CBSE Test Paper-05

Class - 12 Physics (Electromagnetic Waves)

1. The magnetic field in a plane electromagnetic wave is given by By = $2 \times 10^{-7} \sin (0.5 \times 10^{3} \mathrm{x} + 1.5 \times 10^{11} \mathrm{t}) \mathrm{T}$. Wavelength and frequency of the wave are
   a. 1.20 cm, 22.9 GHz
   b. 1.26 cm, 23.9 GHz
   c. 1.06 cm, 21.9 GHz
   d. 1.16 cm, 23.9 GHz
2. Do EM waves need a medium to travel through?
   a. No
   b. Yes
   c. Ether is required
   d. None of these
3. Suppose that the electric field amplitude of an electromagnetic wave is E_0 = 120 N/C and that its frequency is ν = 50.0 MHz B_0, ω, k, and λ. are
   a. 400 nT, 3.14 $\times$ 10^8 rad/s, 1.05 m^{-1}, 6.00 m
   b. 450 nT, 3.0 $\times$ 10^8 rad/s, 1.05 m^{-1}, 6.00 m
   c. 500 nT, 3.3 $\times$ 10^8 rad/s, 1.05 $^{-1}$, 6.00 m
   d. 550 nT, 3.14 $\times$ 10^8 rad/s, 1.05 $^{-1}$, 6.00 m
4. Tanning of the skin in sunlight is due to
   a. UV radiation
   b. cosmic rays
   c. infrared
   d. visible light
5. The r.m.s. value of the electric field of the light coming from the sun is 720 NC^{-1}. The average total energy density of the electromagnetic wave is:
   a. $6.37 \times 10^{-9} Jm^{-3}$
   b. $81.35 \times 10^{-12} Jm^{-3}$
   c. $3.3 \times 10^{-3} Jm^{-3}$
   d. $4.58 \times 10^{-6} Jm^{-3}$

6. To which part of the electromagnetic spectrum does a wave of frequency 5×10^{19} Hz belong?

7. Arrange the following electromagnetic waves in order of increasing frequency : γ - rays, microwaves, infrared rays and ultraviolet rays.

8. Which part of electromagnetic spectrum is used in RADAR systems?

9. To which part of the electromagnetic spectrum does a wave of frequency 3×10^{13} Hz belong?

10. What is the cause of conduction current?

11. Explain briefly how electromagnetic waves are produced by an oscillating charge? How is the frequency of the electromagnetic waves produced related to that of the oscillating charge?

12. Name the constituent radiation of electromagnetic spectrum which is used for
    i. aircraft navigation
    ii. studying the crystal structure Write the frequency range for each.
13. About 5% of the power of a 100 W light bulb is converted to visible radiation. What is the average intensity of visible radiation.
    a. at a distance of 1 m from the bulb?
    b. at a distance of 10 m? Assume that the radiation is emitted isotropically and neglect reflection.
14. The oscillating magnetic field in a plane electromagnetic wave is given by $B_y = (8 \times 10^{-6}) \sin\left[2 \times 10^{11} t + 300\pi x\right] T$
    i. Calculate the wavelength of the electromagnetic wave.
    ii. Write down the expression for the oscillating electric field.

15. The terminology of different parts of the electromagnetic spectrum is given in the text. Use the formula E = h v (for energy of a quantum of radiation: photon) and obtain the photon energy in units of eV for different parts of the electromagnetic spectrum. In what way are the different scales of photon energies that you obtain related to the sources of electromagnetic radiation.

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Answers

1. b. 1.26 cm, 23.9 GHz

   Explanation: Comparing $2 \times 10^{-7} \sin\left(0.5 \times 10^{3} \mathrm{x} + 1.5 \times 10^{11} \mathrm{t}\right) \mathrm{T}$ with $B_o sin(kx + \omega t)$, we get k = 0.5 x 10^3 and *w* = 1.5 x 10^{11}.

