Electromagnetic Waves JEE Main PYQ - 3

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

Instructions

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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. Amplitude modulated wave is represented by $V_{AM} = 10[1 + 0.4\cos(2\pi \times 10^4 t]\cos(2\pi \times 10^7 t)$. The total bandwidth of the amplitude modulated wave is : **(+4, -1)**

a. 10 kHz

b. 20 MHz

c. 20 kHz

d. 10 MHz

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2. A beam of light travelling along X-axis is described by the electric field $E_y = 900\sin\omega(t - x/c)$. The ratio of electric force to magnetic force on a charge q moving along Y-axis with a speed of 3×10^7 ms^{-1} will be : (Given speed of light = 3×10^8 ms^{-1}) **(+4, -1)**

a. 1 : 1

b. 1 : 10

c. 10 : 1

d. 1 : 2

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3. Calculate the average energy density of an electromagnetic wave whose electric field is oscillating with amplitude $50\ V/m$ and frequency $5 \times 10^{10}\ Hz$: **(+4, -1)**

a. $2 \times 10^{-6}\ J/m^3$

b. $1.1 \times 10^{-8}\ J/m^3$

c. $3 \times 10^{-7}\ J/m^3$

d. $1.6 \times 10^{-7}\ J/m^3$

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4. A square wave of the modulating signal is shown in the figure. The carrier wave is given by $C(t) = 5\sin(8\pi t)$ Volt. The modulation index is **(+4, -1)**

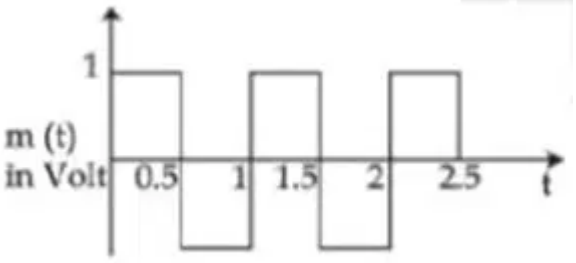

Fig.

a. 0.2

b. 0.1

c. 0.3

d. 0.4

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5. With reference to the observations in photo-electric effect, identify the correct statements from below: **(+4, -1)**

(A) The square of maximum velocity of photoelectrons varies linearly with frequency of incident light.

(B) The value of saturation current increases on moving the source of light away from the metal surface.

(C) The maximum kinetic energy of photo-electrons decreases on decreasing the power of LED (Light emitting diode) source of light.

(D) The immediate emission of photo-electrons out of metal surface can not be explained by particle nature of light/electromagnetic waves.

(E) Existence of threshold wavelength can not be explained by wave nature of light/electromagnetic waves.

Choose the correct answer from the options given below.

a. (A) & (B) only

b. (A) & (E) only

c. (C) & (E) only

d. (D) & (E) only

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6. Identify the correct statements from the following descriptions of various properties of electromagnetic waves. **(+4, -1)**

(A) In a plane electromagnetic wave electric field and magnetic field must be perpendicular to each other and direction of propagation of wave should be along electric field or magnetic field.

(B) The energy in electromagnetic wave is divided equally between electric and magnetic fields.

(C) Both electric field and magnetic field are parallel to each other and perpendicular to the direction of propagation of wave.

(D) The electric field, magnetic field and direction of propagation of wave must be perpendicular to each other.

(E) The ratio of amplitude of magnetic field to the amplitude of electric field is equal to speed of light.

Choose the most appropriate answer from the options given below

a. (D) only

b. (B) & (D) only

c. (B), (C) & (E) only

d. (A), (B) & (E) only

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7. In free space, an electromagnetic wave of 3 GHz frequency strikes over the edge of an object of size $\frac{\lambda}{100}$, where λ is the wavelength of the wave in free space. The phenomenon, which happens there will be **(+4, -1)**

a. Reflection

b. Refraction

c. Diffraction

d. Scattering

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8. If electric field intensity of a uniform plane electromagnetic wave is given as **(+4, -1)**

$E = -301.6\sin(kz - \omega t)\hat{a}_x + 452.4\sin(k\omega - \omega t)\hat{a}_y \frac{V}{m}$

