Electromagnetic Waves

Question1

A plane electromagnetic wave propagating in x-direction is described by

$E_y = (200 Vm^{-1}) sin\ [1.5 \times 10^7 t - 0.05x]$;

The intensity of the wave is :

(Use $E_0 = 8.85 \times 10^{-12} C^2 N^{-1} m^{-2}$)

[27-Jan-2024 Shift 1]

Options:

A.

$35.4 Wm^{-2}$

B.

$53.1 Wm^{-2}$

C.

$26.6 Wm^{-2}$

D.

$106.2 Wm^{-2}$

Answer: B

Solution:

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

$I = \frac{1}{2} \times 8.85 \times 10^{-12} \times 4 \times 10^4 \times 3 \times 10^8$

$I = 53.1 W/m^2$

Question2

An object is placed in a medium of refractive index 3. An electromagnetic wave of intensity $6 \times 10^8 W/m^2$ falls normally on the object and it is absorbed completely. The radiation pressure on the object would be (speed of light in free space = $3 \times 10^8 m/s$):

[27-Jan-2024 Shift 2]

Options:

A.

$36 Nm^{-2}$

B.

$18 Nm^{-2}$

C.

$6 Nm^{-2}$

D.

$2 Nm^{-2}$

Answer: C

Solution:

$$\text{Radiation pressure} = \frac{I}{V}$$

$$= \frac{I \cdot \mu}{c}$$

$$= \frac{6 \times 10^8 \times 3}{3 \times 10^8}$$

$$= 6 N/m^2$$

Question3

A plane electromagnetic wave of frequency 35MHz travels in free space along the X-direction. At a particular point (in space and time) $\vec{E} = 9.6\hat{j} V/m.$ The value of magnetic field at this point is :

[29-Jan-2024 Shift 2]

Options:

A.

$3.2 \times 10^{-8} \hat{k} T$

B.

$3.2 \times 10^{-8} \hat{i} T$

C.

$9.6 \hat{j} T$

D.

$9.6 \times 10^{-8} \hat{k} T$

Answer: A

Solution:

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

$\frac{E}{B} = 3 \times 10^8$

$B = \frac{E}{3 \times 10^8} = \frac{9.6}{3 \times 10^8}$

$B = 3.2 \times 10^{-8} T$

$\hat{B} = \hat{v} \times \hat{E}$

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

So,

$\vec{B} = 3.2 \times 10^{-8} \hat{k} T$

Question4

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 :

[30-Jan-2024 Shift 1]

Options:

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.

$\vec{B} = E_0 \operatorname{Cos}(\omega t + kz) \hat{j}$

D.

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

Answer: B

Solution:

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

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

$$\hat{C} = \hat{E} \times \hat{B}$$

Question5

Match List I with List II

	List-I		List-II
A.	Gauss's law of magnetostatics	I.	$\oint \vec{E} \cdot \vec{d}a = \frac{1}{\varepsilon_0}\int \rho \, dV$
B.	Faraday's law of electro magnetic induction	II.	$\oint \vec{B} \cdot \vec{d}a = -0$
C.	Ampere's law	III.	$\oint \vec{E} \cdot \vec{d}l = \frac{-d}{dt}\int \vec{B} \cdot \vec{d}a$
D.	Gauss's law of electrostatics	IV.	$\oint \vec{B} \cdot \vec{d}l = -\mu_0 I$

Choose the correct answer from the options given below:

[30-Jan-2024 Shift 2]

Options:

A.

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

B.

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

C.

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

D.

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

Answer: D

Solution:

Maxwell's equation

Question6

In a plane EM wave, the electric field oscillates sinusoidally at a frequency of 5×10^{10}Hz and an amplitude of $50Vm^{-1}$. The total average energy density of the electromagnetic field of the wave is : [Use ε0 = $8.85 \times 10^{-12}C^2/Nm^2$]

[31-Jan-2024 Shift 1]

Options:

A.

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

B.

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

C.

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

D.

$2.212 \times 10^{-10}Jm^{-3}$

Answer: A

Solution:

$$U_E = \frac{1}{2}E_0E^2$$

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

$$= 1.106 \times 10^{-8}J/m^3$$

Question7

Given below are two statements:

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:

[31-Jan-2024 Shift 2]

Options:

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.

Answer: B

Solution:

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

$$\because E = CB \text{ and } C = \frac{1}{\mu_0 \varepsilon_0}$$

Question8

If frequency of electromagnetic wave is 60MHz 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 :

[1-Feb-2024 Shift 2]

Options:

A.

2.5

B.

10

C.

5

D.

2

Answer: C

Solution:

$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{60 \times 10^6} = 5m$

Question9

If $\vec{E}$ 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) :
[24-Jan-2023 Shift 1]

Options:

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

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

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

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

Answer: A

Solution:

Magnetic field vector will be in the direction of $\hat{K} \times \hat{E}$
magnitude of B = $\frac{E}{C} = \frac{K}{\omega}E$
Or $\vec{B} = \frac{1}{\omega}(\vec{K} \times \vec{E})$

Question10

The electric field and magnetic field components of an electromagnetic wave going through vacuum is described by
$E_x = E_0 \sin(kz - \omega t)$
$B_y = B_0 \sin(kz - \omega t)$
Then the correct relation between E_0 and B_0 is given by
[24-Jan-2023 Shift 2]

Options:

A. $kE_0 = \omega B_0$

B. $E_0 B_0 = \omega k$

C. $\omega E_0 = kB_0$

D. $E_0 = kB_0$

Answer: A

Solution:

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

Question11

All 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? [25-Jan-2023 Shift 1]

Options:

A. Positive direction of x

B. Positive direction of z

C. Negative direction of x

D. Negative direction of y

Answer: A

Solution:

Solution:
As , poynting vector
$\vec{S} = \vec{E} \times \vec{H}$
Given energy transport = negative z direction
Electric field = positive y direction
$(-\hat{k}) = (+\hat{j}) \times [\hat{i}]$
Hence according to vector cross product magnetic field should be positive x direction.

Question12

Which of the following are true?
A. Speed of light in vacuum is dependent on the direction of propagation.
B. Speed of light in a medium in independent of the wavelength of light.
C. The speed of light is independent of the motion of the source.
D. The speed of light in a medium is independent of intensity.
Choose the correct answer from the option given below :
[29-Jan-2023 Shift 1]

Options:

A. A and C only

B. B and D only

C. B and C only

D. C and D only

Answer: D

Solution:

Solution:
Speed of light does not depend on the motion of source as well as intensity.

Question13

Given below are two statements:
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 $E_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} B_0$

In the light of the above statements, choose the correct answer from the options given below:
[29-Jan-2023 Shift 2]

Options:

A. Statement I is true but statement II is false

B. Both Statement I and Statement II are true

C. Statement I is false but statement II is true

D. Both Statement I and Statement II are false

Answer: A

Solution:

Solution:
Statement-I is correct as EMW are neutral.
Statement-II is wrong.
$E_0 = \sqrt{\frac{1}{\mu_0 \varepsilon_0}} B_0$

Question14

Match List-I with List-II.

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 option given below: [31-Jan-2023 Shift 2]

Options:

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

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

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

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

Answer: C

Solution:

Solution:

Question15

Match the List-I with List-II:

List I	List II
A. Microwaves	I. Radio active decay of the nucleus
B. Gamma rays	II. Rapid acceleration and deceleration of electron in aerials
C. Radio waves	III. Inner shell electrons
D. X-rays	IV. Klystron valve

Choose the correct answer from the options given below: [1-Feb-2023 Shift 1]

Options:

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

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

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

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

Answer: B

Solution:

Based on theory.

Question16

The ratio of average electric energy density and total average energy density of electromagnetic wave is:
[1-Feb-2023 Shift 2]

Options:

A. 2

B. 1

C. 3

D. $\frac{1}{2}$

Answer: D

Solution:

$u_E > \; = u_B > \; = \frac{1}{2} < u_{\text{total}} > ..$

So $\frac{u_E \rangle}{u_{\text{total}} \rangle} = \frac{1}{2}$

Question17

The energy density associated with electric field $\overline{E}$ and magnetic field $\overline{B}$ of an electromagnetic wave in free space is given by (ε_0 − . permittivity of free space, μ_0 - permeability of free space)
[6-Apr-2023 shift 2]

Options:

A. $U_E = \frac{\in_0 E^2}{2}, U_B = \frac{B^2}{2\mu_0}$

B. $U_E = \frac{E^2}{2E_0}, U_B = \frac{\mu_0 B^2}{2}$

C. $U_E = \frac{E^2}{2E_0}, U_B = \frac{B^2}{2\mu_0}$

D. $U_E = \frac{\in_0 E^2}{2}, U_B = \frac{\mu_0 B^2}{2}$

Answer: A

Solution:

Solution:
By theory of electromagnetic waves
$U_E = \frac{1}{2}\varepsilon_0 E^2$ and
$U_B = \frac{1}{2}\frac{B^2}{\mu_0}$

Question18

The waves emitted when a metal target is bombarded with high energy electrons are
[8-Apr-2023 shift 2]

Options:

A. Microwaves

B. X-rays

C. Radio Waves

D. Infrared rays

Answer: B

Solution:

Solution:
By theory

Question19

The amplitude of magnetic field in an electromagnetic wave propagating along y-axis is 6.0×10^{-7}T. The maximum value of electric field in the electromagnetic wave is
[10-Apr-2023 shift 2]

Options:

A. $2 \times 10^{15} Vm^{-1}$

B. $2 \times 10^{14} Vm^{-1}$

C. $6.0 \times 10^{-7} Vm^{-1}$

D. $180 Vm^{-1}$

Answer: D

Solution:

In electromagnetic wave, $E_0 = B_0 C$
$E_0 = 6 \times 10^{-7} \times 3 \times 10^{8}$ $E_0 \rightarrow$ Amplitude of electric field
$= 18 \times 10^{1}$ $B_0 \rightarrow$ Amplitude of magnetic field
$= 180 v / m$ $C \rightarrow$ Speed of light

Question20

A plane electromagnetic wave of frequency 20 MHz propagates in free space along x-direction. At a particular space and time, $\vec{E} = 6.6\hat{j} v / m$. What is $\vec{B}$ at this point?
[11-Apr-2023 shift 2]

Options:

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

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

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

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

Answer: C

Solution:

$$|B| = \frac{|E|}{C} = \frac{6.6}{3 \times 10^{8}} = 2.2 \times 10^{-8}$$

For direction of $\vec{B}$
$= \vec{E} \times \vec{B} = \vec{C}$
$= \hat{j} \times \vec{B} = \hat{i}$
$\vec{B} = (2.2 \times 10^{-8})\hat{k} T$

Question21

Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R
Assertion A : EM waves used for optical communication have longer wavelength than that of microwave, employed in Radar technology.

Reason R : Infrared EM waves are more energetic than microwaves, (used in Radar) In the light of given statements, choose the correct answer from the options given below.
[12-Apr-2023 shift 1]

Options:

A. A is true but R is false

B. Both A and R are true and r is the correct explanation of A

C. A is false but R is true

D. Both A and R are true but R is NOT the correct explanation of A

Answer: C

Solution:

Solution:

Question22

Which of the following Maxwell's equation is valid for time varying conditions but not valid for static conditions:
[13-Apr-2023 shift 1]

Options:

A. $\oint \vec{D} \cdot \vec{dA} = Q$

B. $\oint \vec{E} \cdot \vec{dl} = -\frac{\partial \varphi_B}{\partial t}$

C. $\oint \vec{E} \cdot \vec{dl} = 0$

D. $\oint \vec{B} \cdot \vec{dl} = \mu_0 I$

Answer: B

Solution:

For static conditions
$\oint \vec{E} \cdot d\vec{l} = 0$
For time varying condition,
$\oint \vec{E} \cdot d\vec{l} = -\frac{\partial \varphi_B}{\partial t}$

Question23

Given below are two statements :

Statement I : Out of microwaves, infrared rays and ultraviolet rays, ultraviolet rays are the most effective for the emission of electrons from a metallic surface.
Statement II : Above the threshold frequency, the maximum kinetic energy of photoelectrons is inversely proportional to the frequency of the incident light.
In the light of above statements, choose the correct answer form the options given below
[13-Apr-2023 shift 2]

Options:

A. Statement I is false but statement II is true

B. Both Statement I and Statement II are true

C. Statement I is true but statement II is false

D. Both Statement I and Statement II are false

Answer: C

Solution:

Solution:
UV rays have maximum frequency hence are most effective for emission of electrons from the metallic surface.
$KE_{max} = hf - hf_0$

Question24

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 :
[13-Apr-2023 shift 2]

Options:

A. negative y-axis

B. at 45° angle from positive y-axis

C. positive y-axis

D. positive z-axis

Answer: A

Solution:

Solution:
Direction of propagation of EM wave will be in the direction of $(\vec{E} \times \vec{B})$

Question25

Match List I with List II of Electromagnetic waves with corresponding wavelength range :

List I	List II
(A) Microwave	(I) 400 nm to 1 nm
(B) Ultraviolet	(II) 1 nm to 10^{-3} nm
(C) X-Ray	(III) 1 mm to 700 nm
(D) Infra-rad	(IV) 0.1m to 1 mm

Choose the correct answer from the options given below :
[15-Apr-2023 shift 1]

Options:

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

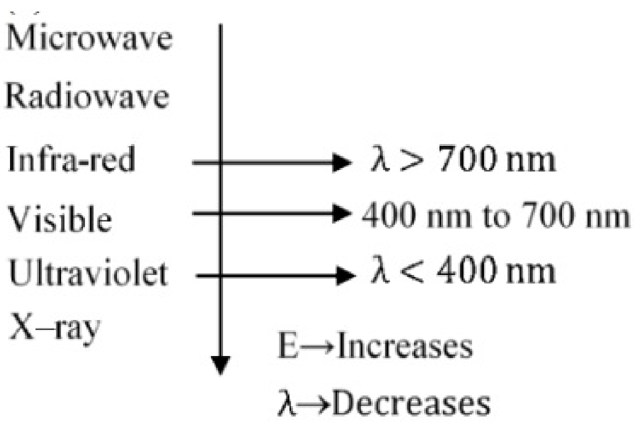
B. (A)-(IV), (B)-(I), (C)-(II), (D)-(III)

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

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

Answer: B

Solution:



Question26

A plane electromagnetic wave travels in a medium of relative permeability 1.61 and relative permittivity 6.44. If magnitude of magnetic intensity is $4.5 \times 10^{-2} Am^{-1}$ at a point, what will be the approximate magnitude of electric field intensity at that point?
(Given : Permeability of free space $\mu_0 = 4\pi \times 10^{-7} NA^{-2}$, speed of light in vacuum $c = 3 \times 10^{8} ms^{-}1$)

[24-Jun-2022-Shift-1]

Options:

A. $16.96 Vm^{-1}$

B. $2.25 \times 10^{-2} Vm^{-1}$

C. $8.48 Vm^{-1}$

D. $6.75 \times 10^{6} Vm^{-1}$

Answer: C

Solution:

$H = 4.5 \times 10^{-2}$
So $B = \mu_0 \mu H$

Thus $E = \frac{c}{n} B$ (where $n \Rightarrow$ refractive index)

So $E = \frac{3 \times 10^{8} \times 4\pi \times 10^{-7} \times 1.61 \times 4.5 \times 10^{-2}}{\sqrt{1.61 \times 6.44}}$

$E = 8.48$

Question27

The electric field in an electromagnetic wave is given by $E = 56.5 \sin \omega(t - x / c) NC^{-1}$. Find the intensity of the wave if it is propagating along x-axis in the free space.
(Given : $\varepsilon_0 = 8.85 \times 10^{-12} C^{2} N^{-1} m^{-2}$)
[25-Jun-2022-Shift-1]

Options:

A. $5.65 Wm^{-2}$

B. $4.24 Wm^{-2}$

C. $1.9 \times 10^{-7} Wm^{-2}$

D. $56.5 Wm^{-2}$

Answer: B

Solution:

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

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

$= 4.24 W / m^2$

Question28

The electromagnetic waves travel in a medium at a speed of $2.0 \times 10^8 m / s$. The relative permeability of the medium is 1.0. The relative permittivity of the medium will be :
[25-Jun-2022-Shift-2]

Options:

A. 2.25

B. 4.25

C. 6.25

D. 8.25

Answer: A

Solution:

$n = \frac{c}{v} = \frac{3}{2}$
$\sqrt{\in\mu} = n$
So $\in = \frac{9}{4} = 2.25$

Question29

If Electric field intensity of a uniform plane electromagnetic wave is given as $E = -301.6 \sin(kz - \omega t) \hat{a}_x + 452.4 \sin(kz - \omega t) \hat{a}_y \frac{V}{m}$. 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 .$\mu_0 = 4\pi \times 10^{-7} NA^{-2}$]
[26-Jun-2022-Shift-1]

Options:

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

B. $+1.0 \times 10^{-6} \sin(kz - \omega t) \hat{a}_y + 1.5 \times 10^{-6}(kz - \omega t) \hat{a}_x$

C. $-0.8 \sin(kz - \omega t) \hat{a}_y - 1.2 \sin(kz - \omega t) \hat{a}_x$

D. $-1.0 \times 10^{-6} \sin(kz - \omega t) \hat{a}_y - 1.5 \times 10^{-6} \sin(kz - \omega t) \hat{a}_x$

Answer: C

Solution:

$\vec{E} = -301.6\sin(kz-\omega t)\hat{a}_x + 452.4\sin(kz-\omega t)\hat{a}_y$
$E_{0x} = 301.6$
$E_{0y} = +452.4$
$E_0 = \sqrt{E_{0x}^2 + E_{0y}^2}$
Now, $\frac{E_0}{B_0} = C \Rightarrow B_0 = \frac{E_0}{C} = \frac{\sqrt{E_{0x}^2 + E_{0y}^2}}{C}$
Also, $\hat{B} = \hat{C} \times \hat{E} \Rightarrow \hat{k} \times \frac{\left(E_{0x}\hat{i} + E_{0y}\hat{j}\right)}{\sqrt{E_{0x}^2 + E_{0y}^2}}$
$\hat{B} = \frac{-E_{0x}\hat{j} - E_{0y}\hat{i}}{\sqrt{E_{0x}^2 + E_{0y}^2}}$
$\vec{B} = -\frac{E_{0x}}{C}\sin(kz-\omega t)\hat{a}_y - \frac{E_{0y}}{C}\sin(kz-\omega t)\hat{a}_x$
$\vec{H} = \frac{\vec{B}}{\mu_0}$
$\vec{H} = -\frac{E_{0x}}{\mu_0 C}\sin(kz-\omega t)\hat{a}_y - \frac{E_{0y}}{\mu_0 C}\sin(kz-\omega t)\hat{a}_x$

Question30

Which is the correct ascending order of wavelengths? [26-Jun-2022-Shift-2]

Options:

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

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

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

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

Answer: B

Solution:

Solution:
Wavelength of microwave is maximum then visible light then X-rays and then gamma rays so the correct order will be
$\lambda_{\text{gamma-ray}} < \lambda_{\text{Xray}} < \lambda_{\text{visible}} < \lambda_{\text{microwave}}$

Question31

	List - I		List - II
(a)	Ultraviolet rays	(i)	Study crystal structure
(b)	Microwaves	(ii)	Greenhouse effect
(c)	Infrared rays	(iii)	Sterilizing surgical instrument
(d)	X-rays	(iv)	Radar system

Choose the correct answer from the options given below:
[27-Jun-2022-Shift-1]

Options:

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

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

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

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

Answer: A

Solution:

UV rays are used to sterilize surgical material.
Microwaves are used in radar system.
Infrared are used for green house effect and
X-rays are used to study crystal structure.

Question32

Given below are two statements:
Statement I : A time varying electric field is a source of changing magnetic field and vice-versa. Thus a disturbance in electric or magnetic field creates EM waves.
Statement II : In a material medium, the EM wave travels with speed $v = \frac{1}{\sqrt{\mu_0 E_0}}$. In the light of the above statements, choose the correct answer from the options given below.
[27-Jun-2022-Shift-2]

Options:

A. Both Statement I and Statement II are true

B. Both Statement I and Statement II are false

C. Statement I is correct but Statement II is false

D. Statement I is incorrect but Statement II is true

Answer: C

Solution:

Solution:
In a material medium speed of light is given by $v = \frac{1}{\sqrt{\varepsilon_0 \varepsilon_r \mu_0 \mu_r}}$. So statement 2 is false.

Question33

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 fields if the EM wave is propagating in vacuum :
[28-Jun-2022-Shift-2]

Options:

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

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

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

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

Answer: B

Solution:

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

Question34

The intensity of the light from a bulb incident on a surface is $0.22 W/m^2$. The amplitude of the magnetic field in this light-wave is _____$\times 10^{-9} T$

(Given : Permittivity of vacuum $E_0 = 8.85 \times 10^{-12} c^2 N^{-1} - m^{-2}$, speed of light in vacuum $c = 3 \times 10^8 ms^{-1}$)
[29-Jun-2022-Shift-1]

Answer: 43

Solution:

$I = \frac{1}{2}\varepsilon_0 E_0{}^2 \cdot c = \frac{1}{2}\varepsilon_0 (cB_0)^2 c$

$\Rightarrow I = \frac{1}{2}\varepsilon_0 c^3 B_0{}^2$

$\Rightarrow 0.22 = \frac{1}{2}(8.85 \times 10^{-12})(3 \times 10^8)^3 B_0{}^2$

$\Rightarrow B_0 \simeq 43 \times 10^{-9} T$

Question35

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 $c = 3 \times 10^8 ms^{-1}$)
[25-Jul-2022-Shift-2]

Options:

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

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

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

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

Answer: A

Solution:

Solution:
$c = 3 \times 10^8 m / sec$
$B = \frac{E}{c} = \frac{540}{3 \times 10^8} = 18 \times 10^{-7} T$

Question36

The magnetic field of a plane electromagnetic wave is given by :
$\vec{B} = 2 \times 10^{-8} \sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t) \hat{j} T$

The amplitude of the electric field would be :
[26-Jul-2022-Shift-1]

Options:

A. $6Vm^{-1}$ along x-axis

B. $3Vm^{-1}$ along z-axis

C. $6Vm^{-1}$ along z-axis

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

Answer: C

Solution:

Speed of light $c = \frac{\omega}{k} = \frac{1.5 \times 10^{11}}{0.5 \times 10^{3}} = 3 \times 10^{8} m / sec$
So, $E_0 = B_0 c$
$= 2 \times 10^{-8} \times 3 \times 10^{8}$
$= 6V / m$
Direction will be along z-axis.

Question37

The oscillating magnetic field in a plane electromagnetic wave is given by $B_y = 5 \times 10^{-6} \sin 1000\pi(5x - 4 \times 10^{8}t)\,T$. The amplitude of electric field will be :
[26-Jul-2022-Shift-2]

Options:

A. $15 \times 10^{2}Vm^{-1}$

B. $5 \times 10^{-6}Vm^{-1}$

C. $16 \times 10^{12}Vm^{-1}$

D. $4 \times 10^{2}Vm^{-1}$

Answer: D

Solution:

Solution:
$B_0 = 5 \times 10^{-6}$
$v =$ Speed of wave $= \frac{4 \times 10^{8}}{5} = 8 \times 10^{7} \left[\therefore v = \frac{W}{k} \right]$
$E_0 = vBB_0 = 40 \times 10^{1}$
$= 4 \times 10^{2} V / m$

Question38

Identify the correct statements from the following descriptions of various properties of electromagnetic waves.
(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 :
[27-Jul-2022-Shift-2]

Options:

A. (D) only

B. (B) and (D) only

C. (B), (C) and (E) only

D. (A), (B) and (E) only

Answer: B

Solution:

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. $|\vec{V}| = |\vec{E}| / |\vec{B}|$

Question39

Match List - I with List - II :

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 :

[29-Jul-2022-Shift-1]

Options:

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)

Answer: B

Solution:

(a) uv rays - used for water purification
(b) x-rays used for diagnosing fracture
(c) Microwaves are used for mobile and radar communication
(d) Infrared waves show less scattering therefore used in foggy days
(a − ii), (b − i), (c − iii), (d − iv)

Question40

A radiation is emitted by 1000W bulb and it generates an electric field and magnetic field at P, placed at a distance of 2m. The efficiency of the bulb is 1.25%. The value of peak electric field at P is $x \times 10^{-1}$ V / m. Value of x is .... (Rounded-off to the nearest integer) [Take, $\varepsilon_0 = 8.85 \times 10^{-12} C^2 N^{-1} m^{-2}$, $c = 3 \times 10^8 ms^{-1}$]
[26 Feb 2021 Shift 1]

Answer: 137

Solution:

Given, power of bulb, $P = 1000W$
Distance $d = 2m$
Efficiency of bulb $= 1.25\%$,
$\varepsilon_0 = 8.854 \times 10^{-12} C^2 N^{-1} m^{-1}$,
$c = 3 \times 10^8 ms^{-1}$
$\therefore$ Intensity, $(I) = \dfrac{\text{Power}(P)}{\text{Area}(A)} = \dfrac{1}{2}\varepsilon_0 E^2 c$
$\Rightarrow \dfrac{1.25}{100} \times \dfrac{1000}{4\pi(2)^2} = \dfrac{1}{2} \times 8.854 \times 10^{-12}$
$\Rightarrow E = \sqrt{\dfrac{12.5}{16\pi} \times \dfrac{2}{8.854 \times 10^{-4} \times 3} \times 10^8}$
$= 13.7 N C^{-1} = 137 \times 10^{-1} N C^{-1}$ or $V m^{-1}$
$\therefore x = 137$

Question41

The peak electric field produced by the radiation coming from the 8W bulb at a distance of 10m is $\frac{x}{10}\sqrt{\frac{\mu_0 c}{\pi}}\frac{V}{m}$. The efficiency of the bulb is 10% and it is a point source. The value of x is ....
[25 Feb 2021 Shift 2]

Answer: 2

Solution:

Given, radiation power (P) = 8W
Distance (d) = 10m
$\because$ Intensity (I) = $\frac{1}{2} \subset \varepsilon_0 E^2 = \frac{\text{Power (P)}}{\text{Area (A)}}$ . . . (i)
where, $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ = speed of light in vacuum ... (ii)
and E = electric field
From Eq. (ii), we get
$\varepsilon_0 = \frac{1}{\mu_0 c^2}$
Put this value of ε_0 in Eq. (i), we get
$I = \frac{1}{2}C\frac{1}{\mu_0 C^2}E^2 = \frac{P}{A} \Rightarrow \frac{1}{2}\frac{1}{\mu_0 C}E^2 = \frac{P}{A}$
$\Rightarrow E = \sqrt{\frac{2P\mu_0 C}{A}} = \sqrt{\frac{2P\mu_0 C}{4\pi d^2}} = \sqrt{\frac{2P}{4d^2}}\sqrt{\frac{\mu_0 C}{\pi}}$
$= \sqrt{\frac{2\times 8}{4\times 100}} = \sqrt{\frac{\mu_0 C}{\pi}} = \frac{2}{10}\sqrt{\frac{\mu_0 C}{\pi}}V/m$
$\therefore x = 2$

Question42

An electromagnetic wave of frequency 3GHz enters a dielectric medium of relative electric permittivity 2.25 from vacuum. The wavelength of this wave in that medium will be .... $\times 10^{-2}$cm.
[24 Feb 2021 Shift 2]

Answer: 667

Solution:

Given, frequency of wave, $f = 3GHz = 3\times 10^9 Hz$
Relative permittivity, $\varepsilon_r = 2.25$

Since, $f = C / \lambda$

$\Rightarrow \lambda = \frac{C}{f} = \frac{3 \times 10^8}{3 \times 10^9} = 0.1m$

$\because \lambda_m$ (wavelength of wave in a medium) $= \lambda / \mu$ and as we know that, $\mu = \sqrt{\mu_r \varepsilon_r}$

As, dielectric is non-magnetic, $\mu_r = 1$

$\Rightarrow \mu = \sqrt{2.25} = 1.5$

$\Rightarrow \lambda_m = \frac{0.1}{1.5} = \frac{1}{15} = 0.0667m$

$= 6.67cm = 667 \times 10^{-2}cm$

Question43

List-I	List-II
A. Source of microwave frequency	1. Radioactive decay of nucleus
B. Source of infrared frequency	2. Magnetron
B. Source gamma rays	3. Inner shell electrons
C. Source of X-rays	Vibration of atoms and molecules
	5.LASER
	6. R-C circuit

choose the correct answer from the options given below [24 Feb 2021 Shift 2]

Options:

A. (A-6), (B-4), (C-1), (D-5)

B. (A-6), (B-5), (C-1), (D-4)

C. (A-2), (B-4), (C-6), (D-3)

D. (A-2), (B-4), (C-1), (D-3)

Answer: D

Solution:

Solution:
As we know that;
A. Source of microwave frequency is magnetron.
B. Source of infrared frequency is vibration of atoms and molecules.
C. Source of gamma ray is radioactive decay of nucleus.
D. Source of X-ray is transition of electron in inner shells.
$\therefore$ The correct match is $A \rightarrow (2)$, $B \rightarrow (4)$, $C \rightarrow (1)$, $D \rightarrow (3)$.

