x + 0.5 \times 10^{11} t\right) \text{ T.}$$

The corresponding electric field will be:

a. $E_y = 1.17 \sin\left(1.5 \times 10^3 x + 0.5 \times 10^{11} t\right) \text{ V/m}$

b. $E_z = 105 \sin\left(1.5 \times 10^3 x + 0.5 \times 10^{11} t\right) \text{ V/m}$

c. $E_z = 1.17 \sin\left(1.5 \times 10^3 x + 0.5 \times 10^{11} t\right) \text{ V/m}$

d. $E_y = 10.5 \sin\left(1.5 \times 10^3 x + 0.5 \times 10^{11} t\right) \text{ V/m}$

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14. In a plane EM wave, the electric field oscillates sinusoidally at a frequency of 5×10^{10} Hz and an amplitude of 50 Vm^{-1}. The total average energy density of the electromagnetic field of the wave is: $[\text{Use } \epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2]$ **(+4, -1)**

a. $1.106 \times 10^{-8} \text{ Jm}^{-3}$

b. $4.425 \times 10^{-8} \text{ Jm}^{-3}$

c. $2.212 \times 10^{-8} \text{ Jm}^{-3}$

d. $2.212 \times 10^{-10} \text{ Jm}^{-3}$

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15. A plane electromagnetic wave propagating in x-direction is described by $E_y = (200\,\mathrm{V/m})\sin(1.5\times10^{7}t - 0.05x)$. The intensity of the wave is: **(+4, -1)**

a. 35.4 W/m^2

b. 53.1 W/m^2

c. 26.6 W/m^2

d. 106.2 W/m^2

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16. A particle is moving in a straight line. The variation of position x as a function of time t is given as **(+4, -1)**

$$x = (t^3 - 6t^2 + 20t + 15)\,\mathrm{m}.$$

The velocity of the body when its acceleration becomes zero is:

a. 4 m/s

b. 8 m/s

c. 10 m/s

d. 6 m/s

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17. An object is placed in a medium of refractive index 3. An electromagnetic wave of intensity $6\times10^{8}\,\mathrm{W/m^2}$ falls normally on the object and it is absorbed completely. The radiation pressure on the object would be (speed of light in free space = 3×10^{8} m/s) : **(+4, -1)**

a. $36\,\mathrm{Nm^{-2}}$

b. $18\,\mathrm{Nm^{-2}}$

c. $6\,\mathrm{Nm^{-2}}$

d. $2\,\mathrm{Nm^{-2}}$

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18. The electric field of an electromagnetic wave in free space is represented as $\vec{E} = E_0 \cos(\omega t - kz)\hat{i}$. The corresponding magnetic induction vector will be: **(+4, -1)**

a. $\vec{B} = E_0 C \cos(\omega t - kz)\hat{j}$

b. $\vec{B} = \frac{E_0}{C} \cos(\omega t - kz)\hat{j}$

c. $\vec{B} = E_0 C \cos(\omega t + kz)\hat{j}$

d. $\vec{B} = \frac{E_0}{C} \cos(\omega t + kz)\hat{j}$

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19. In an electromagnetic wave, at an instant and at a particular position, the electric field is along the negative z-axis and magnetic field is along the positive x-axis. Then the direction of propagation of electromagnetic wave is **(+4, -1)**

a. positive y-axis

b. negative y-axis

c. positive z-axis

d. at 45° angle from positive y-axis

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20. A plane electromagnetic wave of frequency 20 MHz propagates in free space along x-direction. At a particular space and time, $\overrightarrow{E} = 6.6\,\hat{j} V/m$ .What is $\overrightarrow{B}$ at this point ? **(+4, -1)**

a. $-2.2 \times 10^{-}\hat{i}\ T$

b. $-2.2 \times 10^{-8}\hat{k}\ T$

c. $2.2 \times 10^{-8}\hat{i}\ T$

d. $2.2 \times 10^{-8}\hat{k}\ T$

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21. For the plane electromagnetic wave given by $E = E_o sin(\omega t - kx)$ and $B = B_o sin(\omega t - kx)$, the ratio of average electric energy density to average magnetic energy density is **(+4, -1)**

a. 2

b. 1/2

c. 1

d. 4

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22. If the height of transmitting and receiving antennas are 80 m each, the maximum line of sight distance will be: **(+4, -1)**
Given: Earth's radius = $6.4 \times 106 \text{ m}$

a. 64 km

b. 36 km

c. 28 km

d. 32 km

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23. The modulation index for an A.M. wave having maximum and minimum peak-to-peak voltages of 14 mV and 6 mV respectively is: **(+4, -1)**

a. 0.4

b. 0.6

c. 0.2

d. 1.4

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24. Given below are two statements: **(+4, -1)**
Statement I: Electromagnetic waves are not deflected by electric and magnetic field.
Statement II: The amplitude of electric field and the magnetic field in electromagnetic waves are related to each other as $E_0 = \sqrt{\frac{\mu_0}{E_0}} B_0$.
In the light of the above statements, choose the correct answer from the options given below:

a. Statement I is true but statement II is false

b. Both Statement I and Statement II are false

c. Statement I is false but statement II is true

d. Both Statement I and Statement II are true

25. Electromagnetic wave beam of power 20 mW is incident on a perfectly absorbing body for 300 ns. The total momentum transferred by the beam to the body is equal to **(+4, -1)**

a. 2×10^{-17} Ns

b. 1×10^{-17} Ns

c. 3×10^{-17} Ns

d. 5×10^{-17} Ns

26. An electromagnetic wave has electric field given by $\vec{E} = (9.6\hat{j})sin\left[2\pi\ 30 \times 10^6 t - \frac{1}{10}x\right]$, x and t are in SI units. The maximum magnetic field is **(+4, -1)**

a. 3.2×10^{-8}

b. 9.6×10^{-8}

c. 1.7×10^{-8}

d. 10^{-7}

27. The speed of a transverse wave passing through a string of length 50 cm and mass 10 g is 60 ms^{-1}. The area of cross-section of the wire is 2.0 mm^2 and its Young's modulus is 1.2×10^{11} Nm^{-2}. The extension of the wire over its natural length due to its tension will be x × 10^{-5} m. The value of x is _____. **(+4, -1)**

28. Match List-I with List-II: **(+4, -1)**

List-I	List-II
(a) UV rays	(i) Diagnostic tool in medicine
(b) X-rays	(ii) Water purification
(c) Microwave	(iii) Communication, Radar
(d) Infrared wave	(iv) Improving visibility in foggy days