Then, magnetic intensity 'H' of this wave in Am^{-1} will be :

[Given : Speed of light in vacuum c = $3 \times 10^8 ms^{-1}$, Permeability of vacuum $\mu_0 = 4\pi \times 10^{-7}$ NA^{-2}]

a. $0.8\sin(kz - \omega t)\hat{a}_y + 0.8\sin(k\omega - \omega t)\hat{a}_x$

b. $0.1 \times 10^{-6}\sin(kz - \omega t)\hat{a}_y + 1.5 \times 10^{-6}\sin(k\omega - \omega t)\hat{a}_x$

c. $-0.8\sin(kz - \omega t)\hat{a}_y - 1.2\sin(k\omega - \omega t)\hat{a}_z$

d. $-0.1 \times 10^{-6}\sin(kz - \omega t)\hat{a}_y - 1.5 \times 10^{-6}\sin(k\omega - \omega t)\hat{a}_x$

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9. Sun light falls normally on a surface of area $36cm^2$ and exerts an average force of $7.2 \times 10^{-9}N$ within a time period of $20minutes$. Considering a case of complete absorption, the energy flux of incident light is **(+4, -1)**

a. $25.92 \times 10^2 W/cm^2$

b. $8.64 \times 10^{-6} W/cm^2$

c. $6.0 W/cm^2$

d. $0.06 W/cm^2$

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10. The TV transmission tower at a particular station has a height of 125 m. For doubling the coverage of its range, the height of the tower should be increased by **(+4, -1)**

a. 125 m

b. 250 m

c. 375 m

d. 500 m

11. A radar sends an electromagnetic signal of electric field (E_0) = 2.25 V/m and magnetic field (B_0) = 1.5 × 10^{-8} T which strikes a target on line of sight at a distance of 3 km in a medium. After that, a part of signal (echo) reflects back towards the radar with same velocity and by same path. If the signal was transmitted at time t = 0 from radar, then after how much time echo will reach to the radar? **(+4, -1)**

a. 2.0 × 10^{-5} s

b. 4.0 × 10^{-5} s

c. 1.0 × 10^{-5} s

d. 8.0 × 10^{-5} s

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12. The magnetic field of a plane electromagnetic wave is given by: **(+4, -1)**
$\vec{B} = 2 \times 10^{-8} sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t)\hat{j}T$.
The amplitude of the electric field would be

a. 6 Vm^{-1} along x-axis

b. 3 Vm^{-1} along z-axis

c. 6 Vm^{-1} along z-axis

d. 2 × 10^{-8} Vm^{-1} along z-axis

---

13. 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. $Ey = 60sin[\frac{\pi}{4} \times 10^3(x - 3 \times 10^8 t)]\hat{j}Vm^{-1}$
$Bz = 2sin[\frac{\pi}{4} \times 10^3(x - 3 \times 10^8 t)]\hat{k}T$

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

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

d. $Ey = 2 \times 10^{-7} sin[\frac{\pi}{4} \times 10^4(x - 4 \times 10^8 t)]\hat{j} Vm^{-1}$
$Bz = 60 sin[\frac{\pi}{4} \times 10^4(x - 4 \times 10^8 t)]\hat{k} T$

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14. A sinusoidal wave $y(t) = 40\sin(10 \times 10^6 \pi t)$ is amplitude modulated by another sinusoidal wave $x(t) = 20\sin(1000\pi t)$. The amplitude of minimum frequency component of modulated signal is: **(+4, -1)**

a. 0.5

b. 0.25

c. 20

d. 10

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15. Which is the correct ascending order of wavelengths? **(+4, -1)**

a. $\lambda_{visible} < \lambda_{X\text{-}ray} < \lambda_{gamma\text{-}ray} < \lambda_{microwave}$

b. $\lambda_{gamma\text{-}ray} < \lambda_{X\text{-}ray} < \lambda_{visible} < \lambda_{microwave}$

c. $\lambda_{X\text{-}ray} < \lambda_{gamma\text{-}ray} < \lambda_{visible} < \lambda_{microwave}$

d. $\lambda_{microwave} < \lambda_{visible} < \lambda_{gamma\text{-}ray} < \lambda_{X\text{-}ray}$

