SELF ASSESSMENT PAPER - 5

SOLUTIONS

I. Multiple Choice Questions **[1 × 4 = 4]**

1. Option (B) is correct.

Explanation: The wavelength (λ) and frequency (ν) of an electromagnetic wave are related by an equation $c = \nu\lambda$. Given: $\lambda = 5 \times 10^{-5}$ m.

$$\nu = \frac{c}{\lambda} = \frac{3\times10^{8}}{5\times10^{-5}} = 6\times10^{12}\,\text{Hz}$$

2. Option (D) is correct.

Explanation: Maxwell found that the electromagnetic wave propagates in free space with a speed of $c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$.

3. Option (B) is correct.

Explanation: The electric and magnetic field vectors are always perpendicular to the direction of propagation of the electromagnetic wave. They vary sinusoidally, with the same frequency and in phase with each other.

4. Option (A) is correct.

Explanation: Among the given options, gamma rays have the highest frequency ranging from 3×10^{18} Hz to 5×10^{22} Hz.

II. Assertion & Reason **[1 × 2 = 2]**

1. Option (B) is correct.

Explanation: Since, the circular motion is an accelerated motion and an accelerated charge emits electromagnetic waves. Hence, the given assertion is correct.

Also, the electric field vector is always perpendicular to the magnetic field vector in electromagnetic wave. Hence, the given reason statement is also correct. But it is not the correct explanation of the assertion.

2. Option (A) is correct.

Explanation: An electromagnetic wave exchanges momentum and energy with the surface when it falls on it. So, it exerts pressure on the surface.

Hence, both statements are correct and reason are the correct explanation of the assertion.

III. Competency Based Questions **[1 × 4 = 4]**

1. Option (C) is correct.

Explanation: The electromagnetic spectrum in increasing order of the frequencies is given by radio waves < microwaves < infrared < visible light < ultra violet < x-rays < gamma rays.

2. Option (B) is correct.

3. Option (A) is correct.

4. Option (B) is correct.

Explanation: We know the speed of electromagnetic waves with different frequencies remain same in vacuum (free space). So, $\nu_1\lambda_1 = \nu_2\lambda_2$.

i.e., $\frac{\nu_1}{\nu_2} = \frac{\lambda_2}{\lambda_1} = 5\times10^{6}$

$\lambda_2 = 5 \times 10^{6} \times 0.6 \times 10^{-14}$ m

$\lambda_2 = 3 \times 10^{-8}$ m

5. Option (C) is correct.

Explanation: X-rays are used in radio therapy to cure skin diseases and malignant growths.

IV. Very Short Answer Type Questions **[1 × 3 = 3]**

1. Microwaves, infrared rays, yellow light, ultraviolet rays, γ-rays.

2. High energy particle like X-rays and gamma rays both are used in cancer and tumor treatments.

3. No, the electromagnetic waves move with same speed in free space (vacuum) only.

V. Short Answer Type Questions-I **[2 × 3 = 6]**

1. (i) Average surface temperature would be lower. Because there would be no green house effect in the absence of atmosphere.

(ii) Infrared rays are readily absorbed by the water molecules in most of the substances and hence increase their thermal motion.

2. (i) The electromagnetic waves are generated by oscillating charges.

(ii) These waves are transverse in nature.

(iii) These waves do not require any material medium to travel.

(iv) The electric and magnetic field vectors are always mutually perpendicular to each other and they both are perpendicular to the direction of propagation of the electromagnetic wave.

3. The electric and magnetic field vectors oscillate perpendicular to each other and they both are also perpendicular to the direction of propagation of the electromagnetic wave. As, electric field vector is oscillating in *z*-direction, so the respective directions of wave propagation and oscillating magnetic field vector must be along *y*-axis and *x*- axis.

Given: $|\vec{E}| = 1.5\frac{\text{V}}{\text{m}}$

We know $|\vec{B}| = \frac{|\vec{E}|}{c} = \frac{1.5\,\text{V/m}}{3\times10^{8}\,\text{m/s}} = 0.5\times10^{-8}\,\text{T}$

VI. Short Answer Type Questions-II **[3 × 2 = 6]**

1. (a) Given: $B_y = 10^{-7} \sin (1000\pi x + \pi \times 10^{11} t)$ Tesla

Comparing the equation with

$$B_y = B_0 \sin\left[2\pi\left(\frac{x}{\lambda} + \frac{t}{T}\right)\right]$$

We get, $B_0 = 10^{-7}$ T

$$\frac{2\pi}{\lambda} = 1000\pi \text{ or } \lambda = 2 \times 10^{-3} \text{ m}$$

and, $\frac{2\pi}{T} = \pi \times 10^{11}$ or $\frac{1}{T} = \nu = 5 \times 10^{10}$ Hz

(b) It belongs to microwave region of the electromagnetic spectrum.

(c) $E_0 = cB_0 = 3 \times 10^8 \times 10^{-7} = 30$ V/m

The electric field is perpendicular to the direction of propagation and magnetic field vector also. Therefore, the electric field variation is along z-axis. It is given by

$E_z = 30 \sin (1000\,\pi x + \pi \times 10^{11}\, t)$ V/m

2. Given: Energy flux = 10 W/cm². The total energy falling on the surface of 20 cm² is

$$U = \left(\frac{10W}{\text{cm}^2}\right) \times 20 \text{ cm}^2 \times 30 \times 60$$

$U = 3.6 \times 10^5$ J

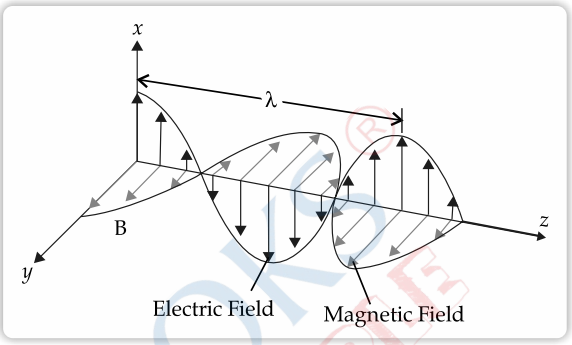
The average force exerted on the surface is

$$F = \frac{p}{t} = \frac{U}{ct} = \frac{3.6 \times 10^5}{3 \times 10^8 \times 1800} = 0.67 \times 10^{-6} \text{ N}.$$

VII. Long Answer Type Question **[5 × 1 = 5]**

1. (a) The electromagnetic waves are the waves which are produced by the accelerated charges in which the electric and magnetic field vectors oscillate at right angles and are perpendicular to the direction of wave propagation.

The diagram representing the wave propagation along z- direction with their oscillating electric and magnetic field components is shown below.



(b) The general expression for the electric and magnetic fields components of the electromagnetic wave is given by

$E_x = E_0 \sin [kz - \omega t]$, $B_y = B_0 \sin [(kz - \omega t)]$

where $B_0 = \frac{E_0}{c}$, $k = \frac{2\pi}{\lambda}$ and $\omega = 2\pi\nu$.

The speed of the propagation of the wave is given by $\frac{\omega}{k}$. In free space, the speed of the propagation becomes equal to the speed of the light (i.e., $c = 3 \times 10^8$ m/s).

In a material medium of permittivity ε and magnetic permeability μ, the velocity of light becomes $v = \frac{1}{\sqrt{\varepsilon\mu}}$. Thus, the velocity of light depends on electric and magnetic properties of the medium.

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