   Now, $\lambda = \frac{2\pi}{k} = \frac{2 \times 3.14}{0.5 \times 10^3} = 0.0126m = 1.26cm$

   $\nu = \frac{\omega}{2\pi} = \frac{(1.5 \times 10^{11})}{(2 \times 3.14)} = 0.239 \times 10^{11} = 23.9GHz$

2. a. No

   Explanation: Oscillatory electric and magnetic field produces EM wave. As electric and magnetic field can propagate in vacuum, EM wave do not necessarily require medium.

3. a. 400 nT, 3.14 × 10^8 rad/s, 1.05 m^{-1}, 6.00 m

   Explanation: $B_o = \frac{E_o}{c} = \frac{120}{3 \times 10^8} = 4 \times 10^{-7} T = 400nT$

   $\omega = 2\pi\nu = 2 \times 3.14 \times 50 \times 10^6$

   $= 3.14 \times 10^8 rad/s$

   $\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{50 \times 10^6} = 6m$

   $k = \frac{2\pi}{\lambda} = \frac{2 \times 3.14}{6} \approx 1.05m^{-1}$

4. a. UV radiation

   Explanation: Exposure to UV radiation induces the production of more melanin, causing tanning of the skin.

5. d. $4.58 \times 10^{-6} Jm^{-3}$

   Explanation: $Energy\ density = \epsilon_o E^2$

   $= 8.85 \times 10^{-12} \times 720 \times 720$

   $= 4.58 \times 10^{-6} Jm^{-3}$

6. A wave of frequency 5 × 10^{19} Hz belong to γ - rays of electromagnetic spectrum. As we know that frequency range of gamma ray is from 10^{16} Hz to 10^{19} Hz.

7. Energy of an electromagnetic wave completely depends on the frequency of the wave.

Hence electromagnetic waves given in the above question arranged in increasing order of frequency is as follows:
Microwaves < Infrared rays < Ultraviolet rays < γ -rays.

8. Short radio waves or microwaves are used in RADAR system.

9. The waves of frequency of 3×10^{13}Hz belongs to the infrared waves. As we know that the frequency range of infrared ray is from 10^{11} Hz to 10^{14} Hz.

10. The cause of conduction current is the flow of electrons in the conductor under the effect of potential difference applied.

11. **For the production of electromagnetic waves**
The oscillating charge produces an oscillating electric field and an oscillating electric field produces a magnetic field which then produces an oscillating emf. An oscillating voltage (emf) produces electric fields and so on. This oscillating electric and magnetic fields regenerate each other as the wave propagates through space. In this way, the oscillating charges produce electromagnetic waves. Electric and magnetic field vector components of the electromagnetic wave vibrate perpendicular to each other and also perpendicular to the direction of propagation of the electromagnetic wave.
The frequency of the electromagnetic waves naturally equals the frequency of oscillation of the charge.

12. i. Microwaves are used for aircraft navigation(RADAR systems), their frequency range is 10^9 Hz 10^{12} Hz.
    ii. X-rays are used to study crystal structure(with the method of X-ray powder diffraction or XRD), their frequency range is 10^{16} Hz to 10^{20} Hz

13. Power converted into visible radiation,
$P = \frac{5}{100} \times 100W = 5w$ = 5 W
Intensity $= \frac{Energy}{Area \times Time} = \frac{Power}{Area} = \frac{P}{4\pi r^2}$
    a. Intensity, $I = \frac{5}{4 \times 3.14 \times 1 \times 1} = 0.4\ Wm^{-2}$
    b. $I = \frac{5}{4 \times 3.14 \times 10 \times 10} Wm^{-2}$
    = 0.004 Wm^{-2}

14. Given equation is:
$B_y = (8 \times 10^{-6}) \sin\left[2 \times 10^{11} t + 300\pi x\right] T$
Comparing the given equation with the equation of magnetic field varying sinusoidally with x and t
$B_y = B_0 \sin\left(\frac{2\pi x}{\lambda} + \frac{2\pi t}{T}\right)$
We get $\frac{2\pi}{\lambda} = 300\pi$
$\therefore \lambda = \frac{2}{300} = 0.0067m$
and $B_0 = 8 \times 10^{-6} T$

    i. The wavelength of the electromagnetic wave
    $\lambda = 0.0067m$
    ii. $E_0 = CB_0 = 3 \times 10^8 \times 8 \times 10^{-6}$
    $= 24 \times 10^2 = 2400 V m^{-1}$
    $\therefore$The required expression for the oscillating electric field is:
    $E_z = E_0 \sin\left(\frac{2\pi x}{\lambda} + \frac{2\pi t}{T}\right)$
    $= 2400 \sin(300\pi x + 2 \times 10^{11} t) V/m$