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16. The electric field in an electromagnetic wave is given by $E = 56.5\ sin\omega(t - \frac{x}{c})\ NC^{-1}$. Find the intensity of the wave if it is propagating along x-axis in the free space. (Given $\in_0 = 8.85 \times 10^{-12} C^2 N^{-1} m^{-2}$) **(+4, -1)**

a. $5.65\ Wm^{-2}$

b. $4.24\ Wm^{-2}$

c. $1.9 \times 10–7\ Wm^{-2}$

d. $56.5\ Wm^{-2}$

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

	List I		**List II**
A	Facsimile	I	Static Document Image
B	Guided media Channel	II	Local Broadcast Radio
C	Frequency Modulation	III	Rectangular wave
D	Digital Single	IV	Optical Fiber

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

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

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

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

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18. A baseband signal of 3.5 MHz frequency is modulated with a carrier signal of 3.5 GHz frequency using amplitude modulation method. What should be the minimum size of antenna required to transmit the modulated signal? **(+4, -1)**

a. 42.8 m

b. 42.8 mm

c. 21.4 mm

d. 21.4 m

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19. A plane of electromagnetic waves travels in a medium with a relative permeability of 1.61 and relative permittivity of 6.44. If the magnitude of magnetic intensity is $4.5 \times 10^{-2}\ Am^{-1}$ at a point, what will be the approximate **(+4, -1)**

magnitude of electric field intensity?(Given: Permeability of free space μ_0 = $4\pi \times 10^{-7}$ NA^{-2}, speed of light in vacuum $c = 3 \times 10^8$ ms^{-1})

a. 16.96 Vm^{-1}

b. 2.25×10^{-2} Vm^{-1}

c. 8.48 Vm^{-1}

d. 6.75 × 106 Vm^{-1}

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20. The magnetic field of a plane electromagnetic wave is given by $\vec{B} = 2 \times 10^{-8} \sin\left(05 \times 10^3 x + 15 \times 10^{11} t\right) \hat{j}T$ The amplitude of the electric field would be **(+4, -1)**

a. $6\,Vm^{-1}$ along x-axis

b. $3\,Vm^{-1}$ along z-axis

c. $6\,Vm^{-1}$ along z-axis

d. $2 \times 10^{-8} Vm^{-1}$ along z-axis

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21. **The waves emitted when a metal target is bombarded with high-energy electrons are:** **(+4, -1)**

a. X-ray

b. Infrared

c. Microwaves

d. Radiowave

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22. Match the list-I with list-II and choose the correct option. **(+4, -1)**

a. A-(s), B-(q), C-(r), D-(p)

b. A-(s), B-(p), C-(q), D-(r)

	List-I		List-II
(A).	Microwave	(P).	1 nm - 400nm
(B).	Ultraviolet	(Q).	1 nm - 1nm
(C).	X-rays	(R).	2.5 μm - 750nm
(D).	Infrared	(S).	1 μm - 1nm

c. A-(p), B-(s), C-(q), D-(r)

d. A-(r), B-(q), C-(s), D-(p)

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23. Light wave travelling in air along x-direction is given by $E_y = 540 \sin \pi \times 10^4 (x - ct) V m^{-1}$ Then, the peak value of magnetic field of wave will be (Given $c = 3 \times 10^8 m s^{-1}$) **(+4, -1)**

a. $18 \times 10^{-7} T$

b. $54 \times 10^{-7} T$

c. $54 \times 10^{-8} T$

d. $18 \times 10^{-8} T$

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24. **In a medium the speed of light wave decreases to 0.2 times to its speed in free space The ratio of relative permittivity to the refractive index of the medium is $x : 1$ The value of x is(Given speed of light in free space $= 3 \times 10^8 m s^{-1}$ and for the given medium $\mu = 1$)** **(+4, -1)**