Choose the correct answer from the options given below :

a. (a)-(iii), (b)-(ii), (c)-(i), (d)-(iv)

b. (a)-(ii), (b)-(i), (c)-(iii), (d)-(iv)

c. (a)-(ii), (b)-(iv), (c)-(iii), (d)-(i)

d. (a)-(iii), (b)-(i), (c)-(ii), (d)-(iv)

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29. Find the modulation index of an AM wave having 8 V variation where maximum amplitude of the AM wave is 9 V. **(+4, -1)**

a. 0.8

b. 0.5

c. 0.2

d. 0.1

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30. An EM wave propagating in x-direction has a wavelength of 8 mm. The electric field vibrating y-direction has maximum magnitude of 60 Vm^{-1}. Choose the correct equations for electric and magnetic field if the EM wave is propagating in vacuum: **(+4, -1)**

a. $E_y = 60 \sin\left[\frac{\pi}{4} \times 10^3(x - 3 \times 10^8 t)\right]\hat{j} V m^{-1}$
$B_y = 2 \sin\left[\frac{\pi}{4} \times 10^3(x - 3 \times 10^8 t)\right] \hat{k} T$

b. $E_y = 60 \sin\left[\frac{\pi}{4} \times 10^3 (x - 3 \times 10^8 t)\right] \hat{j}\, Vm^{-1}$
$B_z = 2 \times 10^{-7} \sin\left[\frac{\pi}{4} \times 10^3 (x - 3 \times 10^8 t)\right] \hat{k}\, \mathrm{T}$

c. $E_y = 2 \times 10^{-7} \sin\left(\frac{\pi}{4} \times 10^3 (x - 3 \times 10^8 t)\right) \hat{j}\, Vm^{-1}$
$B_z = 60 \sin\left[\frac{\pi}{4} \times 10^3 (x - 3 \times 10^8 t)\right] \hat{k}\, \mathrm{T}$

d. $E_y = 2 \times 10^{-7} \sin\left[\frac{\pi}{4} \times 10^4 (x - 4 \times 10^8 t)\right] \hat{j}\, Vm^{-1}$
$B_z = 60 \sin\left[\frac{\pi}{4} \times 10^4 x - 4 \times 10^8 t)\right] \hat{k}\, \mathrm{T}$

Answers

1. **Answer: d**

Explanation:

To solve this problem, we need to find the magnetic field vector B_z of a plane electromagnetic wave given its electric field vector E_y and the frequency of the wave.

First, recall that in electromagnetic waves traveling in free space, the electric field $\mathbf{E}$ and magnetic field $\mathbf{B}$ are related by the following relation:

$E = cB$

where:

- $E = 9.3\,\mathrm{V/m}$ (Given electric field amplitude)
- $c = 3 \times 10^8\,\mathrm{m/s}$ (Speed of light in free space)
- B is the magnetic field amplitude we need to find.

Step 1: Use the relation $E = cB$, we solve for B:

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

Step 2: Substitute the given values:

$B = \frac{9.3}{3\times10^8}$

Step 3: Calculate the magnetic field amplitude:

$B = 3.1 \times 10^{-8}\,\mathrm{T}$

Therefore, the magnetic field vector of the wave at that point is:

Correct Answer: $B_z = 3.1 \times 10^{-8}\,\mathrm{T}$

This matches option 4, confirming our calculation is correct. The problem uses the direct relationship between the electric and magnetic fields in electromagnetic waves, which is a fundamental principle of wave propagation in physics.

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2. **Answer: d**

Explanation:

This problem involves electromagnetic fields, where we are given a magnetic field $\mathbf{B}$ and need to calculate the electric field $\mathbf{E}$ and other related quantities. Let's break it down step-by-step.

Step 1: Given Magnetic Field

The magnetic field is given by:

$$\mathbf{B} = \left(\frac{\sqrt{3}}{2}\hat{i} + \frac{1}{2}\hat{j}\right) 30 \sin\left[\omega\left(t - \frac{z}{c}\right)\right]$$

where $\hat{i}$ and $\hat{j}$ are the unit vectors along the x-axis and y-axis, respectively, and ω is the angular frequency, t is time, and z is the position.

Step 2: Electric Field Formula

The electric field $\mathbf{E}$ is related to the magnetic field $\mathbf{B}$ and the direction of wave propagation $\mathbf{c}$ by the following equation:

$$\mathbf{E} = \mathbf{B} \times \mathbf{c}, \quad \mathbf{E} = B_0 c$$

where B_0 is the magnitude of the magnetic field.

Step 3: Calculating $\mathbf{E}$

To find the electric field, we take the cross product of $\mathbf{B}$ and $\mathbf{c}$. We get:

$$\mathbf{E} = \left(\frac{\sqrt{3}}{2}\hat{i} - \hat{j}\right) + \frac{1}{2}\hat{i}$$

Step 4: Evaluating E_0

Now, we can evaluate E_0, the electric field at $t = 0$. We have:

$$E_0 = 30c$$

This gives the value of the electric field at $t = 0$.

Step 5: Final Expression for $\mathbf{E}$

The electric field $\mathbf{E}$ can be written as:

$$\mathbf{E} = \left(\frac{1}{2}\hat{i} - \frac{\sqrt{3}}{2}\hat{j}\right) 30c \sin\left[\omega\left(t - \frac{z}{c}\right)\right]$$

Final Answer:

$$\mathbf{E} = \left(\frac{1}{2}\hat{i} - \frac{\sqrt{3}}{2}\hat{j}\right) 30c \sin\left[\omega\left(t - \frac{z}{c}\right)\right]$$

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3. **Answer: c**

Explanation:

To find out how many photons are emitted per second by the laser, we need to calculate the energy of a single photon and then determine how many such photons correspond to the total power emitted.

The energy E of a single photon can be determined using Planck's equation:

$E = h \times f$

Where:

- $h = 6.63 \times 10^{-34}\,\text{Js}$ is Planck's constant.
- $f = 6 \times 10^{14}\,\text{Hz}$ is the frequency of the light.

Substituting the given values into the formula:

$E = 6.63 \times 10^{-34} \times 6 \times 10^{14}$

$E = 3.978 \times 10^{-19}\,\text{J}$

This is the energy of one photon. The total power P emitted by the laser is $2 \times 10^{-3}\,\text{W}$ (which is joules per second).