Question44

An electromagnetic wave of frequency 5GHz, is travelling in a medium whose relative electric permittivity and relative magnetic permeability both are 2 . Its velocity in this medium is $\times 10^7 m / s$.

[24feb2021shift1]

Answer: 15

Solution:

Solution:
Given : Frequency of wave $v = 5GHz = 5 \times 10^{9}Hz$

Relative permittivity of the medium, $\varepsilon_r = 2$ and relative permeability of the medium, $\mu_r = 2$
Since speed of light in a medium is given by,
$$v = \frac{1}{\sqrt{\mu\varepsilon}} = \frac{1}{\sqrt{\mu_r\mu_0\varepsilon_r\varepsilon_0}} = \frac{c}{\sqrt{\mu_r\varepsilon_r}}$$
where c is speed of light is vacuum.
$$\therefore v = \frac{3 \times 10^{8}}{\sqrt{4}} = \frac{30 \times 10^{7}}{2} m/s = 15 \times 10^{7} m/s$$

Question45

A plane electromagnetic wave propagating along y-direction can have the following pair of electric field (E) and magnetic field (B) components.
[18 Mar 2021 Shift 2]

Options:

A. E_y, B_y or E_z, B_z

B. E_y, B_x or E_x, B_y

C. E_x, B_z or E_z, B_x

D. E_x, B_y or E_y, B_x

Answer: C

Solution:

Solution:
Electric field, magnetic field and the direction of wave propagation are mutually perpendicular to each other. For electromagnetic waves,
$E \times B = C$
The direction of wave propagation is in along +y-direction.
Therefore, the possible direction of electric field and magnetic field are (E_x, B_z) and (E_x, B_x).

Question46

A plane electromagnetic wave of frequency $100MHz$ is travelling in vacuum along the x-direction. At a particular point in space and time,

$B = 2.0 \times 10^{-8} \hat{k} T$ (where, $\hat{k}$ is unit vector along z-direction). What is E at this point?
[18 Mar 2021 Shift 1]

Options:

A. $0.6\hat{j} V/m$

B. $6.0\hat{k} V/m$

C. $6.0\hat{j} V/m$

D. $0.6\hat{k} V/m$

Answer: C

Solution:

Solution:
Given, $f = 100MHz$
$B = (2.0 \times 10^{-8})\hat{k} T$
The speed of the light in free space,
$c = (3 \times 10^{s})\hat{i} m/s$
(the direction of wave propagates in x-direction)
Magnitude of electric field, $E = Bc = 2 \times 10^{-8} \times 3 \times 10^{8}$
$\Rightarrow E = 6V/m$
If $\hat{n}$ be the direction of E, then $\hat{i} = \hat{n} \times \hat{k}$
$\Rightarrow \hat{n} = \hat{j}$
Hence, the electric field at this point is $6\hat{j} V/m$.

Question47

The electric field intensity produced by the radiation coming from a 100W bulb at a distance of 3m is E. The electric field intensity produced by the radiation coming from 60W at the same distance is $\sqrt{\frac{x}{5}}E$, where the value of x is ....

[17 Mar 2021 Shift 2]

Answer: 3

Solution:

Intensity of the electromagnetic radiation is given as
$$I = \frac{\text{Energy}}{\text{Area} \times \text{Time}} = \frac{\text{Power}}{\text{Area}} = U_{avg} C = \frac{1}{2} C \varepsilon_0 E_0^{\,2}$$
Here,

U_{avg} = average energy density,
C = speed of radiation in air (or vacuum),
ε_0 = permittivity of the free space
and E_0 = peak value of the electric field.

$\Rightarrow P \propto E_0^2 \Rightarrow \frac{P_1}{P_2} = \frac{E_1^2}{E_2^2}$

$\Rightarrow \frac{E_1}{E_2} = \sqrt{\frac{P_1}{P_2}}$

Substituting the values in the above equation, we get

$\Rightarrow \frac{E_1}{E_2} = \sqrt{\frac{60}{100}}$

$\Rightarrow E_1 = \sqrt{\frac{3}{5}} E_2 = \sqrt{\frac{3}{5}} = E \quad (\because E_2 = E)$

Comparing with $\sqrt{\frac{x}{5}} E$, we get

$x = 3$

Question48

Seawater at a frequency $f = 9 \times 10^2 Hz$, has permittivity $\varepsilon = 80\varepsilon_0$ and resistivity $r = 0.25 \Omega - m$. Imagine a parallel plate capacitor is immersed in seawater and is driven by an alternating voltage source $V(t) = V_0 \sin(2\pi f t)$. Then, the conduction current density becomes 10^x times the displacement current density after time $t = \frac{1}{800}$s. The value of x is ....

$\left(\textbf{Take }, \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 N - m^2 C^{-2} \right)$

[17 Mar 2021 Shift 2]

Answer: 6

Solution:

As we know, conduction current,

$I_c = \frac{[v_0 \sin(2\pi f t)]}{\rho \frac{d}{A}}$

$\Rightarrow I_c = \frac{A[v_0 \sin(2\pi f t)]}{\rho d}$..(i)

As we know the displacement current equation,

$I_d = \frac{\varepsilon_0 \varepsilon_t A}{d} \frac{d}{dt}[v_0 \sin(2\pi f t)]$

$I_d = \frac{\varepsilon_0 \varepsilon_t A}{d} v_0 (2\pi f)[\cos(2\pi f t)]$...(ii)

Divide Eq. (ii) by Eq. (i), we get

$\frac{I_d}{I_c} = \varepsilon_0 \varepsilon_r \times \rho 2\pi f \cot(2\pi f t)$

Substituting the values in the above equation, we get

$\frac{I_d}{I_c} = \frac{1}{4\pi \times 9 \times 10^9} \times (80) \times 2\pi \times 900(0.25) \cot\left(2\pi(900) \frac{1}{800}\right)$

$\frac{I_d}{I_c} = \frac{1}{10^6}$
Comparing with 10^x, we get $x = 6$.

Question49

A plane electromagnetic wave of frequency $500 MHz$ is travelling in vacuum along y-direction. At a particular point in space and time, $B = 8.0 \times 10^{-8} \hat{z} T$. The value of electric field at this point is (speed of light $= 3 \times 10^8 ms^{-1}$; $\hat{x}$, $\hat{y}$, $\hat{z}$ are unit vectors along x, y and z-direction). [16 Mar 2021 Shift 1]

Options:

A. $-24\hat{x} V/m$

B. $2.6\hat{x} V/m$

C. $24\hat{x} V/m$

D. $-2.6\hat{x} V/m$

Answer: A

Solution:

Solution:
Given, frequency, $f = 500 MHz = 5 \times 10^8 Hz$
$B = 8.0 \times 10^{-8} \hat{Z} T$
∴ Magnitude of peak value of magnetic field is given by
$B_0 = 8 \times 10^{-8} T$
We know that, $\frac{E_0}{B_0} = C$
where, E_0 is the magnitude of peak value of electric field and c is the speed of electromagnetic wave in air (or vacuum).
$\Rightarrow E_0 = cB_0$
$= 3 \times 10^8 \times 8 \times 10^{-8} = 24 V/m$
Since, the direction of propagation of electromagnetic wave is perpendicular to the direction of E and B both.
∴ Direction of propagation is given by $\hat{E} \times \hat{B}$.
As, the wave is travelling in y-direction,
and the magnetic field is in z-direction.
$\Rightarrow \hat{E} \times \hat{z} = \hat{y}$
$\hat{E} = -\hat{x}$
∴ The value of electric field will be $-24\hat{x} V / m$.

Question50

For an electromagnetic wave travelling in free space, the relation between average energy densities due to electric (U_e) and magnetic (U_m) fields is [16 Mar 2021 Shift 1]

Options:

A. $U_e = U_m$

B. $U_e > U_m$

C. $U_e < U_m$

D. $U_e \neq U_m$

Answer: A

Solution:

We know that,

$U_e = \frac{1}{2}\varepsilon_0 E^2$....(1)

where, $U_e =$ average energy density due to electric field,

$\varepsilon_0 =$ electrical permittivity of free space

and $E =$ electric field.

and $U_m = \frac{B^2}{2\mu_0}$.....(2)

where, $U_m =$ average energy density due to magnetic field, $\mu_0 =$ magnetic permeability of free space

and $B =$ magnetic field.

Also, $E = CB \quad \left(\because C = \frac{1}{\sqrt{\mu_0\varepsilon_0}}\right)$

$\Rightarrow E = \frac{B}{\sqrt{\mu_0\varepsilon_0}}$

Put this value in Eq. (1), we get

$U_e = \frac{1}{2}\varepsilon_0 \times \frac{1}{\mu_0\varepsilon_0}B^2$

$\Rightarrow U_e = \frac{B^2}{2\mu_0}$

$\Rightarrow U_e = U_m$ [using Eq. (2)]

Question51

The relative permittivity of distilled water is 81 . The velocity of light in it will be :
(Given $\mu_r = 1$)
[27 Jul 2021 Shift 1]

Options:

A. $4.33 \times 10^7 m / s$

B. $2.33 \times 10^7 m / s$

C. $3.33 \times 10^7 m / s$

D. $5.33 \times 10^7 m / s$

Answer: C

Solution:

$$V = \frac{c}{\sqrt{\mu_r \varepsilon_r}}$$
$$= 3.33 \times 10^7 m / s$$

Question52

Intensity of sunlight is observed as $0.092 W\, m^{-2}$ at a point in free space. What will be the peak value of magnetic field at that point? $(\varepsilon_0 = 8.85 \times 10^{-12} C^2 N^{-1} m^{-2})$
[22 Jul 2021 Shift 2]

Options:

A. $2.77 \times 10^{-8} T$

B. $1.96 \times 10^{-8} T$

C. $8.31 T$

D. $5.88 T$

Answer: A

Solution:

$$I_{avg} = \frac{B_0^{\ 2} C}{2\mu_0} \ \& \ \frac{1}{\mu_0} = \in_0 C^2$$
$$I = \frac{B_0^{\ 2}}{2} \in_0 C^3$$
$$B_0 = \sqrt{\frac{2I}{\in_0 C^3}}$$
$$B_0 = 2.77 \times 10^{-8} T$$

Question53

In an electromagnetic wave the electric field vector and magnetic field vector are given as $\vec{E} = E_0 \hat{i}$ and $\vec{B} = B_0 \hat{k}$ respectively. The direction of propagation of electromagnetic wave is along:
[20 Jul 2021 Shift 2]

Options:

A. $(\hat{k})$

B. $\hat{j}$

C. $(-\hat{k})$

D. $\left(-\hat{j}\right)$

Answer: D

Solution:

Solution:

Direction of propagation $=\vec{E}\times\vec{B}=\hat{i}\times\hat{k}=-\hat{j}$

Question54

A light beam is described by $E = 800\sin\left(\omega t-\frac{x}{c}\right)$. An electron is allowed to move normal to the propagation of light beam with a speed $3\times10^{7}ms^{-1}$. What is the maximum magnetic force exerted on the electron? [26 Aug 2021 Shift 2]

Options:

A. $1.28\times10^{-17}N$

B. $1.28\times10^{-18}N$

C. $12.8\times10^{-17}N$

D. $12.8\times10^{-18}N$

Answer: 0

Solution:

Equation for light beam is given as

$E=800\sin\left(\omega t-\frac{x}{C}\right)$

Here, c is speed of light.

Comparing with standard equation, we get

$E_0=800Vm^{-1}$

As we know, the magnitude of magnetic field is given as

$E_0=B_0C$

$\Rightarrow 800=B_0\times3\times10^{8}$

$\Rightarrow B_0=\frac{800}{3\times10^{8}}T$

Maximum magnetic force exerted on electron will be

$F_{max}=evB_0$

$=(1.6\times10^{-19})\times(3\times10^{7})\times\frac{800}{3\times10^{8}}$ (Given, $v=3\times10^{7}ms^{-1}$)

$F_{max}=12.8\times10^{-18}$ N or 1.28×10^{-17}

Question55

The magnetic field vector of an electromagnetic wave is given by $B = B_0 \frac{\hat{i} + \hat{j}}{\sqrt{2}} \cos(kz - \omega t)$ T where $\hat{i}$, $\hat{j}$ represents unit vector along X and Y-axis respectively. At t = 0, two electric charges q_1 of 4πC and q_2 of 2π C located at $\left(0, 0, \frac{\pi}{k}\right)$ and $\left(0, 0, \frac{3\pi}{k}\right)$ respectively, have the same velocity of $0.5c\hat{i}$.
(where, c is the velocity of light). The ratio of the force acting on charge q_1 to q_2 is
[31 Aug 2021 Shift 2]

Options:

A. $2\sqrt{2} : 1$

B. $1 : \sqrt{2}$

C. $2 : 1$

D. $\sqrt{2} : 1$

Answer: C

Solution:

The equation of magnetic field vector of an electromagnetic field is
$B = \frac{B_0}{\sqrt{2}}(\hat{i} + \hat{j}) \cos(kz - \omega t)$ T
Electric charges
q_1 at $P\left(0, 0, \frac{\pi}{k}\right) = 4\pi C$
q_2 at $Q\left(0, 0, \frac{3\pi}{k}\right) = 2\pi C$
At t = 0 and $P\left(0, 0, \frac{\pi}{k}\right)$, where $z = \frac{\pi}{k}$
Magnetic field vector,
$B = \frac{B_0}{\sqrt{2}}(\hat{i} + \hat{j}) \cos\left(k\frac{\pi}{k} - 0\right)$ T
$= \frac{B_0}{\sqrt{2}}(\hat{i} + \hat{j}) \cos \pi\, T = -\frac{B_0}{\sqrt{2}}(\hat{i} + \hat{j})$T
and at t = 0 and $Q\left(0, 0, \frac{3\pi}{k}\right)$, where $z = \frac{3\pi}{k}$. Magnetic field vector,
$B = \frac{B_0}{\sqrt{2}}(\hat{i} + \hat{j}) \cos\left(k\frac{3\pi}{k} - 0\right)$
$= -\frac{B_0}{\sqrt{2}}(\hat{i} + \hat{j})$T [∵ Using cos π = cos 3π = − 1]
Velocity of charges q_1 and q_2, $v = 0.5c\hat{i}$
We know that, force on charge in magnetic field is given by $F = q(v \times B)$
∴ For q_1, $F_1 = 4\pi\left[0.5c\hat{i} \times \left\{-\frac{B_0}{\sqrt{2}}(\hat{i} + \hat{j})\right\}\right]$N
$F_1 = -\frac{2\pi c B_0}{\sqrt{2}}\hat{k}$N
Similarly, for q_2
$\Rightarrow F_2 = 2\pi\left[0.5c\hat{i} \times \left\{-\frac{B_0}{\sqrt{2}}(\hat{i} + \hat{j})\right\}\right]$N
$\Rightarrow F_2 = -\frac{\pi c B_0}{\sqrt{2}}\hat{k}$N
Hence, ratio of magnitudes of F_1 to F_2

$$\frac{F_1}{F_2} = \frac{\frac{2\pi c B_0}{\sqrt{2}}}{\frac{\pi c B_0}{\sqrt{2}}} = \frac{2}{1}$$

$\Rightarrow F_1 : F_2 = 2 : 1$

Question56

The electric field in an electromagnetic wave is given by $E = (50NC^{-1}) \sin \omega \left(t - \frac{x}{c} \right)$.The energy contained in a cylinder of volume V is 5.5×10^{-12}J. The value of V is .... cm^3.
(Given $\varepsilon_0 = 8.85 \times 10^{-12} C^2 N^{-1} m^{-2}$).
[31 Aug 2021 Shift 1]

Answer: 500

Solution:

Given, electric field in electromagnetic wave,
$E = 50 \sin \omega \left(t - \frac{x}{c} \right)$
Energy contained in cylinder,
$U = 5.5 \times 10^{-12} J$
Let, volume = V
and permittivity in free space,
$\varepsilon_0 = 8.85 \times 10^{-12} N^{-1} C^2 m^{-2}$
As we know that,
$\frac{\text{Energy}(U)}{\text{Volume}(V)} = \frac{1}{2} \varepsilon_0 {E_0}^2$
$\therefore V = \frac{2U}{\varepsilon_0 {E_0}^2} = \frac{2 \times 5.5 \times 10^{-12}}{8.854 \times 10^{-12} \times (50)^2}$
$= \frac{11}{8.854 \times 50^2} = 4.97 \times 10^{-4}$
$= 497 \times 10^{-6} = 500 cm^3$

Question57

A plane electromagnetic wave with frequency of 30 MHz travels in free space. At particular point in space and time, electric field is 6V / m. The magnetic field at this point will be $x \times 10^{-8}$T. The value of x is.
[27 Aug 2021 Shift 2]

Answer: 2

Solution:

Given, frequency of electromagnetic wave (f)
$= 30 MHz$
$= 30 \times 10^{6} Hz$
Electric field, $E = 6V / m$
Magnetic field, $B = x \times 10^{-8} T$
Speed of light in air, $c = 3 \times 10^{8} ms^{-1}$
We know that, $B = \frac{E}{C}$
$\Rightarrow B = \frac{6}{3 \times 10^{8}}$
$\Rightarrow B = 2 \times 10^{-8} T$
$\therefore x = 2$

Question58

Electric field in a plane electromagnetic wave is given by $E = 50 \sin(500x - 10 \times 10^{10} t) V / m$. The velocity of electromagnetic wave in this medium is (Given, c = speed of light in vacuum) [27 Aug 2021 Shift 1]

Options:

A. $\frac{3}{2}c$

B. c

C. $\frac{2}{3}c$

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

Answer: C

Solution:

Solution:
Given, equation of electromagnetic wave,
$E = 50 \sin(500x - 10 \times 10^{10} t) V / m$
The standard equation of electromagnetic wave,
$E = E_0 \sin(kx - \omega t) V / m$
Comparing with standard equation, we get
$E_0 = 50 V / m$, $\omega = 10^{10} rad\, s^{-1}$, $k = 500 rad\, m^{-1}$
Speed of wave in medium will be
$v = \frac{\omega}{k}$
$= \frac{10 \times 10^{10}}{500}$
$= 2 \times 10^{8} ms^{-1}$
$= \frac{2}{3} \times 3 \times 10^{8} m / s$
$= \frac{2}{3} c$ [$\because c = 3 \times 10^{8} m / s$ = speed of light]

Question59

The electric field in a plane electromagnetic wave is given by
E = 200cos
$$\left[\left(\frac{0.5\times10^{3}}{m}\right)x-\left(1.5\times10^{11}\frac{rad}{s}\times t\right)\right]\frac{v}{m}\hat{j}$$
If this wave falls normally on a perfectly reflecting surface having an area of $100cm^2$. If the radiation pressure exerted by the EM wave on the surface during a 10 min exposure is $\frac{x}{10^9}$. Find the value of x.

[26 Aug 2021 Shift 1]

Answer: 354

Solution:

The electric field in a plane electromagnetic wave is given by

$E = 200\cos\left[\frac{(0.5\times10^{3})x}{m}-\left(1.5\times10^{11}\frac{rad}{s}\times t\right)\right]\frac{V}{m}\hat{j}$

$\therefore E_0 = 200V / m$

Intensity provided by electric field is given by

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

The radiation pressure exerted by electromagnetic wave on surfaceis given by

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

$P = \varepsilon_0 {E_0}^2$

$= 8.85\times10^{-12}\times(200)^2$

$= \frac{354}{10^9}$

According to question,

$\frac{x}{10^9} = \frac{354}{10^9}$

$\therefore x = 354$

Question60

Electric field of plane electromagnetic wave propagating through a non-magnetic medium is given by $E = 20\cos(2\times10^{10}t - 200x)\,V / m$. The dielectric constant of the medium is equal to (Take, $\mu_r = 1$)

[1 Sep 2021 Shift 2]

Options:

A. 9

B. 2

C. $\frac{1}{3}$

D. 3

Answer: A

Solution:

Solution:
Given, electric field,
$E = 20\cos(2\times10^{10}t - 200x)\,V/m$
Comparing with the standard equation,
$E = E_0\cos(\omega t - kx)\,V/m$, we get
Wave constant, k = 200
Angular frequency, $\omega = 2\times10^{10}\,rad/s$
Speed of the wave, $v = \frac{\omega}{k} = \frac{2\times10^{10}}{200} = 10^8 m/s$
Refractive index, $\mu = \frac{C}{V} = \frac{3\times10^8}{10^8} = 3$
As we know the relation between the refractive index and dielectricconstant,
$\mu = \sqrt{\varepsilon_r\mu_r}$
Substituting the value in the above equations, we get
$3 = \sqrt{\varepsilon_r(1)}$
$\varepsilon_r = 9$
Thus, the dielectric constant of the medium is 9.

Question61

The electric fields of two plane electromagnetic plane waves in vacuum are given by
$\vec{E}_1 = E_0\hat{j}\cos(\omega t - kx)$ and $\vec{E}_2 = E_0\hat{k}\cos(\omega t - ky)$.
At t = 0, a particle of charge q is at origin with a velocity $\vec{v} = 0.8c\hat{j}$ (c is the speed of light in vacuum). The instantaneous force experienced by the particle is:
[9 Jan 2020, I]

Options:

A. $E_0q(0.8\hat{i} - \hat{j} + 0.4\hat{k})$

B. $E_0q(0.4\hat{i} - 3\hat{j} + 0.8\hat{k})$

C. $E_0q(-0.8\hat{i} + \hat{j} + \hat{k})$

D. $E_0q(0.8\hat{i} + \hat{j} + 0.2\hat{k})$

Answer: D

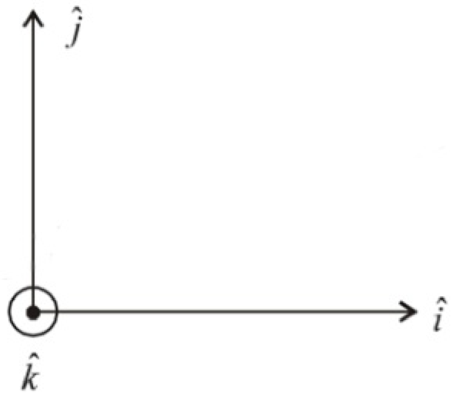
Solution:

Given: $\vec{E}_1 = E_0 \hat{j} \cos(\omega t - kx)$

i.e., Travelling in + ve x -direction $\vec{E} \times \vec{B}$ should be in x direction

$\therefore \vec{B}$ is in $\hat{K}$

$\therefore \vec{B}_1 = \frac{E_0}{C} \cos(\omega t - kx)\,\hat{k}\ \left(\because B_0 = \frac{E_0}{C}\right)$



$\vec{E}_2 = E_0 \hat{k} \cos(\omega t - ky)$

$\vec{B}_2 = \frac{E_0}{C} \hat{i} \cos(\omega t - ky)$

$\therefore$ Travelling in + ve y -axis

$\vec{E} \times \vec{B}$ should be in y -axis

$\therefore$ Net force $\vec{F} = q\vec{E} + q(\vec{v} \times \vec{B})$

$q(\vec{E}_1 + \vec{E}_2) + q(0.8c\hat{j} \times (\vec{B}_1 + \vec{B}_2))$

If $t = 0$ and $x = y = 0$

$\vec{E}_1 = E_0 \hat{j},\ \ \vec{E}_2 = E_0 \hat{k}$

$\vec{B}_1 = \frac{E_0}{c}\hat{k},\ \ \vec{B}_2 = \frac{E_0}{c}\hat{i}$

$\therefore \vec{F}_{net} = qE_0(\hat{j} + \hat{k}) + q \times 0.8c \times \frac{E_0}{C}\hat{j} \times (\hat{k} + \hat{i})$

$= qE_0(\hat{j} + \hat{k}) + 0.8qE_0(\hat{i} - \hat{k})$

$= qE_0(0.8\hat{i} + \hat{j} + 0.2\hat{k})$

Question62

A plane electromagnetic wave is propagating along the direction $\frac{\hat{i} + \hat{j}}{\sqrt{2}}$, with its polarization along the direction $\hat{k}$. The correct form of the magnetic field of the wave would be (here B_0 is an appropriate constant):
[9 Jan 2020, II]

Options:

A. $B_0 \frac{\hat{i} - \hat{j}}{\sqrt{2}} \cos\left(\omega t - k\frac{\hat{i} + \hat{j}}{\sqrt{2}}\right)$

B. $B_0 \frac{\hat{j} - \hat{i}}{\sqrt{2}} \cos\left(\omega t + k\frac{\hat{i} + \hat{j}}{\sqrt{2}}\right)$

C. $B_0 \hat{k} \cos\left(\omega t - k\frac{\hat{i} + \hat{j}}{\sqrt{2}}\right)$

D. $B_0 \frac{\hat{i}+\hat{j}}{\sqrt{2}} \cos\left(\omega t - k\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)$

Answer: A

Solution:

Solution:

Direction of polarisation $= \hat{E} = \hat{k}$

Direction of propagation $= \hat{E} \times \hat{B} = \frac{\hat{i}+\hat{j}}{\sqrt{2}}$

But $\vec{E} \cdot \vec{B} = 0 \therefore \hat{B} = \frac{\hat{i}-j}{\sqrt{2}}$

Question63

A plane electromagnetic wave of frequency 25GH z is propagating in vacuum along the z -direction. At a particular point in space and time, the magnetic field is given by $\vec{B} = 5 \times 10^{-8}\hat{j}T$. The corresponding electric field $\hat{E}$ is (speed of light $c = 3 \times 10^8 ms^{-1}$) [8 Jan 2020, II]

Options:

A. $1.66 \times 10^{-16}\hat{i}V / m$

B. $-1.66 \times 10^{-16}\hat{i}V / m$

C. $-15\hat{i}V / m$

D. $15\hat{i}V / m$

Answer: D

Solution:

Solution:
Amplitude of electric field (E) and Magnetic field (B) of an electromagnetic wave are related by the relation
$\frac{E}{B} = c$
$\Rightarrow E = Bc$
$\Rightarrow E = 5 \times 10^{-8} \times 3 \times 10^8 = 15N / C$
$\Rightarrow \vec{E} = 15\hat{i}V / m$

Question64

If the magnetic field in a plane electromagnetic wave is given by $\vec{B} = 3 \times 10^{-8} \sin(1.6 \times 10^3 x + 48 \times 10^{10} t)\hat{j}T$, then what will be expression for electric field?

[7 Jan 2020, I]

Options:

A. $\vec{E} = \left(60 \sin(1.6 \times 10^3 x + 48 \times 10^{10} t)\, \hat{k}\, v / m\right)$

B. $\vec{E} = \left(9 \sin(1.6 \times 10^3 x + 48 \times 10^{10} t)\, \hat{k}\, v / m\right)$

C. $\vec{E} = \left(3 \times 10^{-8} \sin(1.6 \times 10^3 x + 48 \times 10^{10} t)\, \hat{k}\, v / m\right)$

D. $\vec{E} = \left(-3 \times 10^{-8} \sin(1.6 \times 10^3 x + 48 \times 10^{10} t)\, \hat{k}\, v / m\right)$

Answer: B

Solution:

Solution:

Given , $\vec{B} = 3 \times 10^{-8} \sin(1.6 \times 10^3 x + 48 \times 10^{10} t)\, \hat{j}\, t$

Using, $E_0 = B_0 \times C = 3 \times 10^{-8} \times 3 \times 10^8 = 9V / m$

$\therefore$ Electric field $\vec{E} = 9 \sin(1.6 \times 10^3 x + 48 \times 10^{10} t)\, \vec{k}\, V / m$

Question65

The electric field of a plane electromagnetic wave is given by

$\vec{E} = E_0 \frac{\hat{i} + \hat{j}}{\sqrt{2}} \cos(kz + \omega t)$

At t = 0, a positively charged particle is at the point (x, y, z) = $\left(0, 0, \frac{\pi}{k}\right)$.