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25. The electric field and magnetic field components of an electromagnetic wave going through vacuum are described by: **(+4, -1)**

$$E_x = E_0 \sin(kz - \omega t), \quad B_y = B_0 \sin(kz - \omega t).$$

Then the correct relation between E_0 and B_0 is given by:

a. $E_0 B_0 = \omega k$

b. $E_0 = k B_0$

c. $kE_0 = \omega B_0$

d. $\omega E_0 = kB_0$

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26. In $\vec{E}$ and $\vec{K}$ represent electric field and propagation vectors of the EM waves in vacuum, then magnetic field vector is given by:($\omega-$ angular frequency): **(+4, -1)**

a. $\frac{1}{\omega}(\vec{K} \times \vec{E})$

b. $\omega(\vec{E} \times \vec{K})$

c. $\vec{K} \times \vec{E}$

d. $\omega(\vec{K} \times \vec{E})$

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27. An electromagnetic wave is transporting energy in the negative z direction At a certain point and certain time the direction of electric field of the wave is along positive y direction What will be the direction of the magnetic field of the wave at that point and instant? **(+4, -1)**

a. Positive direction of z

b. Negative direction of y

c. Positive direction of x

d. Negative direction of x

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

List I		List II	
A.	Microwaves	I.	Physiotherapy
B.	UV rays	II.	Treatment of cancer
C.	Infra-red rays	III.	Lasik eye surgery
D.	X-rays	IV.	Aircraft navigation

Choose the correct answer from the options given below:

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

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

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

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

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29. If a source of electromagnetic radiation having power $15kW$ produces 10^{16} photons per second, the radiation belongs to a part of spectrum is(Take Planck constant $h = 6 \times 10^{-34} Js$) **(+4, -1)**

a. Micro waves

b. Radio waves

c. Gamma rays

d. Ultraviolet rays

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30. In an electromagnetic wave electric field and magnetic field is given by **(+4, -1)**

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

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

Find correct relation.

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

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

c. $\frac{\omega}{k} = B_0$

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

Answers

1. Answer: c

Explanation:

To determine the total bandwidth of the given amplitude modulated wave, we begin by understanding the formula for an amplitude modulated (AM) signal. The given equation is:

$$V_{AM} = 10\left[1 + 0.4\cos(2\pi \times 10^4 t)\right]\cos(2\pi \times 10^7 t)$$

where:

- The carrier frequency, f_c, is 10^7 Hz or 10 MHz.
- The modulating frequency, f_m, is 10^4 Hz or 10 kHz.

The general formula for an AM wave is:

$$V_{AM} = [A + A_m\cos(2\pi f_m t)]\cos(2\pi f_c t)$$

where A_m is the modulation index.

The total bandwidth of an AM signal is given by:

$$BW = 2f_m$$

Given that the modulating frequency $f_m = 10\ \text{kHz}$, the total bandwidth BW is calculated as:

$$BW = 2 \times 10\ \text{kHz} = 20\ \text{kHz}$$

Thus, the total bandwidth of the amplitude modulated wave is **20 kHz**, which matches the given correct answer.

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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2. **Answer: c**

Explanation:

$$\text{Ratio} = \frac{|q\vec{E}|}{|q\vec{v}\times\vec{B}|}$$

$$= \frac{E}{v_B} = \frac{v_{wave}}{v}$$

$$\Rightarrow \text{Ratio} = \frac{3\times10^8}{3\times10^7} = \frac{10}{1}$$

Therefore, The correct answer is (C) : $10:1$

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3. **Answer: b**

Explanation:

The Correct Option is (B) : $1.1 \times 10^{-8}\ J/m^3$

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example, sound waves are longitudinal waves because the change of pressure occurs parallel to the direction of wave propagation.

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4. **Answer: a**

Explanation:

The correct answer is (A) : 0.2
Modulation Index , $\mu = \frac{A_m}{A_c}$
$= \frac{1}{5} = 0.2$

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5. **Answer: b**

Explanation:

The correct solution is (B) : (A) & (E) only
$\because \frac{1}{2}mv_m^2 = hv - \Phi$
$\Rightarrow v_m^2$
varies linearly with frequency.
And, threshold wavelength can be explained by particle nature of light.