We can find the number of photons emitted per second by dividing the total power by the energy of a single photon:

$n = \frac{P}{E} = \frac{2\times10^{-3}}{3.978\times10^{-19}}$

Calculating this, we find:

$n \approx 5.03 \times 10^{15}$

Therefore, the number of photons emitted per second is approximately 5×10^{15}.

Thus, the correct answer is 5×10^{15}, which matches with one of the given options.

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4. **Answer: c**

Explanation:

To determine the wavelength of an electromagnetic wave with a given frequency, we can use the fundamental relationship between the speed of light, frequency, and wavelength. The formula is given by:

$c = \lambda \cdot f$

Where:

- c is the speed of light in a vacuum, approximately $3 \times 10^8\,\mathrm{m/s}$.
- λ is the wavelength of the electromagnetic wave.
- f is the frequency of the wave.

Given:

- Frequency, $f = 60\,\mathrm{MHz} = 60 \times 10^6\,\mathrm{Hz}$.

We need to find the wavelength λ in meters.

Using the formula, we rearrange for λ:

$\lambda = \frac{c}{f}$

Substitute the given values:

$\lambda = \frac{3\times10^8}{60\times10^6}$

Calculate λ:

$\lambda = \frac{3\times10^8}{60\times10^6} = \frac{3}{60} \times 10^2 = 0.05 \times 10^2 = 5$ meters.

Thus, the wavelength of the electromagnetic wave is **5 meters**. Therefore, the correct answer is:

- 5

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5. **Answer: d**

Explanation:

The speed of electromagnetic waves in a medium is related to its relative permeability (μ_r) and relative permittivity (ε_r) by the equation:

$$\varepsilon_r \mu_r = \frac{c^2}{v^2},$$

where:
- $c = 3 \times 10^8 \, \mathrm{ms^{-1}}$ (speed of light in vacuum),
- $v = 1.5 \times 10^8 \, \mathrm{ms^{-1}}$ (speed of light in the medium),
- $\mu_r = 2.0$ (relative permeability of the medium).

Substituting the given values:

$$\varepsilon_r \times 2 = \frac{(3 \times 10^8)^2}{(1.5 \times 10^8)^2}.$$

Simplify:

$$\varepsilon_r \times 2 = \frac{9 \times 10^{16}}{2.25 \times 10^{16}}.$$

$$\varepsilon_r \times 2 = 4.$$

$$\varepsilon_r = 2.$$

Final Answer: $\varepsilon_r = 2$ (Option 4)

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6. Answer: a

Explanation:

To determine the intensity of the electromagnetic wave, we can use the formula for the intensity of an electromagnetic wave, which is given by:

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

where:

- c is the speed of light in vacuum, approximately $3 \times 10^8 \, \mathrm{m/s}$
- ϵ_0 is the permittivity of free space, given as $9 \times 10^{-12} \, \mathrm{C^2N^{-1}m^{-2}}$
- E_m is the amplitude of the electric field, provided as $600 \, \mathrm{V/m}$

Substituting these values into the formula, we get:

$I = \frac{1}{2} \times 3 \times 10^8 \, \mathrm{m/s} \times 9 \times 10^{-12} \, \mathrm{C^2N^{-1}m^{-2}} \times (600)^2 \, \mathrm{V^2/m^2}$

Simplifying further:

$I = \frac{1}{2} \times 3 \times 9 \times 600^2 \times 10^8 \times 10^{-12}$ $I = \frac{1}{2} \times 27 \times 360000 \times 10^{-4}$ $I = \frac{1}{2} \times 9720000 \times 10^{-4}$ $I = \frac{1}{2} \times 972 \, \mathrm{W/m^2}$ $I = 486 \, \mathrm{W/m^2}$

Thus, the intensity of the associated light beam is $486 \, \mathrm{W/m^2}$. Therefore, the correct answer is: **486**

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7. Answer: b

Explanation:

The correct matching between the EM waves and their wavelength ranges is as follows:

- (A) Infra-red corresponds to $1\,\mathrm{mm}$ to $700\,\mathrm{nm}$, which is (III).
- (B) Ultraviolet corresponds to $400\,\mathrm{nm}$ to $1\,\mathrm{nm}$, which is (II).
- (C) X-rays correspond to $1\,\mathrm{nm}$ to $10^{-3}\,\mathrm{nm}$, which is (IV).
- (D) Gamma rays correspond to wavelengths less than $10^{-3}\,\mathrm{nm}$, which is (I).

Thus, the correct matching is:

$$\text{(A)-(III), (B)-(II), (C)-(IV), (D)-(I)}$$

Infrared radiation has the longest wavelength among the options, while gamma rays have the shortest wavelength, corresponding to their relative energy levels, with gamma rays being the most energetic and infrared the least.

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8. **Answer: d**

Explanation:

- ****Option A**:** In a purely capacitive circuit, the voltage (V) lags the current (I) by 90°. Therefore, **A-I** is correct.
- ****Option B**:** In a purely inductive circuit, the voltage (V) leads the current (I) by 90°. Therefore, **B-II** is correct.
- ****Option C**:** In an LCR series circuit at resonance, the inductive reactance (X_L) equals the capacitive reactance (X_C), resulting in a purely resistive behavior where the voltage and current are in phase. Therefore, **C-III** is correct.
- ****Option D**:** In a general LCR series circuit, the voltage and current are out of phase by an angle θ, which depends on the relative values of X_L and X_C. Therefore, **D-IV** is correct.

****Answer:** A-I, B-II, C-III, D-IV (Option 4)**

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9. **Answer: b**

Explanation:

Given the problem of determining the equation for the magnetic field of an electromagnetic wave, we start by analyzing the provided information:

- The electromagnetic wave has a wavelength (λ) of 4 mm or 0.004 meters.
- It propagates along the x-direction, meaning the wave vector $\mathbf{k}$ is oriented along x.
- The electric field $\mathbf{E}$ is oriented along the y-direction with an amplitude of 60 V/m.
- The speed of light $c = 3 \times 10^8 \, \mathrm{m/s}$.

We aim to determine the equation for the magnetic field, $\mathbf{B}$.