If its instantaneous velocity at (t = 0) is $v_0 \hat{k}$, the force acting on it due to the wave is:

[7 Jan 2020, II]

Options:

A. parallel to $\frac{\hat{i} + \hat{j}}{\sqrt{2}}$

B. zero

C. antiparallel to $\frac{\hat{i} + \hat{j}}{\sqrt{2}}$

D. parallel to $\hat{k}$

Answer: C

Solution:

Solution:

At $t = 0$, $z = \frac{\pi}{k}$

$\therefore \vec{E} = \frac{E_0}{\sqrt{2}}(\hat{i} + \hat{j})\cos[\pi] = -\frac{E_0}{\sqrt{2}}(\hat{i} + \hat{j})$

$\hat{F}_E = q\hat{E}$

Force due to electric field will be in the direction $\frac{-(\hat{i} + \hat{j})}{\sqrt{2}}$

Force due to magnetic field is in direction

$q(\vec{v} \times \vec{B})$ and $\vec{v} \parallel \vec{k}$. Therefore, it is parallel to $\vec{E}$.

$\Rightarrow \vec{F}_{net} = \vec{F}_E + \vec{F}_B$ is antiparallel to $\frac{\hat{i} + \hat{j}}{\sqrt{2}}$

Question66

For a plane electromagnetic wave, the magnetic field at a point x and time t is

$\vec{B}(x, t) = [1.2 \times 10^{-7} \sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t)\hat{k}]$ T

The instantaneous electric field $\vec{E}$ corresponding to B is: (speed of light $c = 3 \times 10^8 ms^{-1}$)

[Sep. 06, 2020 (II)]

Options:

A. $\vec{E}(x, t) = [-36 \sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t)\hat{j}]\frac{V}{m}$

B. $\vec{E}(x, t) = [36 \sin(1 \times 10^3 x + 0.5 \times 10^{11} t)\hat{j}]\frac{V}{m}$

C. $\vec{E}(x, t) = [36 \sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t)\hat{k}]\frac{V}{m}$

D. $\vec{E}(x, t) = [36 \sin(1 \times 10^3 x + 0.5 \times 10^{11} t)\hat{i}]\frac{V}{m}$

Answer: A

Solution:

Solution:

Relation between electric field E_0 and magnetic field B_0 of an electromagnetic wave is given by

$c = \frac{E_0}{B_0}$ (Here ,c = Speed of light)

$\Rightarrow E_0 = B_0 \times c = 1.2 \times 10^{-7} \times 3 \times 10^8 = 36$

As the wave is propagating along x -direction, magnetic field is along z -direction

and $(\hat{E} \times \hat{B}) \parallel \hat{C}$

$\therefore E$ should be along y -direction.

So, electric field $\vec{E} = E_0 \sin \vec{E} . (x, t)$

$= [-36 \sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t)\hat{j}]\frac{V}{m}$

Question67

An electron is constrained to move along the y -axis with a speed of 0.1c(c is the speed of light) in the presence of electromagnetic wave, whose electric field is $\vec{E} = 30\hat{j}\ \sin(1.5 \times 10^7 t - 5 \times 10^{-2} x)\ V/m$. The maximum magnetic force experienced by the electron will be : (given $c = 3 \times 10^8 ms^{-1}$ & electron charge $= 1.6 \times 10^{-19} C$)
[Sep. 05,2020 (I)]

Options:

A. $3.2 \times 10^{-18} N$

B. $2.4 \times 10^{-18} N$

C. $4.8 \times 10^{-19} N$

D. $1.6 \times 10^{-19} N$

Answer: C

Solution:

Solution:

In electromagnetic wave, $\frac{E_0}{B_0} = C$

∴ Maximum value of magnetic field, $B_0 = \frac{E_0}{C}$

$F_{max} = qV B_{max} \sin 90° = \frac{qV_0 E_0}{C}$

(Given $V_0 = 0.1C$ and $E_0 = 30$)

$= \frac{1.6 \times 10^{-19} \times 0.1 \times 3 \times 10^8 \times 30}{3 \times 10^8} = 4.8 \times 10^{-19} N$

Question68

The electric field of a plane electromagnetic wave is given by
$$\vec{E} = E_0 \left(\hat{x} + \hat{y}\right) \sin(kz - \omega t)$$
Its magnetic field will be given by:
[Sep. 04,2020 (II)]

Options:

A. $\frac{E_0}{c}\left(-\hat{x} + \hat{y}\right) \sin(kz - \omega t)$

B. $\frac{E_0}{c}\left(\hat{x} + \hat{y}\right) \sin(kz - \omega t)$

C. $\frac{E_0}{c}\left(\hat{x} - \hat{y}\right) \sin(kz - \omega t)$

D. $\frac{E_0}{c}\left(\hat{x} - \hat{y}\right) \cos(kz - \omega t)$

Answer: A

Solution:

Solution:

$\vec{E} = E_0(\hat{x} + \hat{y})\sin(kz - \omega t)$

Direction of propagation of em wave $= +\hat{k}$

Unit vector in the direction of electric field, $\hat{E} = \frac{\hat{i} + \hat{j}}{\sqrt{2}}$

The direction of electromagnetic wave is perpendicular to both electric and magnetic field.

$\therefore \hat{k} = \hat{E} \times \hat{B}$

$\Rightarrow \hat{k} = \left(\frac{\hat{i} + \hat{j}}{\sqrt{2}}\right) \times \hat{B} \Rightarrow \hat{B} = \frac{-\hat{i} + \hat{j}}{\sqrt{2}}$

$\therefore \vec{B} = \frac{E_0}{c}(-\hat{x} + \hat{y})\sin(kz - \omega t)$

Question69

The magnetic field of a plane electromagnetic wave is $\vec{B} = 3 \times 10^{-8}\sin[200\pi(y + ct)]\,\hat{i}$ T where $c = 3 \times 10^8 ms^{-1}$ is the speed of light. The corresponding electric field is : [Sep. 03, 2020 (I)]

Options:

A. $\vec{E} = 9\sin[200\pi(y + ct)]\,\hat{k}\,V/m$

B. $\vec{E} = -10^{-6}\sin[200\pi(y + ct)]\,\hat{k}\,V/m$

C. $\vec{E} = 3 \times 10^{-8}\sin[200\pi(y + ct)]\,\hat{k}\,V/m$

D. $\vec{E} = -9\sin[200\pi(y + ct)]\,\hat{k}\,V/m$

Answer: D

Solution:

Solution:

(d) Given: $\vec{B} = 3 \times 10^{-8}\sin[200\pi(y + ct)]\,\hat{i}$ T

$\therefore B_0 = 3 \times 10^{-8}$

$E_0 = CB_0 \Rightarrow E_0 = 3 \times 10^8 \times 3 \times 10^{-8} = 9V/m$

Directiono fwave propagation

$(\vec{E} \times \vec{B}) \parallel \vec{C}$

$\hat{B} = \hat{i}$ and $\hat{C} = -\hat{j}$ $\therefore \hat{E} = -\hat{k}$

$\therefore \vec{E} = E_0\sin[200\pi(y + ct)](-\hat{k})\,V/m$

or, $\vec{E} = -9\sin[200\pi(y + ct)]\,\hat{k}\,V/m$

Question70

The electric field of a plane electromagnetic wave propagating along the x direction in vacuum is $\vec{E} = E_0 \hat{j} \cos(\omega t - kx)$. The magnetic field $\vec{B}$, at the moment t = 0 is:
[Sep. 03, 2020 (II)]

Options:

A. $\vec{B} = \frac{E_0}{\sqrt{\mu_0 \varepsilon_0}} \cos(kx)\, \hat{k}$

B. $\vec{B} = E_0 \sqrt{\mu_0 \varepsilon_0} \cos(kx)\, \hat{j}$

C. $\vec{B} = E_0 \sqrt{\mu_0 \varepsilon_0} \cos(kx)\, \hat{k}$

D. $\vec{B} = \frac{E_0}{\sqrt{\mu_0 \varepsilon_0}} \cos(kx)\, \hat{j}$

Answer: C

Solution:

Relation between electric field and magnetic field for an electromagnetic wave in vacuum is $B_0 = \frac{E_0}{c}$.

In free space, its speed $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

Here, $\mu_0 =$ absolute permeability, $\varepsilon_0 =$ absolute permittivity

$\therefore B_0 = \frac{E_0}{c} = \frac{E_0}{1 / \sqrt{\mu_0 \varepsilon_0}} = E_0 \sqrt{\mu_0 \varepsilon_0}$

As the electromagnetic wave is propagating along x direction and electric field is along y direction.

$\therefore \hat{E} \times \hat{B} \parallel \hat{C}$ (Here, $\hat{C} =$ direction of propagation of wave)

$\therefore \vec{B}$ should be in $\hat{k}$ direction.

$\therefore B = E_0 \sqrt{\mu_0 \varepsilon_0} \cos(\omega t - kx)\, \hat{k}$

At t = 0

$B = E_0 \sqrt{\mu_0 \varepsilon_0} \cos(kx)\, \hat{k}$

Question71

A plane electromagnetic wave, has frequency of 2.0×10^{10} Hz and its energy density is 1.02×10^{-8} J / m^3 in vacuum. The amplitude of the magnetic field of the wave is close to $\left(\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \frac{N\,m^2}{C^2} \right.$ and speed of light $= 3 \times 10^8 ms^{-1}$)
[Sep. 02, 2020 (I)]

Options:

A. 150 nT

B. 160 nT

C. 180 nT

D. 190 nT

Answer: B

Solution:

Energy density $= \frac{1}{2}\frac{B^2}{\mu_0}$

$\Rightarrow B = \sqrt{2 \times \mu_0 \times \text{ Energy density}}$

$mu_0 = \frac{1}{C^2\varepsilon_0} = 4\pi \times 10^{-7}$

$\therefore B = \sqrt{2 \times 4\pi \times 10^{-7} \times 1.02 \times 10^{-8}} = 160 \times 10^{-9}$

$= 160nT$

Question72

In a plane electromagnetic wave, the directions of electric field and magnetic field are represented by $\hat{k}$ and $2\hat{i} - 2\hat{j}$ respectively. What is the unit vector along direction of propagation of the wave.
[Sep. 02, 2020 (II)]

Options:

A. $\frac{1}{\sqrt{2}}\left(\hat{i} + \hat{j}\right)$

B. $\frac{1}{\sqrt{2}}\left(\hat{j} + \hat{k}\right)$

C. $\frac{1}{\sqrt{5}}\left(\hat{i} + 2\hat{j}\right)$

D. $\frac{1}{\sqrt{5}}\left(2\hat{i} + \hat{j}\right)$

Answer: A

Solution:

Solution:

Electromagnetic wave will propagate perpendicular to the direction of Electric and Magnetic fields $\hat{C} = \hat{E} \times \hat{B}$

Here unit vector $\hat{C}$ is perpendicular to both $\hat{E}$ and $\hat{B}$ Given, $\vec{E} = \hat{k}, \vec{B} = 2\hat{i} - 2\hat{j}$

$$\hat{C} = \hat{E} \times \hat{B} = \frac{1}{\sqrt{2}}\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & 0 & 1 \\ 1 & -1 & 0 \end{vmatrix} = \frac{\hat{i} + \hat{j}}{\sqrt{2}}$$

$$\Rightarrow \hat{C} = \frac{\hat{i} + \hat{j}}{\sqrt{2}}$$

Question73

TOPIC 2 - Electromagnetic Spectrum

The correct match between the entries in column I and column II are :

I	II
Radiation	**Wavelength**
(A) Microwave	(i) 100 m
(B) Gamma rays	(ii) 10^{-15} m
(C) A.M. radio waves	(iii) 10^{-10} m
(D) X-rays	(iv) 10^{-3} m

[Sep. 05, 2020 (II)]

Options:

A. (A)-(ii), (B)-(i), (C)-(iv), (D)-(iii)

B. (A)-(i), (B)-(iii), (C)-(iv), (D)-(ii)

C. (A)-(iii), (B)-(ii), (C)-(i), (D)-(iv)

D. (A)-(iv), (B)-(ii), (C)-(i), (D)-(iii)

Answer: D

Solution:

Energy sequence of radiations is

$E_{\gamma-\text{ Rays}} > E_{\text{X-Rays}} > E_{\text{microwave}} > E_{\text{AM Radiowaves}}$

$\therefore \lambda_{\gamma-\text{Rays}} < \lambda_{\text{X -Rays}} < \lambda_{\text{microwave}} < \lambda_{\text{AM Radiowaves}}$

From the above sequence, we have

(a) Microwave $\rightarrow 10^{-3}$m (iv)

(b) Gamma Rays $\rightarrow 10^{-15}$m (ii)

(c) AM Radio wave $\rightarrow 100$m (i)

(d) X-Rays $\rightarrow 10^{-10}$m (iii)

Question74

Chosse the correct option relating wavelengths of different parts of electromagnetic wave spectrum :

[Sep. 04, 2020 (I)]

Options:

A. $\lambda_{\text{visible}} < \lambda_{\text{micro waves}} < \lambda_{\text{radio waves}} < \lambda_{\text{X -rays}}$

B. $\lambda_{\text{radio waves}} > \lambda_{\text{micro waves}} > \lambda_{\text{visible}} > \lambda_{\text{X -rays}}$

C. $\lambda_{\text{X -rays}} < \lambda_{\text{micro waves}} > \lambda_{\text{radio waves}} < \lambda_{\text{visible}}$

D. $\lambda_{\text{visible}} > \lambda_{\text{X -rays}} > \lambda_{\text{radio waves}} > \lambda_{\text{micro waves}}$

Answer: B

Solution:

The orderly arrangement of different parts of EM wave in decreasing order of wavelength is as follows:
$\lambda_{\text{radio waves}} > \lambda_{\text{micro waves}} > \lambda_{\text{visible}} > \lambda_{\text{X -rays}}$

Question75

The mean intensity of radiation on the surface of the Sun is about $10^8 W / m^2$. The rms value of the corresponding magnetic field is closest to :
[12 Jan 2019, II]

Options:

A. 1T

B. $10^2 T$

C. $10^{-2} T$

D. $10^{-4} T$

Answer: D

Solution:

Solution:

$I = \frac{B_0^{\ 2}}{2\mu_0} . C$

$\Rightarrow \frac{B_0^{\ 2}}{2} = \frac{I \, mu_0}{C}$

$\Rightarrow B_{rms} = \sqrt{\frac{I \mu_0}{C}}$

$= \sqrt{\frac{10^8 \times 4\pi \times 10^{-7}}{3 \times 10^8}}$

$\simeq 6 \times 10^{-4} T$

Which is closest to 10^{-4}

Question76

An electromagnetic wave of intensity $50 W m^{-2}$ enters in a medium of refractive index 'n' without any loss. The ratio of the magnitudes of electric fields, and the ratio of the magnitudes of magnetic fields of the wave before and after entering into the medium are respectively, given by:
[11 Jan 2019, I]

Options:

A. $\left(\frac{1}{\sqrt{n}}, \frac{1}{\sqrt{n}}\right)$

B. $(\sqrt{n}, \sqrt{n})$

C. $\left(\sqrt{n}, \frac{1}{\sqrt{n}}\right)$

D. $\left(\frac{1}{\sqrt{n}}, \sqrt{n}\right)$

Answer: C

Solution:

Solution:
The speed of electromagnetic wave in free space is given by
$C = \frac{1}{\sqrt{\mu_0 \in_0}}$ .....(i)
In medium, $v = \frac{1}{\sqrt{k \in_0 \mu_0}}$ ......(ii)
Dividing equation (i) by (ii), we get
$\therefore \frac{C}{V} = \sqrt{k} = n$
$\frac{1}{2} \in_0 E_0{}^2 C = \text{ intensity } = \frac{1}{2} \in_0 kE^2 v$
$\therefore E_0{}^2 C = kE^2 v$
$\Rightarrow \frac{E_0{}^2}{E^2} = \frac{kV}{C} = \frac{n^2}{n} \Rightarrow \frac{E_0}{E} = \sqrt{n}$
similarly
$\frac{B_0{}^2 C}{2\mu_0} = \frac{B^2 v}{2\mu_0} \Rightarrow \frac{B_0}{B} = \frac{1}{\sqrt{n}}$

Question77

A 27mW laser beam has a cross-sectional area of $10 mm^2$ The magnitude of the maximum electric field in this electromagnetic wave is given by : [Given permittivity of space $\in_0 = 9 \times 10^{-12}$ SI units, Speed of light $c = 3 \times 10^8 m/s$] [11 Jan 2019, II]

Options:

A. 2 kV/m

B. 0.7 kV/m

C. 1 kV/m

D. 1.4 kV/m

Answer: D

Solution:

EM wave intensity

$\Rightarrow I = \frac{\text{Power}}{\text{Area}} = \frac{1}{2} \in_0 E_0{}^2 c$

[where $E_0 =$ maximum electric field]

$\Rightarrow \frac{27 \times 10^{-3}}{10 \times 10^{-6}} = \frac{1}{2} \times 9 \times 10^{-12} \times E_0{}^2 \times 3 \times 10^8$

$\Rightarrow E_0 = \sqrt{2} \times 10^3 \mathrm{kV} / \mathrm{m} = 1.4 \mathrm{kV} / \mathrm{m}$

Question78

If the magnetic field of a plane electromagnetic wave is given by (The speed of light $= 3 \times 10^8 \mathrm{m} / \mathrm{s}$) $B = 100 \times 10^{-6} \sin\left[2\pi \times 2 \times 10^{15}\left(t - \frac{x}{c}\right)\right]$ then the maximum electric field associated with it is: [10 Jan. 2019 I]

Options:

A. $6 \times 10^4 \mathrm{N} / \mathrm{C}$

B. $3 \times 10^4 \mathrm{N} / \mathrm{C}$

C. $4 \times 10^4 \mathrm{N} / \mathrm{C}$

D. $4.510^4 \sim \mathrm{N} / \mathrm{C}$

Answer: B

Solution:

Solution:

Using, formula $E_0 = B_0 \times C$

$= 100 \times 10^{-6} \times 3 \times 10^8$

$= 3 \times 10^4 \mathrm{N} / \mathrm{C}$

Here we assumed that

$B_0 = 100 \times 10^{-6}$ is in tesla (T) units

Question79

The electric field of a plane polarized electromagnetic wave in free space at time t = 0 is given by an expression $\vec{E}(x, y) = 10\hat{j} \cos[(6x + 8z)]$ The magnetic field $\vec{B}(x, z, t)$ is given by: (c is the velocity of light) [10 Jan 2019, II]

Options:

A. $\frac{1}{c}\left(6\hat{k} + 8\hat{i}\right) \cos[(6x - 8z + 10ct)]$

B. $\frac{1}{c}\left(6\hat{k} - 8\hat{i}\right)\cos[(6x + 8z - 10ct)]$

C. $\frac{1}{c}\left(6\hat{k} + 8\hat{i}\right)\cos[(6x + 8z - 10ct)]$

D. $\frac{1}{c}\left(6\hat{k} - 8\hat{i}\right)\cos[(6x + 8z + 10ct)]$

Answer: B

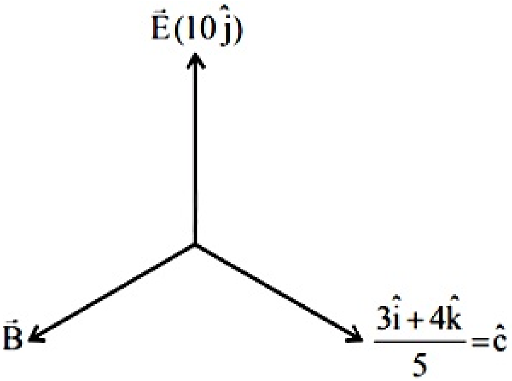
Solution:

$E = 10\hat{j}\cos\left[\left(6\hat{i} + 8\hat{k}\right) . \left(x\hat{i} + z\hat{k}\right)\right]$

$= 10\hat{j}\cos\left[\vec{K} . \vec{r}\right]$

$\therefore \vec{K} = 6\hat{i} + 8\hat{K}$; direction of waves travel

i. e. direction of 'c'



$\hat{C} \times \hat{E} = \frac{-4\hat{i} + 3\hat{k}}{5}$

$\vec{B} = \frac{E}{C} = \frac{10}{C}$

$\therefore \vec{B}\frac{10}{C}\left(\frac{-4\hat{i} + 3\hat{k}}{5}\right) = \left(\frac{-8\hat{i} + 6\hat{k}}{C}\right)$

or, magnetic field $\vec{B}(x, z, t) = \frac{1}{C}$

$\left(6\hat{k} - 8\hat{i}\right)\cos(6x + 8z - 10ct)$

Question80

An EM wave from air enters a medium. The electric fields are $\vec{E}_1 = E_{01}\hat{x}\cos\left[2\pi v\left(\frac{z}{c} - t\right)\right]$ in air and $\vec{E}_2 = E_{02}\hat{x}\cos[k(2z - ct)]$ in medium, where the wave number k and frequency v refer to their values in air. The medium is nonmagnetic. If $\in_{r_1}$ and $\in_{r_2}$ refer to relative permittivities of air and medium respectively, which of the following options is correct?
[9 Jan 2019, I]

Options:

A. $\frac{\in_{r_1}}{\in_{r_2}} = 4$

B. $\frac{\in_{r_1}}{\in_{r_2}} = 2$

C. $\frac{\in_{r_1}}{\in_{r_2}} = \frac{1}{4}$

D. $\frac{\in_{r_1}}{\in_{r_2}} = \frac{1}{2}$

Answer: C

Solution:

Solution:
Velocity of EM wave is given by $v = \frac{1}{\sqrt{\mu \in}}$
Velocity in air $= \frac{\omega}{k} = C$
Velocity in medium $= \frac{C}{2}$
Here, $\mu_1 = \mu_2 = 1$ as medium is non-magnetic
$\therefore \frac{\frac{1}{\sqrt{\in_{r_1}}}}{\frac{1}{\sqrt{\in_{r_2}}}} = \frac{C}{\left(\frac{C}{2}\right)} = 2 \Rightarrow \frac{\in_{r_1}}{\in_{r_2}} = \frac{1}{4}$

Question81

The energy associated with electric field is (U_E) and with magnetic fields is (U_B) for an electromagnetic wave in free space. Then : [9 Jan 2019, II]

Options:

A. $U_E = \frac{U_B}{2}$

B. $U_E > U_B$

C. $U_{E}

D. $U_E = U_B$

Answer: D

Solution:

Solution:
Average energy density of magnetic field,
$u_B = \frac{B_0^2}{4\mu_0}$
Average energy density of electric field,
$u_E = \frac{\varepsilon_0 E_0^2}{4}$

Now, $E_0 = CB_0$ and $C^2 = \frac{1}{\mu_0 \in_0}$

$u_E = \frac{\in_0}{4} \times C^2 B_0^{\ 2} = \frac{\varepsilon_0}{4} \times \frac{1}{\mu_0 \varepsilon_0} \times B_0^{\ 2} = \frac{B_0^{\ 2}}{4\mu_0} = u_B$

$\therefore u_E = u_B$

Since energy density of electric and magnetic field is same, so energy associated with equal volume will be equal i.e.
$u_E = u_B$

Question82

Given below in the left column are different modes of communication using the kinds of waves given in the right column.

A. Optical Fibre Communication	P. Ultrasound
B. Radar	Q. Infrared Light
C. Sonar	R. Microwaves
D. Mobile Phones	S. Radio Waves

From the options given below, find the most appropriate match between entries in the left and the right column. [10 April 2019, I]

Options:

A. A – Q, B – S, C – R, D – P

B. A – S, B – Q, C – R, D – P

C. A – Q, B – S, C – P, D – R

D. A – R, B – P, C – S, D – Q

Answer: C

Solution:

Solution:
Optical Fibre Communication - Infrared Light
Radar-Radio Waves
Sonar-Ultrasound
Mobile Phones - Microwaves

Question83

An electromagnetic wave is represented by the electric field $\vec{E} = E_0 \hat{n} \sin[\omega t + (6y - 8z)]$. Taking unit vectors inx, y and z directions to be $\hat{i}$, $\hat{j}$, $\hat{k}$, the direction of propogation $\hat{s}$ is : [12 April 2019, I]

Options:

A. $\hat{s} = \frac{3\hat{i} - 4\hat{j}}{5}$

B. $\hat{s} = \frac{-4\hat{k} + 3\hat{j}}{5}$

C. $\hat{s} = \left(\frac{-3\hat{j} + 4\hat{k}}{5}\right)$

D. $\hat{s} = \frac{3\hat{j} - 3\hat{k}}{5}$

Answer: C

Solution:

Solution:

$\hat{S} = \frac{6\hat{j} + 8\hat{k}}{\sqrt{6^2 + 8^2}} = \frac{-3\hat{j} + 4\hat{k}}{5}$

Question84

A plane electromagnetic wave having a frequency v = 23.9 GHz propagates along the positive z -direction in free space. The peak value of the Electric Field is 60V / m. Which among the following is the acceptable magnetic field component in the electromagnetic wave? [12 April 2019, II]

Options:

A. $\vec{B} = 2 \times 10^7 \sin(0.5 \times 10^3 z + 1.5 \times 10^{11} t)\hat{i}$

B. $\vec{B} = 2 \times 10^7 \sin(0.5 \times 10^3 z - 1.5 \times 10^{11} t)\hat{i}$

C. $\vec{B} = 60 \sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t)\hat{k}$

D. $\vec{B} = 2 \times 10^{-7} \sin(1.5 \times 10^2 x + 0.5 \times 10^{11} t)\hat{j}$

Answer: B

Solution:

Solution:

$B_0 = \frac{E_0}{C} = \frac{60}{3 \times 10^8}$

$= 20 \times 10^{-8} T = 2 \times 10^{-7} T$

$K = \frac{\omega}{v} = \frac{2\pi f}{v} = \frac{2\pi \times 23.9 \times 10^9}{3 \times 10^8} = 500$

Therefore, $\vec{B} = B_0 \sin(kz - \omega t)$

$= 2 \times 10^{-7} \sin(0.5 \times 10^3 z - 1.5 \times 10^{11} t) i$

Question85

The electric field of a plane electromagnetic wave is given by $\vec{E} = E_0 \hat{i} \cos(kz) \cos(\omega t)$
The corresponding magnetic field is then given by :
[10 April 2019, I]

Options:

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

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

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

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

Answer: A

Solution:

Solution:

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

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

Given that $\vec{E} = E_0 \cos(kz) \cos(\omega t) \vec{i}$

$\vec{E} = \frac{E_0}{2} \left[\cos(kz - \omega t) \hat{i} - \cos(kz + \omega t) \hat{i} \right]$

Correspondingly

$\vec{B} = \frac{B_0}{2} \left[\cos(kz - \omega t) \hat{j} - \cos(kz + \omega t) \hat{j} \right]$

$\vec{B} = \frac{B_0}{2} \times 2 \sin kz \sin \omega t$

$\vec{B} = \left(\frac{E_0}{C} \sin kz \sin \omega t \right) \hat{j}$

Question86

Light is incident normally on a completely absorbing surface with an energy flux of $25 \mathrm{W\,cm^{-2}}$. If the surface has an area of $25 \mathrm{cm^2}$, the momentum transferred to the surface in 40 min time duration will be:
[10 April 2019, II]

Options:

A. $6.3 \times 10^{-4} \mathrm{N\,s}$

B. $1.4 \times 10^{-6} \mathrm{N\,s}$

C. $5.0 \times 10^{-3} \mathrm{N\,s}$

D. 3.5×10^{-6}N s

Answer: C

Solution:

Solution:

Pressure, $P = \frac{I}{C}$

$\Rightarrow \frac{F}{A} = \frac{I}{C}$

$\Rightarrow F = \frac{I\,A}{C} = \frac{\Delta p}{\Delta t}$

$\Rightarrow \Delta p = \frac{I}{C} A \Delta t$

$= \frac{(25 \times 25) \times 10^{4} \times 10^{-4} \times 40 \times 60}{3 \times 10^{8}} N - s$

$= 5 \times 10^{-3} N - s$

Question87

The magnetic field of a plane electromagnetic wave is given by:
$\vec{B} = B_0 \hat{i} [\cos(kz - \omega t)] + B_1 \hat{j} \cos(kz + \omega t)$
Where $B_0 = 3 \times 10^{-5}$T and $B_1 = 2 \times 10^{-6}$T
The rms value of the force experienced by a stationary charge $Q = 10^{-4}$C at z = 0 is closest to:
[9 April 2019 I]

Options:

A. 0.6 N

B. 0.1 N

C. 0.9 N

D. 3×10^{-2} N

Answer: A

Solution:

Solution:

$B_0 = \sqrt{B_0^{\,2} + B_1^{\,2}} = \sqrt{30^2 + 2^2} \times 10^{-6} = 30 \times 10^{-6} T$

$\therefore E_0 = CB = 3 \times 10^{8} \times 30 \times 10^{-6}$

$= 9 \times 10^{3} V / m$

$\frac{E_0}{V_2} = \frac{9}{\sqrt{2}} \times 10^{3} V / m$

Force on the charge,

$F = E\,Q = \frac{9}{\sqrt{2}} \times 10^{3} \times 10^{-4} \simeq 0.64 N$

Question88

A plane electromagnetic wave of frequency 50 MHz travels in free space along the positive x - direction. At a particular point in space and time, $\vec{E} = 6.3\hat{j} V / m$. The corresponding magnetic field $\vec{B}$, at that point will be: [9 April 2019 I]

Options:

A. $18.9 \times 10^{-8} \hat{k} T$

B. $2.1 \times 10^{-8} \hat{k} T$

C. $6.3 \times 10^{-8} \hat{k} T$

D. $18.9 \times 10^{8} \hat{k} T$

Answer: B

Solution:

Solution:
As we know,
$|\vec{B}| = \frac{|\vec{E}|}{C} = \frac{6.3}{3 \times 10^8} = 2.1 \times 10^{-8} T$
and $\hat{E} \times \hat{B} = \hat{C}$
$\hat{J} \times \hat{B} = \hat{i}$ [$\because$ E M wave travels along +(ve)x -direction.]
$\therefore \hat{B} = \hat{k}$ or $\hat{B} = 2.1 \times 10^{-8} \hat{k} T$

Question89

$50 W / m^2$ energy density of sunlight is normally incident on the surface of a solar panel. Some part of incident energy (25%) is reflected from the surface and the rest is absorbed. The force exerted on $1 m^2$ surface area will be [9 April 2019, II]

Options:

A. $15 \times 10^{-8} N$

B. $20 \times 10^{-8} N$

C. $10 \times 10^{-8} N$

D. $35 \times 10^{-8} N$

Answer: B

Solution:

$F = (1+r)\frac{IA}{C}$
$= \frac{(1+0.25)\times 50\times 1}{3\times 10^8}$
$\simeq 20\times 10^{-8}N$

Question90

A plane electromagnetic wave travels in free space along the x -direction. The electric field component of the wave at a particular point of space and time is $E = 6 V m^{-1}$ along y -direction. Its corresponding magnetic field component, B would be: [8 April 2019 I]

Options:

A. $2\times 10^{-8}T$ along z -direction

B. $6\times 10^{-8}T$ along x -direction

C. $6\times 10^{-8}T$ along z -direction

D. $2\times 10^{-8}T$ along y -direction

Answer: A

Solution:

Solution:
The relation between amplitudes of electric and magnetic field in free space is given by
$B_0 = \frac{E_0}{c} = \frac{6}{3\times 10^8} = 2\times 10^{-8}T$
Propagation direction $= \hat{E}\times\hat{B}$
$\hat{i} = \hat{j}\times\hat{B}$
$\Rightarrow \hat{B} = \hat{k}$
∴ The magnetic field component will be along z direction.

Question91

The magnetic field of an electromagnetic wave is given by: $\vec{B} = 1.6\times 10^{-6}\cos(2\times 10^7 z + 6\times 10^{15}t)\left(2\hat{i}+\hat{j}\right)\frac{Wb}{m^2}$ The associated electric field will be : [8 April 2019 II]

Options:

A. $\vec{E} = 4.8\times 10^2\cos(2\times 10^7 z - 6\times 10^{15}t)\left(2\hat{i}+\hat{j}\right)\frac{V}{m}$

B. $\vec{E} = 4.8\times 10^2\cos(2\times 10^7 z - 6\times 10^{15}t)\left(-2\hat{j}+\hat{i}\right)\frac{V}{m}$

C. $\vec{E} = 4.8 \times 10^{2} \cos(2 \times 10^{7} z + 6 \times 10^{15} t)(-\hat{i} + 2\hat{j}) \frac{V}{m}$

D. $\vec{E} = 4.8 \times 10^{2} \cos(2 \times 10^{7} z + 6 \times 10^{15} t)(\hat{i} - 2\hat{j}) \frac{V}{m}$

Answer: C

Solution:

Solution:
$E_0 = cB_0 = 3 \times 10^{8} \times 1.6 \times 10^{-6} = 4.8 \times 10^{2} V / m$
Also $\vec{S} \Rightarrow \vec{E} \times \vec{B}$
or $-\vec{K} \Rightarrow \vec{E} \times (2\hat{i} + \hat{j})$
Therefore direction of $\vec{E} \rightarrow (-\hat{i} + 2\hat{j})$

Question92

A plane electromagnetic wave of wavelength l has an intensity I. It is propagating along the positive Y– direction. The allowed expressions for the electric and magnetic fields are given by
[Online April 16, 2018]

Options:

A. $\vec{E} = \sqrt{\frac{I}{\varepsilon_0 C}} \cos\left[\frac{2\pi}{\lambda}(y - ct)\right] \hat{i}; \vec{B} = \frac{1}{c} E \hat{k}$

B. $\vec{E} = \sqrt{\frac{I}{\varepsilon_0 C}} \cos\left[\frac{2\pi}{\lambda}(y - ct)\right] \hat{k}; \vec{B} = -\frac{1}{c} E \hat{i}$

C. $\vec{E} = \sqrt{\frac{2I}{\varepsilon_0 C}} \cos\left[\frac{2\pi}{\lambda}(y - ct)\right] \hat{k}; \vec{B} = +\frac{1}{c} E \hat{i}$

D. $\vec{E} = \sqrt{\frac{2I}{\varepsilon_0 C}} \cos\left[\frac{2\pi}{\lambda}(y + ct)\right] \hat{k}; \vec{B} = \frac{1}{c} E \hat{i}$

Answer: C

Solution:

Solution:
If E_0 is magnitude of electric field then
$\frac{1}{2}\varepsilon_0 E^{2} \times C = 1 \Rightarrow E_0 = \sqrt{\frac{2I}{C\varepsilon_0}}$
$E_0 = \frac{E_0}{C}$
Direction of $\vec{E} \times \vec{B}$ will be along $+\hat{j}$

Question93

A monochromatic beam of light has a frequency$v = \frac{3}{2\pi} \times 10^{12}$Hz and is propagating along the direction $\frac{\hat{i} + \hat{j}}{\sqrt{2}}$. It is polarized along the $\hat{k}$ direction. The acceptable form for the magnetic field is:
[Online April 15, 2018]

Options:

A.

$$k\frac{E_0}{C}\left(\frac{\hat{i} - \hat{j}}{\sqrt{2}}\right)\cos\left[10^4\left(\frac{\hat{i} - \hat{j}}{\sqrt{2}}\right).\vec{r} - (3 \times 10^{12})t\right]$$

B.

$$\frac{E_0}{C}\left(\frac{\hat{i} - \hat{j}}{\sqrt{2}}\right)\cos\left[10^4\left(\frac{\hat{i} - \hat{j}}{\sqrt{2}}\right).\vec{r} - (3 \times 10^{12})t\right]$$

C.

$$\frac{E_0}{C}\hat{k}\cos\left[10^4\left(\frac{\hat{i} + \hat{j}}{\sqrt{2}}\right).\vec{r} - (3 \times 10^{12})t\right]$$

D.

$$\frac{E_0}{C}\frac{\left(\hat{i} + \hat{j} + \hat{k}\right)}{\sqrt{3}}\cos\left[10^4\left(\frac{\hat{i} + \hat{j}}{\sqrt{2}}\right).\vec{r} + (3 \times 10^{12})t\right]$$

Answer: C

Solution:

$\hat{E} \times \hat{B}$ should give the direction of wave propagation

$$\Rightarrow \hat{K} \times \hat{B} \parallel \frac{\hat{i} \times \hat{j}}{\sqrt{2}} \Rightarrow \hat{K} \times \left(\frac{\hat{i} + \hat{j}}{\sqrt{2}}\right) = \frac{\hat{j} - \left(-\hat{i}\right)}{\sqrt{2}} = \frac{\hat{i} + \hat{j}}{\sqrt{2}} \parallel \frac{\hat{i} + \hat{j}}{\sqrt{2}}$$

Option (a), option (b) and option (d) does not satisfy.

Wave propagation vector $\hat{K}$ should along $\frac{\hat{i} + \hat{j}}{\sqrt{2}}$

Question94

The electric field component of a monochromatic radiation is given by $\vec{E} = 2E_0\hat{i}\cos kz\cos\omega t$Its magnetic field $\vec{B}$ is then given by :
[Online April 9, 2017]

Options:

A. $\frac{2E_0}{c}\hat{j}\sin kz\cos\omega t$

B. $-\frac{2E_0}{c}\hat{j}\sin kz\cos\omega t$

C. $\frac{2E_0}{c}\hat{j}\sin kz\cos\omega t$

D. $\frac{2E_0}{c}\hat{j}\cos kz\cos\omega t$

Answer: C

Solution:

Given, Electric field component of monochromatic radiation, $(\vec{E}) = 2E_0\hat{i}\cos kz\cos\omega t$

We know that, $\frac{dE}{dz} = -\frac{dB}{dt}$

$\frac{dE}{dz} = -2E_0 k\sin kz\cos\omega t = -\frac{dB}{dt}$

$dB = +2E_0 k\sin kz\cos\omega t\,dt$ .....(i)

Integrating eq^n (i), we have

$B = +2E_0 k\sin kz\int\cos\omega t\,dt$

Magnetic field is given by,

$= +2E_0\frac{k}{\omega}\sin kz\sin\omega t$

We also know that,

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

Magnetic field vector,

$\vec{B} = \frac{2E_0}{c}\hat{j}\sin kz\cos\omega t$

Question95

Magnetic field in a plane electromagnetic wave is given by $\vec{B} = B_0\sin(kx+\omega t)\hat{j}$ T Expression for corresponding electric field will be : Where c is speed of light. [Online April 8,2017]

Options:

A. $\vec{E} = B_0 c\sin(kx+\omega t)\hat{k}$ V / m

B. $\vec{E} = \frac{B_0}{c}\sin(kx+\omega t)\hat{k}$ V / m

C. $\vec{E} = -B_0 c\sin(kx+\omega t)\hat{k}$ V / m

D. $\vec{E} = B_0 c\sin(kx-\omega t)\hat{k}$ V / m

Answer: A

Solution:

Speed of EM wave in force space (c) $= \frac{E_0}{B_0}$

or $\vec{E} = cB_0 \sin(kx + \omega t)\hat{k}$

Question96

Consider an electromagnetic wave propagating in vacuum. Choose the correct statement:
[Online April 10, 2016]

Options:

A. For an electromagnetic wave propagating in +y direction the electric field is $\vec{E} = \frac{1}{\sqrt{2}}E_{yz}(x, t)\hat{z}$ and the magnetic field is $\vec{B} = \frac{1}{\sqrt{2}}B_z(x, t)\vec{y}$

B. For an electromagnetic wave propagating in +y direction the electric field is $\vec{E} = \frac{1}{\sqrt{2}}E_{yz}(x, t)\hat{y}$ and the magnetic field is $\vec{B} = \frac{1}{\sqrt{2}}B_{yz}(x, t)\hat{z}$

C. For an electromagnetic wave propagating in +x direction the electric field is $\vec{E} = \frac{1}{\sqrt{2}}E_{yz}(y, z, t)\left(\hat{y} + \hat{z}\right)$ and the magnetic field is $\vec{B} = \frac{1}{\sqrt{2}}B_{yz}(y, z, t)\left(\hat{y} + \hat{z}\right)$

D. For an electromagnetic wave propagating in +x direction the electric field is $\vec{E} = \frac{1}{\sqrt{2}}E_{yz}(x, t)\left(\hat{y} - \hat{z}\right)$ and the magnetic field is $\vec{B} = \frac{1}{\sqrt{2}}B_{yz}(x, t)\left(\hat{y} + \hat{z}\right)$

Answer: D

Solution:

Solution:
Wave in X-direction means E and B should be function of x and t
$\hat{y} - \hat{z} \perp \hat{y} + \hat{z}$

Question97

Arrange the following electromagnetic radiations per quantum in the order of increasing energy :
A : Blue light
B : Yellow light
C : X-ray
D : Radio wave.
[2016]

Options:

A. C, A, B, D

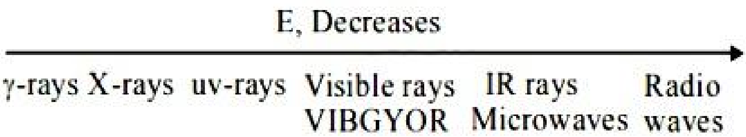
B. B, A, D, C

C. D, B, A, C

D. A, B, D, C

Answer: C

Solution:



Radio wave < yellow light < blue light $ (Increasing order of energy)

Question98

Microwave oven acts on the principle of :
[Online April 9, 2016]

Options:

A. giving rotational energy to water molecules

B. giving translational energy to water molecules

C. giving vibrational energy to water molecules

D. transferring electrons from lower to higher energy levels in water molecule

Answer: C

Solution:

Solution:
Microwave oven acts on the principle of giving vibrational energy to water molecules.

Question99

For plane electromagnetic waves propagating in the z-direction, which one of the following combination gives the correct possible direction for $\vec{E}$ and $\vec{B}$ field respectively?
[Online April 11, 2015]

Options:

A. $\left(2\hat{i}+3\hat{j}\right)$ and $\left(\hat{i}+2\hat{j}\right)$

B. $\left(-2\hat{i}-3\hat{j}\right)$ and $\left(3\hat{i}-2\hat{j}\right)$

C. $\left(\hat{i}+2\hat{j}\right)$ and $\left(2\hat{i}-\hat{j}\right)$

D. $\left(3\hat{i}+4\hat{j}\right)$ and $\left(4\hat{i}-3\hat{j}\right)$

Answer: B

Solution:

As we know, $\vec{E}\cdot\vec{B}=0 \because \left[\vec{E}\perp\vec{B}\right]$
and $\vec{E}\times\vec{B}$ should be along Z direction
As $\left(-2\hat{i}-3j\right)\times\left(3\hat{i}-2\hat{j}\right)=5\hat{k}$
Hence option (b) is the correct answer.