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6. **Answer: b**

Explanation:

The correct answer is (B) : (B) & (D) only
In an EM wave :
1. $\vec{E} \perp \vec{B}$
2. $\vec{V} \equiv \vec{E} \times \vec{B}$
3. Energy is equally divided
4. $|\vec{V}| = |\vec{E}|I|\vec{B}|$

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7. Answer: d

Explanation:

Since size is of the order of $\frac{\lambda}{100}$, hence scattering will take place.
So, Correct option is (D)

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8. Answer: c

Explanation:

We know, $\vec{\mathbf{B}} \times \vec{\mathbf{C}} = \vec{\mathbf{E}}$

Taking cross product of vector C both the sides-

$\vec{\mathbf{C}} \times (\vec{\mathbf{B}} \times \vec{\mathbf{C}}) = \vec{\mathbf{C}} \times \vec{\mathbf{E}}$

So

$\vec{B} = \frac{\vec{\mathbf{C}} \times \vec{\mathbf{E}}}{C^2}$

$\vec{\mathbf{C}} = C\hat{\mathbf{k}}$

$\vec{\mathbf{E}} = -301.6 \sin(Kz - \omega t)\hat{a}_x + 452.4 \sin(kz - \omega t)\hat{a}_y$

and

$\vec{\mathbf{H}} = \frac{\vec{\mathbf{B}}}{\mu_0}$

On solving
$\overrightarrow{\mathbf{H}} = -0.8\sin(kz - \omega t)\hat{a}_y - 1.2\sin(k\omega - \omega t)\hat{a}_z$

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9. Answer: d

Explanation:

$\frac{I}{c} \times area = force$
$\frac{I}{c} \times 36 \times 10^{-4} = 7.2 \times 10^{-9}$
$I = \frac{7.2\times10^{-9}\times3\times10^{8}}{36\times10^{-4}} = \frac{6\times10^{-1}}{10^{-3}}$
$I = 6 \times 10^{2}\frac{W}{m^2} = 0.06\frac{W}{cm^2}$

Concepts:

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10. Answer: c

Explanation:

The correct answer is (C) : 375
Let's consider H' as the antenna's new height.
As the range of antenna , $d = \sqrt{2RH}$
Hence , $d_1 = d = \sqrt{2 \times R \times 125}$ ..... (i)
$d_2 = 2d = \sqrt{2 \times R \times H'}$ ..... (ii)
By dividing (i) and (ii) , we get
$\frac{d}{2d} = \sqrt{\frac{125}{H'}}$
Then , squaring the above equation , we get
$\frac{1}{4} = \frac{125}{H'}$
H' = 500 m
∴ Increase in height = H' - H

= 500 - 125
= 375 m

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.

---

11. Answer: b

Explanation:

The correct answer is (B) : 4.0×10^{-5} s
E_0 = 2.25 V/m
B_0 = 1.5×10^{-8}T
$\Rightarrow \frac{E_0}{B_0} = 1.5 \times 10^8$ m/s
⇒ Refractive index = 2

Distance to be travelled = 6 km
Time taken
$= \frac{6\times10^3}{1.5\times10^8} = 4 \times 10^{-5}$ s

Concepts:

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---

12. Answer: c

Explanation:

Speed of light,
$c = \frac{w}{k}$
$c = \frac{1.5\times10^{11}}{0.5\times10^3}$
$c = 3 \times 10^8\ m/sec$
So, $E_0 = B_0 c$
$E_0 = 2 \times 10^{-8} \times 3 \times 10^8$

$E_0 = 6\ V/m$
And the direction will be along z-axis.

So, the correct option is (C): 6 Vm^{-1} along z-axis

Concepts:

1. Electromagnetic waves:

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---

13. Answer: b

Explanation:

In first 3 options speed of light is 3×10^8 m/sec and in the fourth option it is 4×10^8 m/sec.
Using E = CB
We can check the option is B.