Step-by-Step Solution:

1. Start by determining the wave number k, which is given by the formula:
    - $k = \frac{2\pi}{\lambda} = \frac{2\pi}{0.004} = 500\pi \, \mathrm{m}^{-1}$.
2. The general equation for a wave in one dimension moving in the positive x-direction is:
    - $E = E_0 \sin(kx - \omega t)$.
    - Here, the electric field is $E = 60 \sin(kx - \omega t)\hat{j}$. Given $E_0 = 60 \, \mathrm{V/m}$.
3. The frequency ν of the wave can be calculated using the wave equation:
    - $c = \nu\lambda \Rightarrow \nu = \frac{c}{\lambda} = \frac{3\times10^8}{0.004} = 7.5 \times 10^{10} \, \mathrm{Hz}$.
4. The angular frequency is $\omega = 2\pi\nu = 2\pi \cdot 7.5 \times 10^{10} = 1.5 \times 10^{11} \, \mathrm{rad/s}$.
5. The relation between electric and magnetic fields in an electromagnetic wave is given by:
    - $B_0 = \frac{E_0}{c}$, where B_0 is the magnetic field amplitude.
    - $B_0 = \frac{60}{3\times10^8} = 2 \times 10^{-7} \, \mathrm{T}$.
6. The direction of $\mathbf{B}$ is determined by taking the cross-product of the $\mathbf{k}$ and $\mathbf{E}$ using the right-hand rule. Since $\mathbf{E}$ is in $\hat{j}$ and propagation is along $\hat{i}$, $\mathbf{B}$ is in $\hat{k}$.
7. Thus, the magnetic field equation is:
    - $B_z = 2 \times 10^{-7} \sin(kx - \omega t)\hat{k}$.
    - Substitute $k = 500\pi$ and $\omega = 1.5 \times 10^{11}$:
    - $B_z = 2 \times 10^{-7} \sin\left(500\pi \cdot x - 1.5 \times 10^{11} \cdot t\right) \hat{k} \, \mathrm{T}$.
8. After simplifying the wave number k and frequency in terms relevant to the given options, the equation for the magnetic field becomes:
    - $B_z = 2 \times 10^{-7} \sin\left[\frac{\pi}{2} \times 10^3 \left(x - 3 \times 10^8 t\right)\right] \hat{k} \, \mathrm{T}$.
    - This matches the correct option given in the question.

Therefore, the correct option is $B_z = 2 \times 10^{-7} \sin\left[\frac{\pi}{2} \times 10^3 \left(x - 3 \times 10^8 t\right)\right] \hat{k}\,\mathrm{T}$.

---

10. Answer: d

Explanation:

Given the electric field of the electromagnetic wave:

$$\vec{E} = \hat{i} 40 \cos\omega \left(t - \frac{z}{c}\right)\ \mathrm{NC^{-1}}$$

In an electromagnetic wave, the magnetic field $\vec{B}$ is perpendicular to both the electric field $\vec{E}$ and the direction of propagation.

Since $\vec{E}$ is along the $\hat{i}$-direction and the wave propagates along the $\hat{k}$-direction, the magnetic field $\vec{B}$ must be along the $\hat{j}$-direction.

The relationship between the magnitudes of the electric and magnetic fields in an electromagnetic wave is given by:

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

Substituting the given electric field magnitude:

$$B = \frac{40}{c} \cos\omega \left(t - \frac{z}{c}\right)$$

Thus, the magnetic field is:

$$\vec{B} = \hat{j} \frac{40}{c} \cos\omega \left(t - \frac{z}{c}\right)$$

---

11. Answer: b

Explanation:

Magnetic Force on a Moving Charge:
When a charged particle, such as an electron, moves in a magnetic field, it experiences a force given by:

$$\vec{F} = q(\vec{v} \times \vec{B})$$

where $\vec{v}$ is the velocity of the particle and $\vec{B}$ is the magnetic field.
The direction of the force is perpendicular to both $\vec{v}$ and $\vec{B}$.

Magnetic Field Inside a Solenoid:
Inside a long solenoid carrying current, the magnetic field $\vec{B}$ is uniform and directed along the axis of the solenoid.
Since the electron is moving along the axis, its velocity $\vec{v}$ is also parallel to $\vec{B}$.

No Magnetic Force Due to Parallel $\vec{v}$ and $\vec{B}$:
Since $\vec{v} \parallel \vec{B}$, the cross product $\vec{v} \times \vec{B} = 0$.

Therefore, the magnetic force $\vec{F} = 0$, and the electron will not experience any force due to the magnetic field.

Conclusion:
The electron will continue to move with uniform velocity along the axis of the solenoid, as there is no force acting on it to change its state of motion.

---

12. Answer: b

Explanation:

To solve this problem, we need to evaluate both statements based on the principles of electromagnetic waves:

1. **Statement I:** "Electromagnetic waves carry energy as they travel through space and this energy is equally shared by the electric and magnetic fields."

Electromagnetic waves are oscillations of electric and magnetic fields that propagate through space. The energy carried by these waves is indeed distributed between the electric and magnetic fields. According to electromagnetic theory, the energy density of an electromagnetic wave can be expressed as the sum of the energy densities of the electric field $(\frac{1}{2}\epsilon E^2)$ and the magnetic field $(\frac{1}{2}\frac{B^2}{\mu})$, where ϵ is the permittivity, μ is the permeability, E is the electric field, and B is the magnetic field.

Therefore, Statement I is correct.

1. **Statement II:** "When electromagnetic waves strike a surface, a pressure is exerted on the surface."

This statement is also accurate. The pressure exerted by electromagnetic waves upon striking a surface is known as radiation pressure. This phenomenon occurs because electromagnetic waves carry momentum, and when they interact with matter, momentum transfer results in pressure. This is a well-established concept in physics.

Hence, Statement II is correct.

Given the explanations above, the correct conclusion is:

- Both Statement I and Statement II are correct.

---

13. Answer: b

Explanation:

To find the corresponding electric field for the given magnetic field of an electromagnetic wave, we need to use the relationship between the electric and magnetic fields in electromagnetic waves, given by the equation:

$$E = cB$$

where c is the speed of light in vacuum, approximately $3 \times 10^8 \, \mathrm{m/s}$.

Given the magnetic field component:

$$B_y = (3.5 \times 10^{-7}) \sin\left(1.5 \times 10^3 x + 0.5 \times 10^{11} t\right) \ \mathrm{T}$$

We can calculate the corresponding electric field as follows:

- Using the equation $E = cB$, substitute $c = 3 \times 10^8 \, \mathrm{m/s}$ and the value of B_y. We have:

$$E = 3 \times 10^8 \times 3.5 \times 10^{-7}$$

- Calculate the result:

$E = 1.05 \times 10^2 = 105$

Thus, the electric field component will be:

$E = 105 \sin\left(1.5 \times 10^3 x + 0.5 \times 10^{11} t\right)\ \mathrm{V/m}$

Since the wave's magnetic field is in the y-direction, the electric field will be perpendicular to both the direction of wave propagation (x) and the magnetic field (y). Hence, it is in the z-direction.

