

Electromagnetic Waves

Question1

Match the following types of waves with their wavelength ranges

Waves	Wavelength ranges
i. Microwave	a. 700 nm to 400 nm
ii. Visible light	b. 1 nm to 10^{-3} nm
iii. Ultraviolet	c. 0.1 m to 1 mm
iv. X-rays	d. 400 nm to 1 nm

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Options:

- A. i-c, ii-a, iii-d, iv-b
- B. i-d, ii-b, iii-c, iv-a
- C. i-b, ii-c, iii-a, iv-d
- D. i-a, ii-d, iii-b, iv-c

Answer: A

Solution:

The correct matching is

- i. Microwave → c. 0.1 m to 1 mm
- ii. Visible light → a. 700 nm to 400 nm
- iii. Ultraviolet → d. 400 nm to 1 nm
- iv. X-rays → b. 1 nm to 10^{-3} nm

That corresponds to **Option A**.



Question2

The total energy carried by the light wave when it travels from a rarer to a non-reflecting and nonabsorbing medium

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Options:

- A. remains same
- B. increases
- C. either increases or decreases depending upon angle of incidence
- D. decreases

Answer: A

Solution:

When light passes into a non-reflecting, non-absorbing medium, no energy is lost at the boundary. In particular:

Energy flux is given by the (time-averaged) Poynting vector

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

For no reflection and no absorption, the tangential components of both fields are continuous across the interface:

$$E_1 = E_2, \quad H_1 = H_2.$$

Hence the incident and transmitted fluxes are equal:

$$S_1 = E_1 H_1 = E_2 H_2 = S_2.$$

Since all the energy that arrives is carried forward, the total energy carried by the wave remains the same.

Answer: Option A (remains same).

Question3



Electromagnetic waves are incident normally on a perfectly reflecting surface having surface area A . If I is the intensity of the incident electromagnetic radiation and c is the speed of light in vacuum, the force exerted by the electromagnetic wave on the reflecting surface is

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Options:

A. $2IA/c$

B. LA/C

C. $IA/2c$

D. $I/2Ac$

Answer: A

Solution:

The force exerted by electromagnetic waves on a perfectly reflecting surface can be derived using the concept of radiation pressure. When electromagnetic waves are incident on a reflecting surface, they exert a pressure due to the change in momentum as they reflect.

For a perfectly reflecting surface, the radiation pressure P is given by:

$$P = \frac{2I}{c}$$

where:

I is the intensity of the incident radiation,

c is the speed of light.

The force F exerted on a surface due to radiation pressure is given by multiplying the radiation pressure by the surface area A :

$$F = P \times A = \frac{2I}{c} \times A = \frac{2IA}{c}$$

Therefore, the correct expression for the force exerted by the electromagnetic wave on the reflecting surface is:

Option A

$$\frac{2IA}{c}$$



Question4

The ratio of the magnitudes of electric field to the magnetic field of an electromagnetic wave is of the order of

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Options:

A. 10^{-8} ms^{-1}

B. 10^5 ms^{-1}

C. 10^{-5} ms^{-1}

D. 10^8 ms^{-1}

Answer: D

Solution:

As we know,

$$v = \frac{E}{B} \text{ or } v = \frac{|E|}{|B|}$$

For an electromagnetic wave, $v = c$

$$\therefore \frac{|E|}{|B|} = c = 3 \times 10^8 \text{ ms}^{-1}$$

$$\therefore |E| : |B| \text{ is of the order of } 10^8 \text{ ms}^{-1}.$$

Question5

Which of the following radiations of electromagnetic waves has the highest wavelength ?

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Options:

- A. UV-rays
- B. IR-rays
- C. Microwaves
- D. X-rays

Answer: C

Solution:

Increasing order of wavelength of given electromagnetic wave is given as

$$\lambda_{\text{X-rays}} < \lambda_{\text{UV-rays}} < \lambda_{\text{IR-rays}} < \lambda_{\text{microwaves}}$$

Hence, microwaves has highest wavelengths.

Question6

Suppose that the electric field amplitude of electromagnetic wave is $E_0 = 120 \text{ NC}^{-1}$ and its frequency $f = 50 \text{ MHz}$. Then, which of the following value is incorrectly computed?

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Options:

- A. Magnetic field amplitude is 400nT.
- B. Angular frequency of EM wave is $\pi \times 10^8 \text{ rad/s}$.
- C. Propagation constant (angular wave number) is 2.1 rad/m.
- D. Wavelength of EM wave is 6 m.

Answer: C

Solution:

Given,

$$E_0 = 120 \text{NC}^{-1}$$

$$f = 50 \text{MHz} = 50 \times 10^6 \text{ Hz}$$

(a) magnetic field amplitude,

$$B_0 = \frac{E_0}{c} = \frac{120}{3 \times 10^8} = 40 \times 10^{-8} \text{ T} \\ = 400 \text{nT}$$

(b) Angular frequency, $\omega = 2\pi f = 2\pi \times 50 \times 10^6$

$$= \pi \times 10^8 \text{ rad/s}$$

(c) Propagation constant,

$$k = \frac{\omega}{c} = \frac{\pi \times 10^8}{3 \times 10^8} = 1.047 \text{rad/m}$$

(d) Wavelength, $\lambda = \frac{c}{f} = \frac{3 \times 10^8}{50 \times 10^6} = \frac{30}{5} = 6 \text{ m}$

Question 7

The source of electromagnetic wave can be a charge

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Options:

- A. moving with a constant velocity
- B. moving in a circular orbit
- C. at rest
- D. moving parallel to the magnetic field

Answer: B

Solution:

Electromagnetic waves are produced by accelerated charges. In given options, only a charge particle moving in a circular orbit is in accelerated motion. So, it produces electromagnetic wave.