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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14. Answer: d

Explanation:

The correct answer is (D): 10

Explanation:

Modulate signal $s(t) \equiv [1 + 20\sin(1000\pi t)]\sin(10^7\pi t)$
$\equiv \sin(10^7\pi t) + 10\cos(10^7\pi t - 10^3\pi t) + 10\cos(10^7\pi t + 10^3\pi t)$
$\Rightarrow$ Required amplitude = 10

Concepts:

1. Electromagnetic waves:

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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:

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---

15. **Answer: b**

Explanation:

The correct answer is (B) : $\lambda_{\text{gamma-ray}} < \lambda_{\text{X-ray}} < \lambda_{\text{visible}} < \lambda_{\text{microwave}}$

Explanation:

Wave length of microwave is maximum then visible light then X-rays and then gamma rays.
so the correct order will be
$\Rightarrow \lambda_{\text{gamma-ray}} < \lambda_{\text{X-ray}} < \lambda_{\text{visible}} < \lambda_{\text{microwave}}$

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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---

16. Answer: b

Explanation:

Intensity of the wave,

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

$I = \frac{1}{2} \times 8.5 \times 10^{-12} \times (56.5)^2 \times 3 \times 10^8$

$I = 4.24\ w/m^2$

So, the correct option is (B): $4.24\ Wm^{-2}$

Concepts:

1. Electromagnetic waves:

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---

17. Answer: a

Explanation:

The correct match is:

List I		List II
Facsimile	-	Static Document Image
Guided media Channel	-	Optical Fiber
Frequency Modulation	-	Local Broadcast Radio
Digital Single	-	Rectangular Wave

Concepts:

1. **Types of Differential Equations:**

There are various types of Differential Equation, such as:

Ordinary Differential Equations:

Ordinary Differential Equations is an equation that indicates the relation of having one independent variable x, and one dependent variable y, along with some of its other derivatives.

$$F(\frac{dy}{dt}, y, t) = 0$$

Partial Differential Equations:

A partial differential equation is a type, in which the equation carries many unknown variables with their partial derivatives.

1. $\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$
2. $u_{xx} + u_{yy} = 0$
3. $ux\frac{\partial^2 u}{\partial x^2} + u^2 xy\frac{\partial^2 u}{\partial x \partial y} + uy\frac{\partial^2 u}{\partial y^2} + \left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial u}{\partial y}\right)^2 + u^3 = 0$
4. $\frac{\partial^2 u}{\partial x^2} + (\frac{\partial^2 u}{\partial x \partial y})^2 + \frac{\partial^2 u}{\partial y^2} = x^2 + y^2$

Linear Differential Equations:

It is the linear polynomial equation in which derivatives of different variables exist. Linear Partial Differential Equation derivatives are partial and function is dependent on the variable.

Linear Differential Equation in y

$$\frac{dy}{dx} + Py = Q$$

Linear Differential Equation in x

$$\frac{dx}{dy} + P_1 x = Q_1$$

Homogeneous Differential Equations:

When the degree of f(x,y) and g(x,y) is the same, it is known to be a homogeneous differential equation.

$$\frac{dy}{dx} = \frac{a_1 x + b_1 y + c_1}{a_2 x + b_2 y + c_2}$$

Read More: Differential Equations

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18. Answer: c

Explanation:

ν_c = 3.5×10^9 Hz

$\therefore \lambda = \frac{c}{\nu}$

$\lambda = \frac{3\times10^8}{3.5\times10^9} = 8.57 \times 10^{-24}$

$\therefore$ Size of antenna = $\frac{\lambda}{4}$

$= \frac{8.57\times10^{-24}}{4}$

$= 21.4mm$

The correct option is (C) : 21.4 mm

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:

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---

19. Answer: c

Explanation:

$H = 4.5 \times 10^{-2}$

So $B = \mu_{0\mu}H$

Thus

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

(where $n \Rightarrow$ refractive index)

So

$E = \frac{3\times10^{8}\times4\pi\times10-7\times1.61\times4.5\times10^{-2}}{\sqrt{1.61\times6.44}}$

$E = 8.48$

The correct option is (A): 16.96 Vm^{-1}

Concepts:

1. Transverse Waves:

Transverse waves are a type of wave in which the disturbance moves perpendicular to the direction of the wave propagation. In other words, the particles of the medium through which the wave is travelling oscillate perpendicular to the direction of the wave's movement.

Examples of transverse waves include light waves, electromagnetic waves, and waves on a string or rope. In these types of waves, the oscillations are perpendicular to the direction of the wave propagation.

Transverse waves have several characteristics that define their behavior. One of these is wavelength, which is the distance between two consecutive crests or troughs in the wave. Another characteristic is frequency, which is the number of waves that pass a given point per unit time. The amplitude of a transverse wave is

the maximum displacement of the particles of the medium from their equilibrium position.