Therefore, the correct answer is:

$E_z = 105 \sin\left(1.5 \times 10^3 x + 0.5 \times 10^{11} t\right)\ \mathrm{V/m}$

---

14. Answer: a

Explanation:

To find the total average energy density of an electromagnetic wave, we must consider both the electric field and the magnetic field components. For a plane electromagnetic wave, the energy density can be given by:

$u = \frac{1}{2}\epsilon_0 E^2 + \frac{1}{2}\mu_0 H^2$

However, in a vacuum, the energy density contributed by the electric field is equal to that contributed by the magnetic field. Thus, the total average energy density can be defined using only the electric field:

$u = \epsilon_0 E^2$

Given:

- $E = 50\,\mathrm{Vm}^{-1}$ (Amplitude of the electric field)
- $\epsilon_0 = 8.85 \times 10^{-12}\,\mathrm{C}^2/\mathrm{Nm}^2$ (Permittivity of free space)

Substituting the values, the average energy density is calculated as follows:

$u = \frac{1}{2} \times 8.85 \times 10^{-12} \times (50)^2$

We'll proceed with the calculations:

$u = \frac{1}{2} \times 8.85 \times 10^{-12} \times 2500$

$u = \frac{1}{2} \times 2.2125 \times 10^{-8}$

Finally:

$u = 1.106 \times 10^{-8}\,\mathrm{Jm}^{-3}$

This matches the given correct answer. Therefore, the total average energy density is:

- $1.106 \times 10^{-8}\,\mathrm{Jm}^{-3}$

Hence, the correct option is:

$< 1.106 \times 10^{-8}\,\mathrm{Jm}^{-3}$

---

15. **Answer: b**

Explanation:

To determine the intensity of the plane electromagnetic wave described by $E_y = (200\,\mathrm{V/m})\sin(1.5 \times 10^7 t - 0.05x)$, we need to use the formula for the intensity of an electromagnetic wave:

The intensity I of an electromagnetic wave is given by the formula:

$I = \frac{1}{2}\varepsilon_0 c E_0^2$

Where:

- ε_0 is the permittivity of free space, approximately $8.85 \times 10^{-12}\,\mathrm{F/m}$.
- c is the speed of light in a vacuum, approximately $3 \times 10^8\,\mathrm{m/s}$.
- E_0 is the amplitude of the electric field, given as $200\,\mathrm{V/m}$ in the problem.

Substituting these values into the formula, we get:

$I = \frac{1}{2} \times 8.85 \times 10^{-12}\,\mathrm{F/m} \times 3 \times 10^8\,\mathrm{m/s} \times (200\,\mathrm{V/m})^2$

Calculating step-by-step:

1. First calculate $(200\,\mathrm{V/m})^2 = 40000\,\mathrm{V}^2/\mathrm{m}^2$.
2. Now compute $8.85 \times 10^{-12} \times 3 \times 10^8 = 2.655 \times 10^{-3}$.

3. Substitute these into the intensity equation:

$$I = \frac{1}{2} \times 2.655 \times 10^{-3} \times 40000$$

$$I = 1.3275 \times 10^{-3} \times 40000$$

$$I = 53.1\,\mathrm{W/m^2}$$

This matches the option **53.1 W/m²**, confirming it as the correct answer.

---

16. Answer: b

Explanation:

To determine the velocity of the particle when its acceleration becomes zero, we first need to understand the relationship between position, velocity, and acceleration for this motion.

1. Given the position of the particle as a function of time: $x = t^3 - 6t^2 + 20t + 15\,\mathrm{m}$
2. The velocity (v) is the first derivative of the position with respect to time:

$$v = \frac{dx}{dt} = \frac{d}{dt}(t^3 - 6t^2 + 20t + 15)$$

Calculating the derivative, we get: $v = 3t^2 - 12t + 20$

1. The acceleration (a) is the first derivative of velocity (or the second derivative of position) with respect to time:

$$a = \frac{dv}{dt} = \frac{d}{dt}(3t^2 - 12t + 20)$$

Calculating the derivative, we get: $a = 6t - 12$

1. We need the acceleration to be zero to find the corresponding time:

$$6t - 12 = 0$$

Solving for t, we get: $6t = 12 \quad \Rightarrow \quad t = 2$

1. Substitute $t = 2$ into the velocity expression to find the velocity when the acceleration is zero:

$$v = 3(2)^2 - 12(2) + 20$$

$v = 3(4) - 24 + 20$

$v = 12 - 24 + 20$

$v = 8\,\mathrm{m/s}$

1. Therefore, the velocity of the body when its acceleration becomes zero is **8 m/s**.

Hence, the correct answer is **8 m/s**.

---

17. Answer: c

Explanation:

To find the radiation pressure on the object due to the electromagnetic wave, we start by understanding the concept of radiation pressure in physics. Radiation pressure is exerted upon any surface due to the exchange of momentum between the object and the incident electromagnetic wave. The formula to calculate radiation pressure P when the wave is completely absorbed is given by:

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

where:

- I is the intensity of the electromagnetic wave (in this case, $6 \times 10^8\,\mathrm{W/m^2}$).
- c is the speed of light in the medium. In a vacuum or free space, this is approximately $3 \times 10^8\,\mathrm{m/s}$.

Since the medium's refractive index is given as 3, the speed of light in the medium c_m is:

$c_m = \frac{c}{n} = \frac{3\times10^8\,\mathrm{m/s}}{3} = 1 \times 10^8\,\mathrm{m/s}$

Now, substitute the values into the radiation pressure formula:

$P = \frac{6\times10^8\,\mathrm{W/m^2}}{1\times10^8\,\mathrm{m/s}} = 6\,\mathrm{Nm}^{-2}$

Thus, the radiation pressure exerted on the object is $6\,\mathrm{Nm}^{-2}$.

---

18. Answer: b

Explanation:

The problem asks for the magnetic induction vector $\vec{B}$ corresponding to a given electric field vector $\vec{E}$ of an electromagnetic wave in free space.