Question100

An electromagnetic wave travelling in the x -direction has frequency of $2\times10^{14}Hz$ and electric field amplitude of $27\ V m^{-1}$. From the options given below, which one describes the magnetic field for this wave ? [Online April 10,2015]

Options:

A. $\vec{B}(x,t)=(3\times10^{-8}T)\hat{j}\ \sin[2\pi(1.5\times10^{-8}x-2\times10^{14}t)$

B. $\vec{B}(x,t)=(9\times10^{-8}T)\hat{i}\ \sin[2\pi(1.5\times10^{-8}x-2\times10^{14}t)$

C. $\vec{B}(x,t)=(9\times10^{-8}T)\hat{j}\ \sin[(1.5\times10^{-8}x-2\times10^{14}t)$

D. $\vec{B}(x,t)=(9\times10^{-8}T)\hat{k}\ \sin[2\pi(1.5\times10^{-6}x-2\times10^{14}t)$

Answer: D

Solution:

Solution:
As we know,
$B_0=\frac{E_0}{C}=\frac{27}{3\times10^{8}}=9\times10^{-8}$ tesla
Oscillation of B can be only along $\hat{j}$ or $\hat{k}$ direction. $\omega=2\pi f=2\pi\times2\times10^{14}Hz$
$\therefore\vec{B}(x,t)=(9\times10^{-8}T)\hat{k}\ \sin[2\pi(1.5\times10^{-6}x-2\times10^{4}t)]$

Question101

During the propagation of electromagnetic waves in a medium: [2014]

Options:

A. Electric energy density is double of the magnetic energy density.

B. Electric energy density is half of the magnetic energy density.

C. Electric energy density is equal to the magnetic energy density.

D. Both electric and magnetic energy densities are zero

Answer: C

Solution:

Solution:

$E_0 = CB_0$ and $C = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

Electric energy density $= \frac{1}{2}\varepsilon_0 E_0^2 = \mu_E$

Magnetic energy density $= \frac{1}{2}\frac{Bo^2}{\mu_0} = \mu_B$

Thus, $\mu_E = \mu_B$

Energy is equally divided between electric and magnetic field

----

Question102

A lamp emits monochromatic green light uniformly in all directions. The lamp is 3% efficient in converting electrical power to electromagnetic waves and consumes 100 W of power. The amplitude of the electric field associated with the electromagnetic radiation at a distance of 5 m from the lamp will be nearly: [Online April 12, 2014]

Options:

A. 1.34 V/m

B. 2.68 V/m

C. 4.02 V/m

D. 5.36 V/m

Answer: B

Solution:

Solution:

Wavelength of monochromatic green light $= 5.5 \times 10^{-5}\text{cm}$

Intensity I $= \frac{\text{Power}}{\text{Area}}$

$= \frac{100 \times (3 / 100)}{4\pi(5)^2} = \frac{3}{100\pi}\text{W m}^{-2}$

Now, half of this intensity (I) belongs to electric field and half of that to magnetic field, therefore,

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

or $E_0 = \sqrt{\frac{2I}{\varepsilon_0 C}}$

$$= \sqrt{\frac{2 \times \left(\frac{3}{100}\pi\right)}{\left(\frac{1}{4\pi \times 9 \times 10^9}\right) \times (3 \times 10^8)}}$$

$$= \sqrt{\frac{6}{25} \times 30} = \sqrt{7.2}$$

$\therefore E_0 = 2.68 V / m$

Question103

An electromagnetic wave of frequency 1×10^{14} hertz is propagating along z-axis. The amplitude of electric field is $4V / m$. If $\varepsilon_0 = 8.8 \times 10^{-12} C^2 / N - m^2$, then average energy density of electric field will be:
[Online April 11,2014]

Options:

A. $35.2 \times 10^{-10} J / m^3$

B. $35.2 \times 10^{-11} J / m^3$

C. $35.2 \times 10^{-12} J / m^3$

D. $35.2 \times 10^{-13} J / m^3$

Answer: C

Solution:

Solution:
Given: Amplitude of electric field,
$E_0 = 4v / m$
Absolute permitivity, $\varepsilon_0 = 8.8 \times 10^{-12} c^2 / N - m^2$
Average energy density $u_E = ?$
Applying formula,
Average energy density $u_E = \frac{1}{4}\varepsilon_0 E^2$
$\Rightarrow u_E = \frac{1}{4} \times 8.8 \times 10^{-12} \times (4)^2$
$= 35.2 \times 10^{-12} J / m^3$

Question104

Match List - I (Electromagnetic wave type) with List - II (Its association/application) and select the correct option from the choices given below the lists:

List 1	List 2
1. Infrared waves	(i) To treat muscular strain
2. Radio waves	(ii) For broadcasting
3. X-rays	(iii) To detect fracture of bones
4. Ultraviolet rays	(iv) Absorbed by the ozone layer of the atmosphere

[2014]

Options:

A. 1-(iv), 2-(iii), 3-(ii), 4-(i)

B. 1-(i), 2-(ii), 3-(iv), 4-(iii)

C. 1-(iii), 2-(ii), 3-(i), 4-(iv)

D. 1-(i), 2-(ii), 3-(iii), 4-(iv)

Answer: D

Solution:

Solution:
(1) Infrared rays are used to treat muscular strain because these are heat rays.
(2) Radio waves are used for broadcasting because these waves have very long wavelength ranging from few centimeters to few hundred kilometers.
(3) X-rays are used to detect fracture of bones because they have high penetrating power but they can't penetrate through denser medium like dones.
(4) Ultraviolet rays are absorbed by ozone of the atmosphere.

Question105

If microwaves, X rays, infrared, gamma rays, ultra-violet,radio waves and visible parts of the electromagnetic spectrum are denoted by M, X, I, G, U, R and V then which of the following is the arrangement in ascending order of wavelength ?
[Online April 19, 2014]

Options:

A. R, M, I, V, U, X and G

B. M, R, V, X, U, G and I

C. G, X, U, V, I, M and R

D. I, M, R, U, V, X and G

Answer: C

Solution:

Solution:
(c) Gamma rays <mathrm X -rays < Ultra violet < Visible rays < Infrared rays < Microwaves < Radio waves.

Question106

Match the List-I (Phenomenon associated with electromagnetic radiation) with List-II (Part of electromagnetic spectrum) and select the correct code from the choices given below this lists:

	List I		List II
I	Doublet of sodium	(A)	Visible radiation
II	Wavelength corresponding to temperature associated with the isotropic radiation filling all space	(B)	Microwave
III	Wavelength emitted by atomic hydrogen in interstellar space	(C)	Short radio wave
IV	Wavelength of radiation arising from two close energy levels in hydrogen	(D)	X-rays

[Online April 11, 2014]

Options:

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

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

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

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

Answer: D

Solution:

Solution:
Wavelength emitted by atomic hydrogen in interstellar space - Part of short radio wave of electromagnetic spectrum.
Doublet of sodium - visible radiation.

Question107

Match List I (Wavelength range of electromagnetic spectrum) with List II (Method of production of these waves) and select the correct option from the options given below the lists.

	List I		List II
(1)	700 nm to 1 mm	(i)	Vibration of atoms and molecules.
(2)	1 nm to 400 nm	(ii)	Inner shell electrons in atoms moving from one energy level to a lower level.
(3)	$<10^{-3}$ nm	(iii)	Radioactive decay of the nucleus.
(4)	1 mm to0.1 m	(iv)	Magnetron valve.

[Online April 9, 2014]

Options:

A. (1)-(iv), (2)-(iii), (3)-(ii), (4)-(i)

B. (1)-(iii), (2)-(iv), (3)-(i), (4)-(ii)

C. (1)-(ii), (2)-(iii), (3)-(iv), (4)-(i)

D. (1)-(i), (2)-(ii), (3)-(iii), (4)-(iv)

Answer: D

Solution:

Solution:
Vibration of atoms and molecules 700nm to 1mm
Radioactive decay of the nucleus $<10^{-3}$nm
Magnetron valve 1mm to 0.1m

Question108

The magnetic field in a travelling electromagnetic wave has a peak value of 20 nT. The peak value of electric field strength is : [2013]

Options:

A. 3 V/m

B. 6 V/m

C. 9 V/m

D. 12 V/m

Answer: B

Solution:

From question,
$B_0 = 20nT = 20 \times 10^{-9}T$
(∵ velocity of light in vacuum $C = 3 \times 10^8 ms^{-1}$)
$\vec{E}_0 = \vec{B}_0 \times \vec{C}$

$\left|\vec{E}_0\right| = \left|\vec{B}\right| . \left|\vec{C}\right| = 20 \times 10^{-9} \times 3 \times 10^{8}$
$= 6V / m$

Question109

A plane electromagnetic wave in a non-magnetic dielectric medium is given by $\vec{E} = \vec{E}_0(4 \times 10^{-7}x - 50t)$ with distance being in meter and time in seconds. The dielectric constant of the medium is : [Online April 22, 2013]

Options:

A. 2.4

B. 5.8

C. 8.2

D. 4.8

Answer: B

Solution:

Solution:

Question110

Select the correct statement from the following : [Online April 9, 2013]

Options:

A. Electromagnetic waves cannot travel in vacuum.

B. Electromagnetic waves are longitudinal waves.

C. Electromagnetic waves are produced by charges moving with uniform velocity.

D. Electromagnetic waves carry both energy and momentum as they propagate through space.

Answer: D

Solution:

Solution:
Electromagnetic waves do not required any medium to propagate. They can travel in vacuum. They are transverse in nature like light. They carry both energy and momentum.
A changing electric field produces a changing magnetic field and vice-versa. Which gives rise to a transverse wave known as electromagnetic wave.

Question111

Photons of an electromagnetic radiation has an energy 11 keV each. To which region of electromagnetic spectrum does it belong ?
[Online April 9, 2013]

Options:

A. X-ray region

B. Ultra violet region

C. Infrared region

D. Visible region

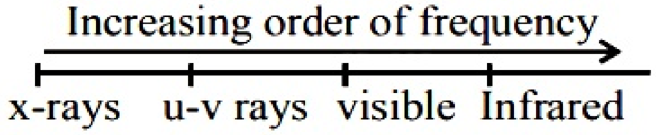
Answer: A

Solution:

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

$\Rightarrow \lambda = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{11 \times 1000 \times 1.6 \times 10^{-19}}$

$= 12.4\ \text{Å}$



wavelength range of visible region is 4000Å to 7800Å.

Question112

An electromagnetic wave in vacuum has the electric and magnetic field $\vec{E}$ and $\vec{B}$, which are always perpendicular to each other. The direction of polarization is given by vec X and that of wave propagation by $\vec{k}$. Then [2012]

Options:

A. $\vec{X} \parallel \vec{B}$ and $\vec{k} \parallel \vec{B} \times \vec{E}$

B. $\vec{X} \parallel \vec{E}$ and $\vec{k} \parallel \vec{E} \times \vec{B}$

C. $\vec{X} \parallel \vec{B}$ and $\vec{k} \parallel \vec{E} \times \vec{B}$

D. $\vec{X} \parallel \vec{E}$ and $\vec{k} \parallel \vec{B} \times \vec{E}$

Answer: B

Solution:

∵ The E.M. wave are transverse in nature i.e.,

$= \frac{\vec{k} \times \vec{E}}{\mu} = \vec{H}$ .....(i)

where $\vec{H} = \frac{\vec{B}}{\mu}$

and $\frac{\vec{k} \times \vec{H}}{\omega\varepsilon} = -\vec{E}$ ....(ii)

$\vec{k}$ is $\perp \vec{H}$ and $\vec{k}$ is also $\perp$ to $\vec{E}$

The direction of wave propagation is parallel to $\vec{E} \times \vec{B}$.

The direction of polarization is parallel to electric field.

Question113

An electromagnetic wave with frequency ω and wavelength λ travels in the + y direction. Its magnetic field is along + x-axis. The vector equation for the associated electric field (of amplitude E_0) is [Online May 19, 2012]

Options:

A. $\vec{E} = -E_0 \cos\left(\omega t + \frac{2\pi}{\lambda}y\right)\hat{x}$

B. $\vec{E} = E_0 \cos\left(\omega t - \frac{2\pi}{\lambda}y\right)\hat{x}$

C. $\vec{E} = E_0 \cos\left(\omega t - \frac{2\pi}{\lambda}y\right)\hat{z}$

D. $\vec{E} = -E_0 \cos\left(\omega t - \frac{2\pi}{\lambda}y\right)\hat{z}$

Answer: C

Solution:

Solution:

In an electromagnetic wave electric field and magnetic field are perpendicular to the direction of propagation of wave. The vector equation for the electric field is

$\vec{E} = E_0 \cos\left(\omega t - \frac{2\pi}{\lambda}y\right)\hat{z}$

Question114

The frequency of X-rays; γ-rays and ultraviolet rays are respectively a, b and c then [Online May 26, 2012]

Options:

A. a < b; b > c

B. a > b ; b > c

C. a < b < c

D. a = b = c

Answer: A

Solution:

Solution:
Frequency range of γ -ray,
$b = 10^{18} - 10^{23} Hz$
Frequency range of X-ray,
$a = 10^{16} - 10^{20} Hz$
Frequency range of ultraviolet ray,
$c = 10^{15} - 10^{17} Hz$
$\therefore a < b; b > c$

Question115

An electromagnetic wave of frequency v = 3.0 MHz passes from vacuum into a dielectric medium with permittivity ∈ = 4.0 . Then [2004]

Options:

A. wave length is halved and frequency remains unchanged

B. wave length is doubled and frequency becomes half

C. wave length is doubled and the frequency remains unchanged

D. wave length and frequency both remain unchanged.

Answer: A

Solution:

Solution:
Frequency remains unchanged during refraction Velocity of EM wave in vacuum

$$V_{vacuum} = \frac{1}{\sqrt{\mu_0 \in_0}} = C$$

$$v_{med} = \frac{1}{\sqrt{\mu_0 \in_0 \times 4}} = \frac{c}{2}$$

$$\frac{\lambda_{med}}{\lambda_{vacuum}} = \frac{v_{med}}{v_{vacuum}} = \frac{c/2}{c} = \frac{1}{2}$$

∴ Wavelength is halved and frequency remains unchanged

Question116

Electromagnetic waves are transverse in nature is evident by [2002]

Options:

A. polarization

B. interference

C. reflection

D. diffraction

Answer: A

Solution:

The phenomenon of polarisation is shown only by transverse waves. The vibration of electromagnetic wave are restricted through polarization in a direction perpendicular to wave propagation.