Also Read: Amplitude Formula

Transverse waves can be reflected, refracted, and diffracted, just like other types of waves. They obey the laws of superposition, which means that the displacement of the medium caused by two waves passing through each other is equal to the sum of their individual displacements.

Transverse waves have many practical applications, such as in the transmission of information through fiber-optic cables, the creation of images in microscopy, and in the production of electromagnetic radiation for various uses.

---

20. Answer: c

Explanation:

The correct option is(C): $6\,Vm^{-1}$ along z-axis.

Concepts:

1. Dimensional Analysis:

Dimensional Analysis is a process which helps verify any formula by the using the **principle of homogeneity.** Basically dimensions of each term of a dimensional equation on both sides should be the same.

Limitation of Dimensional Analysis: Dimensional analysis does not check for the correctness of value of constants in an equation.

Using Dimensional Analysis to check the correctness of the equation

Let us understand this with an example:

Suppose we don't know the correct formula relation between speed, distance and time,

We don't know whether

(i) Speed = Distance/Time is correct or

(ii) Speed =Time/Distance.

Now, we can use dimensional analysis to check whether this equation is correct or not.

By reducing both sides of the equation in its fundamental units form, we get

(i) $[L][T]^{-1} = [L] / [T]$ (Right)

(ii) $[L][T]^{-1} = [T] / [L]$ (Wrong)

From the above example it is evident that the dimensional formula establishes the correctness of an equation.

---

21. **Answer: a**

Explanation:

X-rays have higher frequencies and shorter wavelengths compared to the other options listed. As electromagnetic waves, they are situated in the high-frequency end of the electromagnetic spectrum, above ultraviolet light. Therefore, X-rays have more energy and higher electromagnetic frequencies compared to infrared, microwaves, and radio waves.

So, the correct option is (A): X-rays.

Concepts:

1. Electromagnetic waves:

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Types of Electromagnetic Waves:

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---

22. Answer: a

Explanation:

Understanding the Problem

We are given different types of electromagnetic waves and their corresponding wavelength ranges. We need to match the waves with their correct uses based on their wavelengths.

Solution

1. **Microwave:**

Has a wavelength $\lambda > 700\,\text{nm}$.

Suitable for communication purposes.

2. **Ultraviolet:**

Has wavelengths less than $400\,\text{nm}$.

Typically used for sterilization and curing.

3. **X-Ray:**

Has a very short wavelength in the range of $1\,\text{nm}$ to $10^{-3}\,\text{nm}$.

Ideal for medical imaging.

4. **Infra-red:**

With a wavelength between $400\,\text{nm}$ to $700\,\text{nm}$.

Used in thermal cameras and night vision technologies.

Matching Waves with Wavelengths

Based on the wavelength ranges and uses, we can match the waves as follows:

Microwave - Communication

Ultraviolet - Sterilization

X-Ray - Medical Imaging

- Infra-red - Thermal Imaging

Final Answer

Therefore, matching the waves with their wavelengths gives us the correct answer as option (2).

Concepts:

1. Electromagnetic Spectrum:

The term used by scientists to describe the entire range of light that exists is the **electrostatic spectrum**. Light is a wave of alternating electric and magnetic fields. The propagation of light doesn't vary from waves crossing an ocean. Like any other wave, light also has a few fundamental properties that describe it. One is its frequency. The frequency is measured in Hz, which counts the number of waves that pass by a point in one second.

The electromagnetic waves that your eyes detect are visible light and oscillate between 400 and 790 terahertz (THz). That's several hundred trillion times a second.

