JEE Main Physics Previous Year Questions With Solutions on "Electromagnetic Waves"

Q1: 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

(a) 10^{-2} T

(b) 1 T

(c) 10^{-4} T

(d) 10^2 T

Solution

Mean intensity = $(B^2_{rms}/\mu_0)c$

$B^2rms = (10^8 \times 4\pi \times 10^{-7})/(3 \times 10^8)$

$Brms = 10^{-4}$ T

Answer: (c) 10^{-4} T

Q2: 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 the y-direction. Its corresponding magnetic field component, B would be

(a) 6×10^{-8} T along the x-direction

(b) 2×10^{-8} T along the y-direction

(c) 2×10^{-8} T along the z-direction

(d) 6×10^{-8} T along the z-direction

Solution

The direction of electromagnetic wave travelling is given by

$$\bar{k} = \bar{E} \times \bar{B}$$

As the wave is travelling along x-direction and E is along the y-direction.

So B must point towards the z-direction.

The magnetic field, $B = E/c = 6/(3 \times 10^8) = 2 \times 10^{-8}$ T

Answer: (b) 2×10^{-8} T along the y-direction

Q3: 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 1m^2 surface area will be close to ($c = 3 \times 10^8$ m/s)

(a) 20×10^{-8} N

(b) 10×10^{-8} N

(c) 35×10^{-8} N

(d) 15×10^{-8} N

Solution

Given energy density = 50 W/m^2

Here, change in momentum $\Delta p = p_f - p_i$

$\Delta p = (-p_i/4) - p_i$

$\Delta p = -5p_i/4$ ∵ $p_i = E/c = 50 \text{ W/s}/(3 \times 10^8)$

$\Delta p/\Delta t = F = | -5p_i/4 | = (5/4) \times (50/(3 \times 10^8)) = 20.8 \times 10^{-8} \text{ N} \approx 20 \times 10^{-8} \text{ N}$

Answer: (a) 20×10^{-8} N

Q4: A red LED emits light at 0.1 watts uniformly around it. The amplitude of the electric field of the light at a distance of 1 m from the diode is

(a) 5.48 V/m

(b) 7.75 V/m

(c) 1.73 V/m

(d) 2.45 V/m

Solution

The intensity of light, $I = u_{av} c$

Also, $I = P/4\pi r^2$ and $u_{av} = \frac{1}{2}\varepsilon_0 E_0^2$

∴ $P/4\pi r^2 = (\frac{1}{2})\varepsilon_0 E_0^2$

Or $E_0 = \sqrt{\frac{2P}{4\pi\epsilon_0 r^2 c}}$

Here, $P = 0.1$ W, $r = 1$ m, $c = 3 \times 10^8 \text{ m s}^{-1}$

$1/4\pi\varepsilon_0 = 9 \times 10^9 \text{ N C}^{-2} \text{ m}^2$

$$E_0 = \sqrt{\frac{2 \times 0.1 \times 9 \times 10^9}{1^2 \times 3 \times 10^8}} = \sqrt{6}$$

Answer: (d) 2.45 V/m

Q5: 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-I	List-II
(P) Infrared waves	(i) To treat muscular strain
(Q) Radio waves	(ii) For broadcasting
(R) X-rays	(iii) To detect fracture of bones
(S) Ultraviolet rays	(iv) Absorbed by the ozone layer of the atmosphere

P Q R S

(a) (i) (ii) (iii) (iv)

(b) (iv) (iii) (ii) (i)

(c) (i) (ii) (iv) (iii)

(d) (iii) (ii) (i) (iv)

Solution

Infrared waves are used to treat muscular strain. Radio waves are used for broadcasting. X-rays are used to detect the fracture of bones. Ultraviolet rays are absorbed by the ozone layer of the atmosphere.

Answer: (a)

P Q R S

(i) (ii) (iii) (iv)

Q6: During the propagation of electromagnetic waves in a medium

(a) both electric and magnetic energy densities are zero

(b) electric energy density is double of the magnetic energy density

(c) electric energy density is half of the magnetic energy density

(d) electric energy density is equal to the magnetic energy density

Solution: In an em wave, energy is equally divided between the electric and the magnetic fields.

Answer: (d) The electric energy density is equal to the magnetic energy density

Q7: The magnetic field in a travelling electromagnetic wave has a peak value of 20 nT. The peak value of electric field strength is

(a)12 V/m

(b) 3 V/m

(c) 6 V/m

(d) 9 V/m

Solution

In an electromagnetic wave, the peak value of the electric field (E_0) and peak value of magnetic field (B_0) are related by

$E_0 = B_0C$

$E_0 = (20 \times 10^{-9}\ T)\ (3 \times 10^{8}\ m\ s^{-1}) = 6\ V/m$

Answer: (c) 6 V/m

Q8: An electromagnetic wave of frequency = 3.0 MHz passes from vacuum into a dielectric medium with permittivity = 4.0. Then

(a) wavelength is doubled and the frequency remains unchanged

(b) wavelength is doubled and frequency becomes half

(c) wavelength is halved and frequency remains unchanged

(d) wavelength and frequency both remain unchanged

Solution

During propagation of a wave from one medium to another, the frequency remains constant and wavelength changes.

$$\mu = \sqrt{\frac{\epsilon}{\epsilon_0}} = \sqrt{4} = 2$$

Since μ = 1/λ

Wavelength is halved

Answer: (c) wavelength is halved and frequency remains unchanged

Q9: Electromagnetic waves are transverse in nature is evident by

(a) polarization

(b) interference

(c) reflection

(d) diffraction

Answer: (a) Polarization proves the transverse nature of electromagnetic waves.