15. Energy of photon
E = hv
or $E = h\frac{C}{\lambda}$
$h = 6.62 \times 10^{-34} Js$ $C = 3 \times 10^8 m s^{-1}$
If λ is in metre, E in J, then we divide by 1.6×10^{-19} to convert E into eV.
$\therefore E = \frac{hc}{\lambda \times 1.6 \times 10^{-19}} eV$

    1. $\gamma-$ **rays:** 1 ranges from 10^{-10}m to less that 10^{-14} m
    $\therefore$ Energy $= \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{10^{-10} \times 1.6 \times 10^{-19}} eV$
    $= 12.4 \times 10^3 eV \approx 10^4 eV$
    Thus for $\lambda = 10^{-10} m$ Energy = 10^4eV
    For $\lambda = 10^{-14} m$, energy = 10^8eV
    Energy of γ - rays between 10^4 to 10^8eV
    2. **X-rays.** 1 ranges from 10^{-8}m to 10^{-13}m
    For $\lambda = 10^{-8}$

Energy $= \frac{6.62\times10^{-34}\times3\times10^{8}}{10^{-8}\times1.6\times10^{-19}}eV$

$= 124 \approx 10^{2}eV$

For $\lambda = 10^{-13}m$, energy = 10^{7}eV

3. **Ultraviolet radiations.** λ ranges from $4 \times 10^{-7}m$ to $6 \times 10^{-10}m$

   For $\lambda = 4 \times 10^{-7}$

   Energy $= \frac{6.62\times10^{-34}\times3\times10^{8}}{4\times10^{-7}\times1.6\times10^{-19}}eV$

   $= 3.1eV \approx 10^{0}eV$

   Energy of ultraviolet radiations vary between 10^{0} to 10^{3}eV.

4. **Visible radiations.** λ ranges from $4 \times 10^{-7}m$ to $7 \times 10^{-7}m$

   For $\lambda = 4 \times 10^{-7}$, energy = 10° eV (as proved above)

   For $\lambda = 7 \times 10^{-7}$

   $\therefore$ Energy $= \frac{6.62\times10^{-34}\times3\times10^{8}}{7\times10^{-7}\times1.6\times10^{-19}}eV$

   $= 1.77eV \approx 10^{\circ}eV$

5. **Infrared radiations.** λ ranges from $7 \times 10^{-7}m$ to $7 \times 10^{-4}m$

   For $\lambda = 7 \times 10^{-7}$energy = 10° eV (as proved above)

   For $\lambda = 7 \times 10^{-4}$

   The energy is $\frac{1}{1000}$ times i.e. of the order of 10^{-3}eV.

6. **Micro waves.** λranges from 1 mm to 0.3 m.

   For λ = 1 mm or 10^{-3}

   Energy is equal to $E = \frac{6.62\times10^{-34}\times3\times10^{8}}{10^{-3}\times1.6\times10^{-19}}eV$

   $= 1.24 \times 10^{-3}eV = 10^{-3}eV$

   For $\lambda = 0.3m$, Energy $= 4.1 \times 10^{-6}eV = 10^{-6}eV$

7. **Radio waves.** λ ranges from 1 m to few km.

   For $\lambda = 1m$

   Energy is equal to $E = \frac{6.62\times10^{-34}\times3\times10^{8}}{10^{\circ}\times1.6\times10^{-19}}eV$

   $= 1.24 \times 10^{-6}eV = 10^{-6}eV$

   Energy for λ of the order of few km = 10^{-6}eV

   Energy of a photon that a source produces indicates the spacing of relevant energy levels of the source.