---

23. Answer: a

Explanation:

$E_y = 540 \sin \pi \times 10^4 (x - ct) V m^{-1}$
$E_0 = 540 V m^{-1}$
$B_0 = \frac{E_0}{C} = \frac{540}{3 \times 10^8} = 18 \times 10^{-7} T$

Concepts:

1. Electromagnetic waves:

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---

24. Answer: 5 - 5

Explanation:

The correct answer is 5.
$V = \frac{C}{\mu} \Rightarrow \mu = \frac{C}{V} = \frac{C}{0.2C}$
$\mu = 5$

$\mu = \sqrt{\epsilon_r \mu_r}$
$\Rightarrow \epsilon_r = \frac{\mu^2}{\mu_r}$
$\therefore \frac{\epsilon_r}{\mu} = \frac{\mu}{\mu_r} = 5$

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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---

25. Answer: c

Explanation:

For an electromagnetic wave propagating in vacuum:

- The speed of the wave c is related to the angular frequency ω and the wave number k:

$$c = \frac{\omega}{k}.$$

- The speed of light c in terms of the electric field E_0 and magnetic field B_0 is given by:

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

Equating both expressions for c:

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

Rearranging terms:

$$kE_0 = \omega B_0.$$

Thus, the correct relation is:

$$kE_0 = \omega B_0.$$

Concepts:

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of the wave.

---

26. Answer: a

Explanation:

Electromagnetic (EM) waves consist of oscillating electric and magnetic fields that are perpendicular to each other and to the direction of wave propagation. The following relationships hold for the electric field ($\vec{E}$), magnetic field ($\vec{B}$), and wave vector ($\vec{K}$):
1. The wave vector $\vec{K}$ indicates the direction of wave propagation.
2. The electric field $\vec{E}$ oscillates perpendicular to $\vec{K}$.
3. The magnetic field $\vec{B}$ is perpendicular to both $\vec{E}$ and $\vec{K}$.
The magnitude and direction of $\vec{B}$ are determined using the cross product:

$$\vec{B} = \frac{\vec{K} \times \vec{E}}{\omega}$$

where ω is the angular frequency of the wave.
Explanation of Options: Option (1): Correct. This represents the magnetic field as proportional to the cross product of $\vec{K}$ and $\vec{E}$, divided by the angular frequency.
Option (2): Incorrect. The direction of $\vec{B}$ would be wrong as the cross product order matters ($\vec{K} \times \vec{E} \neq \vec{E} \times \vec{K}$).
Option (3): Incorrect. Multiplying by ω gives a dimensionally incorrect magnetic field.
Option (4): Incorrect. The dot product results in a scalar, not a vector.
Thus, the correct option is (1).

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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---

27. Answer: c

Explanation:

1. The energy transport in an electromagnetic wave is given by the Poynting vector:

$$\vec{S} = \vec{E} \times \vec{H},$$

where $\vec{E}$ is the electric field vector and $\vec{H}$ is the magnetic field vector.
2. Given: - Energy transport ($\vec{S}$) is in the negative z-direction: $\vec{S} = -\hat{k}$. - Electric field ($\vec{E}$) is in the positive y-direction: $\vec{E} = +\hat{j}$.
3. Substituting into the cross-product:

$$\vec{S} = \vec{E} \times \vec{H} \implies -\hat{k} = (+\hat{j}) \times \vec{H}.$$

4. Solving for $\vec{H}$:

$$\vec{H} = -\hat{i}.$$

Thus, the magnetic field is in the **positive direction of** x.
In an electromagnetic wave, the directions of the electric field, magnetic field, and energy transport (Poynting vector) are mutually perpendicular, forming a right-handed coordinate system.

Concepts:

1. Electromagnetic waves:

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---

28. Answer: c

Explanation:

- Microwaves are used in aircraft navigation (A-IV).
- UV rays are used for Lasik eye surgery (B-III).
- Infra-red rays are used in physiotherapy (C-I).
- X-rays are used for the treatment of cancer (D-II).

Concepts:

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---

29. Answer: c

Explanation:

$$\text{Energy of one photon } = \frac{\text{Power}}{\text{Photon frequency}}$$

$E = hv = \frac{15\times10^{3}}{10^{16}}$

$v = \frac{15\times10^{-13}}{6\times10^{-34}} = 2.5 \times 10^{21}$

So gamma Rays. Option 3

Concepts:

1. Electromagnetic waves:

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---

30. **Answer: a**

Explanation:

$E_0 = B_0C$

Speed of light $C = \frac{\omega}{k}$

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

So, the correct option is (A) : $\frac{\omega}{k} = \frac{E_0}{B_0}$

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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