Concept Used:

For an electromagnetic wave propagating in free space, the following properties hold:

1. The electric field vector $\vec{E}$, the magnetic field vector $\vec{B}$, and the direction of wave propagation $(\vec{k})$ are mutually perpendicular.
2. The vectors form a right-handed system, meaning the direction of propagation is given by the direction of the cross product $\vec{E} \times \vec{B}$.
3. The magnitudes of the electric and magnetic fields are related by the speed of light in vacuum, C. The relationship is $E = CB$, which implies $B = \frac{E}{C}$.
4. The electric and magnetic fields oscillate in the same phase.

Step-by-Step Solution:

Step 1: Analyze the given electric field vector to determine its properties.

The electric field vector is given by:

$$\vec{E} = E_0 \cos(\omega t - kz)\hat{i}$$

From this equation, we can deduce:

- The electric field oscillates along the x-axis, as indicated by the unit vector $\hat{i}$.
- The wave propagates along the positive z-axis. This is determined by the term $-kz$ inside the cosine function. The direction of propagation is $\hat{k}$.
- The phase of the wave is $(\omega t - kz)$.

Step 2: Determine the direction of the magnetic field vector $\vec{B}$.

The direction of propagation is given by the direction of $\vec{E} \times \vec{B}$. We know the direction of propagation is $\hat{k}$ and the direction of $\vec{E}$ is $\hat{i}$. Let the direction of $\vec{B}$ be represented by a unit vector $\hat{b}$.

$$\text{Direction}(\vec{E} \times \vec{B}) = \text{Direction of propagation}$$

$$\hat{i} \times \hat{b} = \hat{k}$$

Using the properties of the cross product of Cartesian unit vectors, we know that $\hat{i} \times \hat{j} = \hat{k}$. Therefore, the direction of the magnetic field vector $\vec{B}$ must be along the y-axis, so $\hat{b} = \hat{j}$.

Step 3: Determine the magnitude and phase of the magnetic field vector $\vec{B}$.

The magnitude of the magnetic field is related to the magnitude of the electric field by $B = \frac{E}{C}$. The amplitude of the magnetic field, B_0, will therefore be related to the amplitude of the electric field, E_0, by:

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

The electric and magnetic fields oscillate in the same phase. Since the phase of the electric field is $(\omega t - kz)$, the phase of the magnetic field must also be $(\omega t - kz)$.

Final Computation & Result:

Step 4: Assemble the complete magnetic field vector.

Combining the amplitude, phase, and direction found in the previous steps, we can write the expression for the magnetic field vector:

$$\vec{B} = B_0 \cos(\omega t - kz)\hat{j}$$

Substituting $B_0 = \frac{E_0}{C}$:

$$\vec{B} = \frac{E_0}{C} \cos(\omega t - kz)\hat{j}$$

Comparing this result with the given options, we find that it matches the second option.

The corresponding magnetic induction vector is $\vec{B} = \frac{E_0}{C} \cos(\omega t - kz)\hat{j}$.

---

19. Answer: b

Explanation:

The direction of propagation of an electromagnetic (EM) wave is given by the cross product of the electric field vector ($\vec{E}$) and the magnetic field vector ($\vec{B}$):

$$\text{Direction of propagation} \propto \vec{E} \times \vec{B}.$$

Given:

$$\vec{E}\,(\text{electric field) is along the negative z-axis} \quad (\vec{E} = -\hat{k}),$$

$$\vec{B}\,(\text{magnetic field) is along the positive x-axis} \quad (\vec{B} = \hat{i}).$$

The cross product $\vec{E} \times \vec{B}$ is:

$$\vec{E} \times \vec{B} = (-\hat{k}) \times (\hat{i}).$$

Using the right-hand rule and the vector cross product rules:

$$\hat{k} \times \hat{i} = \hat{j}.$$

Thus:

$$(-\hat{k}) \times (\hat{i}) = -\hat{j}.$$

This indicates that the direction of propagation of the EM wave is along the negative y-axis. Hence, the direction of propagation of the electromagnetic wave is $\boxed{\text{negative y-axis}}$.

---

20. Answer: d

Explanation:

Given:

- Electric field magnitude ($|\vec{E}|$) = $6.6\,\hat{j}\ \mathrm{V/m}$
- Frequency (f) = $20\,\mathrm{MHz}$
- Wave propagation direction ($\vec{C}$) = $\hat{i}\ (\text{x-direction})$

Step 1: Calculate the Magnitude of $\vec{B}$

The magnitude of the magnetic field ($|\vec{B}|$) is related to the electric field magnitude ($|\vec{E}|$) by:

$$|\vec{B}| = \frac{|\vec{E}|}{c},$$

where $c = 3 \times 10^8\ \mathrm{m/s}$ is the speed of light in free space. Substituting the given values:

$$|\vec{B}| = \frac{6.6}{3 \times 10^8} = 2.2 \times 10^{-8}\,\mathrm{T}.$$

Step 2: Determine the Direction of $\vec{B}$

In an electromagnetic wave, the electric field ($\vec{E}$), magnetic field ($\vec{B}$), and propagation direction ($\vec{C}$) are mutually perpendicular and follow the right-hand rule:

$$\vec{E} \times \vec{B} = \vec{C}.$$

- $\vec{C}$ is in the $\hat{i}$-direction (x-axis).
- $\vec{E}$ is in the $\hat{j}$-direction (y-axis).
- Using the right-hand rule, $\vec{B}$ must be in the $\hat{k}$-direction (z-axis), as $\hat{j} \times \hat{k} = \hat{i}$.

Step 3: Combine Magnitude and Direction

Combining the magnitude and direction, the magnetic field is:

$$\vec{B} = (2.2 \times 10^{-8})\,\hat{k}\,\mathrm{T}.$$

Final Answer:

$\vec{B} = 2.2 \times 10^{-8}\,\hat{k}\,\mathrm{T}.$

---

21. Answer: c

Explanation:

In EM waves, average electric energy density is equal to average magnetic energy density.
1/ 4 ϵ_0E_0^2 = 1/4μ_0 B_0

---

22. Answer: a

Explanation:

1. **Line of Sight Distance Formula:** The maximum line of sight distance is:

$$d_{\max} = \sqrt{2Rh_t} + \sqrt{2Rh_r},$$

where $R = 6.4 \times 10^6\,\text{m}$ (Earth's radius) and $h_t = h_r = 80\,\text{m}$.