Question8

A light beam of intensity 20 W/cm^2 is incident normally on a perfectly reflecting surface of sides $25 \text{ cm} \times 15 \text{ cm}$. The momentum imparted to the surface by the light per second is

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Options:

- A. $2 \times 10^{-5} \text{ kg} - \text{ms}^{-1}$
- B. $1 \times 10^{-5} \text{ kg} - \text{ms}^{-1}$
- C. $5 \times 10^{-5} \text{ kg} - \text{ms}^{-1}$
- D. $1.2 \times 10^{-5} \text{ kg} - \text{ms}^{-1}$

Answer: C

Solution:

Given, intensity, $I = 20 \text{ W/cm}^2$

Area of surface, $A = (25 \times 15)\text{cm}^2$

and time, $t = 1 \text{ s}$

The intensity of light of energy E is given by

$$I = \frac{E}{At} \Rightarrow 20 = \frac{E}{25 \times 15 \times 1}$$
$$\Rightarrow E = 20 \times 25 \times 15 \text{ J}$$

The momentum imparted to a perfectly reflecting surface is given by

$$p = \frac{2E}{c} = \frac{2 \times 20 \times 25 \times 15}{3 \times 10^8} = 5 \times 10^{-5} \text{ kg ms}^{-1}$$

Question9

An antenna uses electromagnetic waves of frequency 5 MHz . For proper working, the size of the antenna should be



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Options:

- A. 15 m
- B. 300 m
- C. 15 km
- D. 3 km

Answer: A

Solution:

Given, Frequency of wave, $f = 5 \text{ MHz} = 5 \times 10^6 \text{ Hz}$

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

For proper working, the size of antenna should be $\frac{\lambda}{4}$

$$\text{i.e. } l = \frac{\lambda}{4} = \frac{60}{4} = 15 \text{ m}$$

Question10

Due to Doppler's effect the shift in wavelength observed is $0.1 \overset{\circ}{\text{A}}$ for a star producing wavelength $6000 \overset{\circ}{\text{A}}$. Velocity of recession of the star will be

KCET 2019

Options:

- A. 25 km/s
- B. 10 km/s
- C. 5 km/s



D. 20 km/s

Answer: C

Solution:

Given, Doppler's shift, $\Delta\lambda = 0.1\overset{\circ}{\text{A}}$

$$= 0.1 \times 10^{-10} \text{ m} = 10^{-11} \text{ m}$$

wavelength, $\lambda = 6000\overset{\circ}{\text{A}} = 6 \times 10^{-7} \text{ m}$

If v_s is the velocity of recession of the star and c is velocity of light, then Doppler's shift

$$\begin{aligned} \Delta\lambda &= \left(\frac{v_s}{c}\right)\lambda \Rightarrow v_s = \frac{c \cdot \Delta\lambda}{\lambda} = \frac{3 \times 10^8 \times 10^{-11}}{6 \times 10^{-7}} \\ &= 0.5 \times 10^4 = 5 \times 10^3 \text{ m/s} = 5 \text{ km/s} \end{aligned}$$

Question11

An electromagnetic wave is travelling in x -direction with electric field vector given by, $\mathbf{E}_y = E_0 \sin(kx - \omega t)\hat{\mathbf{j}}$. The correct expression for magnetic field vector is

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Options:

A. $\mathbf{B}_y = E_0 C \sin(kx - \omega t)\hat{\mathbf{j}}$

B. $\mathbf{B}_z = E_0 C \sin(kx - \omega t)\hat{\mathbf{k}}$

C. $\mathbf{B}_y = \frac{E_0}{C} \sin(kx - \omega t)\hat{\mathbf{j}}$

D. $\mathbf{B}_z = \frac{E_0}{C} \sin(kx - \omega t)\hat{\mathbf{k}}$

Answer: D

Solution:

As in Electromagnetic wave, v , E and B are mutually perpendicular,



$\therefore \mathbf{B}$ is along Z - axis

$$\text{So, } \mathbf{B}_z = B_0 \sin(kx - \omega t) \hat{\mathbf{k}}$$

$$\text{further, } B_0 = \frac{E_0}{C}$$

$$\therefore \mathbf{B}_z = \frac{E_0}{C} \sin(kx - \omega t) \hat{\mathbf{k}}$$

Question12

The phenomenon involved in the reflection of radio-waves by ionosphere is similar to

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Options:

- A. reflection of light by plane mirror
- B. total internal reflection of light in air during a mirage
- C. dispersion of light by water molecules during the formation
- D. scattering of light by air particles

Answer: B

Solution:

Radio waves (frequencies upto 30 MHz) propagate from transmitters as sky waves le they are totally reflected by the ionosphere layer of atmosphere, (after which they are received by various receivers) so phenomena is similar to TIR (Total Internal Reflection) of light in air resulting in mirage effect.

Question13

If \mathbf{E} and \mathbf{B} represent electric and magnetic field vectors of an electromagnetic wave, the direction of propagation of the wave is along

KCET 2017



Options:

A. $\mathbf{E} \times \mathbf{B}$

B. $\mathbf{B} \times \mathbf{E}$

C. \mathbf{E}

D. \mathbf{B}

Answer: A

Solution:

According to electromagnetic wave property, the electric field is perpendicular to the magnetic field. The direction of electromagnetic wave propagation will perpendicular to \mathbf{E} and \mathbf{B} . then $\mathbf{E} \times \mathbf{B} = \mathbf{C}$