Q10: The energy associated with electric field is (U_E) and with magnetic field is (U_B) for an electromagnetic wave in free space. Then

(a) $U_E > U_B$

(b) $U_E = U_B/2$

(c) $U_E = U_B$

(d) $U_E < U_B$

Answer: (c) $U_E = U_B$

Q11: A 27 mW 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 $\varepsilon_0 = 9 \times 10^{-12}$ SI units, speed of light $c = 3 \times 10^8$ m/s]

(a) 2 kV/m

(b) 0.7 kV/m

(c) 1 kV/m

(d) 1.4 kV/m

Solution

The intensity of the electromagnetic wave is given by

I = Power(P)/Area(A) = ½ ε_0 E^2C

$$E = \sqrt{\frac{2P}{A\epsilon_0 c}} = \sqrt{\frac{2\times27\times10^{-3}}{10^{-5}\times9\times3\times10^{8}}}$$

Answer: (d) 1.4 kV/m

Q12: The RMS value of the electric field of the light coming from the sun is 720 N/C. The average total energy density of the electromagnetic wave is

(a) 3.3×10^{-3} J/m^3

(b) 4.58×10^{-6} J/m^3

(c) 6.37×10^{-9} J/m^3

(d) 81.35×10^{-12} J/m^3

Solution

$U = (½)\epsilon_0 (E^2_{rms}) + (½\mu_0) (B^2_{rms})$

$U = (½)\epsilon_0 (E^2_{rms}) + (½\mu_0) (E^2_{rms}/c^2)$

$U = (½)\epsilon_0 (E^2_{rms}) + (½\mu_0) (E^2_{rms}\epsilon_0\mu_0)$

$U = (½)\epsilon_0 (E^2_{rms}) + (½)\epsilon_0 (E^2_{rms}) = \epsilon_0 (E^2_{rms})$

U = (8.85 x 10^{-12}) x $(720)^2$ = 4.58 x10^{-6} Jm^{-1}

Answer (b) 4.58 × 10^{-6} J/m^3

Q13: Which of the following are not electromagnetic waves?

(a) cosmic rays

(b) gamma rays

(c) β-rays

(d) X-rays

Answer: (c) β-rays are not electromagnetic waves

Q14: If a source of power 4kW produces 10^{20} photons/second, the radiation belongs to a part of the spectrum called

(a) microwaves

(b) y-rays

(c) X-rays

(d) ultraviolet rays

Solution

E_{proton} = (4 x 10^3)/10^{20} = 4 x 10^{-17} J = (4/1.6) x 10^2 eV = 250 eV

λ_{proton} = 1242/250 = 50 Å (x -ray)

Answer: (c) X-rays

Q15: An EM wave from the air enters a medium. The electric fields are

$$\vec{E}_1 = E_{01}\hat{x}cos\left[2\pi f\left(\frac{z}{c} - t\right)\right]$$

in air and $\vec{E}_2 = E_{02}\hat{x}cos\left[k(2z - ct)\right]$

in medium, where the wavenumber k and frequency f refer to their values in air. The medium is non-magnetic. If ε_{r1} and ε_{r2} refer to relative permittivities of air and medium respectively, which of the following options is correct?

(a) ε_{r1} /ε_{r2} = 4

(b) ε_{r1} /ε_{r2} = 2

(c) ε_{r1} /ε_{r2} = 1/4

(d) ε_{r1} /ε_{r2} = ½

Solution

In the air, the EM wave is

$$\vec{E_1} = E_{01}\hat{x}cos\left[2\pi f\left(\frac{z}{c} - t\right)\right]$$

$$= \vec{E_2} = E_{02}\hat{x}cos\left[k(z - ct)\right]$$ (since, $k = 2\pi/\lambda_0 = 2\pi f/c$)

In the medium, the EM wave is

$$\vec{E_2} = E_{02}\hat{x}cos\left[k(2z - ct)\right] \ \vec{E_2} =$$

$$E_{02}\hat{x}cos\left[2k(z - (c/2)t)\right]$$

During refraction, frequency remains unchanged, whereas the wavelength gets changed

k' = 2k (From equations)

$2\pi/\lambda' = 2(2\pi/\lambda_0) = \lambda' = \lambda_0/2$

Since, v = c/2

$$\frac{1}{\sqrt{\mu_0 \epsilon_{r2}}} = \frac{1}{2} \times \frac{1}{\sqrt{\mu_0 \epsilon_{r1}}}$$

$\varepsilon_{r1}/\varepsilon_{r2} = 1/4$

Answer: (c) $\varepsilon_{r1} / \varepsilon_{r2} = 1/4$