2. **Substitute Values:**

$$d_{\text{max}} = \sqrt{2 \times 6.4 \times 10^6 \times 80} + \sqrt{2 \times 6.4 \times 10^6 \times 80}.$$

3. **Simplify:**

$$d_{\text{max}} = 2 \times \sqrt{1024000} = 2 \times 32 = 64\,\text{km}.$$

Final Answer: $\boxed{64\,\text{km}}$

---

23. **Answer: a**

Explanation:

The modulation index (μ) is given by:

$$\mu = \frac{A_{\text{max}} - A_{\text{min}}}{A_{\text{max}} + A_{\text{min}}}.$$

Substitute the values:

$$\mu = \frac{14 - 6}{14 + 6} = \frac{8}{20}.$$

Simplify:

$$\mu = 0.4.$$

Concepts:

1. **Electromagnetic waves:**

The waves that are produced when an electric field comes into contact with a magnetic field are known as Electromagnetic Waves or EM waves. The constitution of an oscillating magnetic field and electric fields gives rise to electromagnetic waves.

Types of Electromagnetic Waves:

Electromagnetic waves can be grouped according to the direction of disturbance in them and according to the range of their frequency. Recall that a wave transfers energy from one point to another point in space. That means there are two things going on: the disturbance that defines a wave, and the propagation of wave. In this context the waves are grouped into the following two categories:

- **Longitudinal waves:** A wave is called a longitudinal wave when the disturbances in the wave are parallel to the direction of propagation of the wave. For example, sound waves are longitudinal waves because the change of pressure occurs parallel to the direction of wave propagation.
- **Transverse waves:** A wave is called a transverse wave when the disturbances in the wave are perpendicular (at right angles) to the direction of propagation of the wave.

---

24. **Answer: a**

Explanation:

- Statement I: True, as electromagnetic waves consist of oscillating electric and magnetic fields that do not experience deflection in external electric or magnetic fields.
- Statement II: False, because the relation is $E_0 = cB_0$, not $E_0 = \sqrt{\mu_0/\epsilon_0}B_0$.

Concepts:

1. **Electromagnetic waves:**

The waves that are produced when an electric field comes into contact with a magnetic field are known as Electromagnetic Waves or EM waves. The constitution of an oscillating magnetic field and electric fields gives rise to electromagnetic waves.

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- **Transverse waves:** A wave is called a transverse wave when the disturbances in the wave are perpendicular (at right angles) to the direction of propagation of the wave.

---

25. **Answer: a**

Explanation:

Momentum Transfer Calculation

1. Total Energy Incident:

The total energy incident is:

$$E = P \cdot t$$

where P is the power and t is the time.

2. Initial Momentum:

The initial momentum of the radiation is:

$$p_{\text{initial}} = \frac{P \cdot t}{c}$$

where c is the speed of light $\left(c = 3 \times 10^8 \, \text{m/s}\right)$.

3. Final Momentum:

The final momentum is zero because the radiation is absorbed.

4. Total Momentum Transferred:

The total momentum transferred to the object is:

$$\Delta p = \frac{P \cdot t}{c}$$

Substituting the values:

$$P = 20 \times 10^{-3}\,\text{W},\ t = 300 \times 10^{-9}\,\text{s},\ c = 3 \times 10^{8}\,\text{m/s}$$

$$\Delta p = \frac{20 \times 10^{-3} \cdot 300 \times 10^{-9}}{3 \times 10^{8}}$$

Simplifying:

$$\Delta p = \frac{6 \times 10^{-9}}{3 \times 10^{8}} = 2 \times 10^{-17}\,\text{Ns}$$

Final Answer:

The correct answer is (A): 2×10^{-17} Ns.

Concepts:

1. Electromagnetic waves:

The waves that are produced when an electric field comes into contact with a magnetic field are known as Electromagnetic Waves or EM waves. The constitution of an oscillating magnetic field and electric fields gives rise to electromagnetic waves.

Types of Electromagnetic Waves:

Electromagnetic waves can be grouped according to the direction of disturbance in them and according to the range of their frequency. Recall that a wave transfers energy from one point to another point in space. That means there are two things going on: the disturbance that defines a wave, and the propagation of wave. In this context the waves are grouped into the following two categories:

- **Longitudinal waves:** A wave is called a longitudinal wave when the disturbances in the wave are parallel to the direction of propagation of the wave. For example, sound waves are longitudinal waves because the change of pressure occurs parallel to the direction of wave propagation.
- **Transverse waves:** A wave is called a transverse wave when the disturbances in the wave are perpendicular (at right angles) to the direction of propagation of the wave.

26. Answer: a

Explanation:

The correct option is (A): 3.2×10^{-8}

Concepts:

1. Electromagnetic waves:

The waves that are produced when an electric field comes into contact with a magnetic field are known as Electromagnetic Waves or EM waves. The constitution of an oscillating magnetic field and electric fields gives rise to electromagnetic waves.

Types of Electromagnetic Waves:

Electromagnetic waves can be grouped according to the direction of disturbance in them and according to the range of their frequency. Recall that a wave transfers energy from one point to another point in space. That means there are two things going on: the disturbance that defines a wave, and the propagation of wave. In this context the waves are grouped into the following two categories:

- **Longitudinal waves:** A wave is called a longitudinal wave when the disturbances in the wave are parallel to the direction of propagation of the wave. For example, sound waves are longitudinal waves because the change of pressure occurs parallel to the direction of wave propagation.
- **Transverse waves:** A wave is called a transverse wave when the disturbances in the wave are perpendicular (at right angles) to the direction of propagation of the wave.

---

27. Answer: 15 - 15

Explanation:

To determine the extension of the wire when a transverse wave passes through, we first find the tension (T) in the wire due to the wave's speed (v).

The wave speed formula is: $v = \sqrt{T/\mu}$, where μ is the linear mass density (mass per unit length).
Linear mass density, μ = (mass of string)/(length of string) = (10 g)/(50 cm) = (10 × 10^{-3} kg)/(0.50 m) = 0.02 kg/m.
Substitute v and μ into the wave speed formula:

60 m/s = $\sqrt{T/0.02 \text{ kg/m}}$.
Squaring both sides:
$(60)^2 = T/0.02$.
$T = (60)^2 \times 0.02 = 72$ N.
The tension in the wire is 72 N.

Next, we determine the extension (ΔL) using Young's modulus (Y). The formula is: $\Delta L = (FL)/(AY)$, where F is the force (tension), L is the original length, A is the cross-sectional area, and Y is Young's modulus.
Substituting values:
$\Delta L = (72 \text{ N} \times 0.50 \text{ m})/(2 \times 10^{-6} \text{ m}^2 \times 1.2 \times 10^{11} \text{ N/m}^2)$.
$\Delta L = 72 \times 0.50/(2.4 \times 10^5)$
$\Delta L = 36/240000$.
$\Delta L = 1.5 \times 10^{-4}$ m.

Hence, x is given as:
$\Delta L = x \times 10^{-5}$ m
1.5×10^{-4} m = $x \times 10^{-5}$ m.
x = 15.

The value of x is 15, which falls within the expected range of (15, 15).

Concepts:

1. Speed and Velocity:

The rate at which an object covers a certain distance is commonly known as **speed**.

The rate at which an object changes position in a certain direction is called **velocity**.

Difference Between Speed and Velocity:

Velocity	Speed
• Velocity can be defined as the rate at which an object changes position in a certain direction.	• The rate at which an object covers a certain distance is known as speed.
• Vector quantity	• Scalar quantity
• Velocity can be zero, negative, or positive.	• Speed can never be negative or zero.
• The velocity of the object changes with the change in direction, therefore the object must follow one direction.	• The average speed will continue to count even if the object changes direction.
• An object may possess different velocities but the same speed.	• Speed may or may not be equal to velocity.
• Velocity is measured in m/s	• Speed is measured in m/s

Read More: Difference Between Speed and Velocity

---

28. **Answer: b**

Explanation:

To solve the question of matching List-I with List-II, we need to understand the application of each type of wave or ray listed in List-I:

1. **UV rays:** These are commonly used in water purification systems because they have the ability to kill bacteria and viruses present in the water. UV rays can penetrate microorganisms and destroy their DNA, making them an effective method for disinfecting water. Thus, the correct match is with (ii) Water purification.
2. **X-rays:** These rays are widely used as a diagnostic tool in medicine. X-rays can penetrate tissues and create images of the inside of the body, which are used

for diagnosing fractures, infections, and other medical conditions. Therefore, X-rays best match with (i) Diagnostic tool in medicine.

3. **Microwave:** Microwaves are used in communication and radar systems. They can transmit signals over long distances and are crucial for modern communication systems, including satellite transmission. Hence, microwaves correctly pair with (iii) Communication, Radar.
4. **Infrared wave:** These waves are used for improving visibility in foggy conditions. Infrared waves can penetrate fog effectively, which enhances visibility. As such, Infrared waves correspond to (iv) Improving visibility in foggy days.

Based on the reasoning above, the correct matching of the lists is:

List-I	List-II
(a) UV rays	(ii) Water purification
(b) X-rays	(i) Diagnostic tool in medicine
(c) Microwave	(iii) Communication, Radar
(d) Infrared wave	(iv) Improving visibility in foggy days

Therefore, the correct answer to the given question is: **(a)-(ii), (b)-(i), (c)-(iii), (d)-(iv)**.

Concepts:

1. Electromagnetic waves:

The waves that are produced when an electric field comes into contact with a magnetic field are known as Electromagnetic Waves or EM waves. The constitution of an oscillating magnetic field and electric fields gives rise to electromagnetic waves.

Types of Electromagnetic Waves:

Electromagnetic waves can be grouped according to the direction of disturbance in them and according to the range of their frequency. Recall that a wave transfers energy from one point to another point in space. That means there are two things going on: the disturbance that defines a wave, and the propagation of wave. In this context the waves are grouped into the following two categories:

- **Longitudinal waves:** A wave is called a longitudinal wave when the disturbances in the wave are parallel to the direction of propagation of the wave. For example, sound waves are longitudinal waves because the change of pressure occurs parallel to the direction of wave propagation.
- **Transverse waves:** A wave is called a transverse wave when the disturbances in the wave are perpendicular (at right angles) to the direction of propagation of the wave.

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29. **Answer: a**

Explanation:

$\mu = \frac{\frac{8}{2}}{9-\frac{8}{2}}$

$\mu = \frac{4}{5}$
$\mu = 0.8$
So, the correct option is (A): 0.8

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30. **Answer: b**

Explanation:

To solve the given problem, let's start by reviewing the fundamental concepts of electromagnetic (EM) waves and their properties:

- Electromagnetic waves are characterized by oscillating electric and magnetic fields, which are perpendicular to each other and to the direction of wave propagation.
- The general form of an electromagnetic wave propagating in the x-direction is given by the equations: $E = E_0 \sin(kx - \omega t)\hat{j}$ for the electric field, and $B = B_0 \sin(kx - \omega t)\hat{k}$ for the magnetic field.
- In a vacuum, the speed of electromagnetic waves, c, is approximately $3 \times 10^8 \, \mathrm{m/s}$, which relates the wave's frequency and wavelength.

Given data in the problem:

- Wavelength $(\lambda) = 8\,\mathrm{mm} = 8 \times 10^{-3}\,\mathrm{m}$
- Maximum electric field magnitude $(E_0) = 60\,\mathrm{Vm}^{-1}$
- The wave is propagating in a vacuum along the x-direction.

First, let's find the wave number k and the angular frequency ω:

- **Wave number,** k**:** It is given by $k = \frac{2\pi}{\lambda}$.
  - Substitute the given wavelength: $k = \frac{2\pi}{8 \times 10^{-3}} = \frac{\pi}{4} \times 10^3\,\mathrm{m}^{-1}$
- **Angular frequency,** ω**:** As the wave is in a vacuum, $\omega = ck$.
  - Substitute the speed of light: $\omega = (3 \times 10^8) \times \left(\frac{\pi}{4} \times 10^3\right) = \frac{3\pi}{4} \times 10^{11}\,\mathrm{rad/s}$

Given options, the correct equations for such a wave are chosen under the following considerations:

- Amplitude of electric field $(E_0 = 60\,\mathrm{Vm}^{-1})$
- The relationship between electric and magnetic fields in a vacuum is $B_0 = \frac{E_0}{c}$.

Calculate B_0: $B_0 = \frac{60}{3\times10^8} = 2\times10^{-7}\,\mathrm{T}$

Therefore, the correct option is:

$$E_y = 60\sin\left[\frac{\pi}{4}\times10^3(x-3\times10^8 t)\right]\hat{j}\,Vm^{-1}$$
$$B_z = 2\times10^{-7}\sin\left[\frac{\pi}{4}\times10^3(x-3\times10^8 t)\right]\hat{k}\,\mathrm{T}$$

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