CHAPTER

8

Electromagnetic Waves

Syllabus

Electromagnetic waves, their characteristics, their Transverse nature (qualitative ideas only).

Electromagnetic spectrum (radio waves, microwaves, infrared, visible, ultraviolet, X-rays, gamma rays) including elementary facts about their uses.

CASE STUDY / PASSAGE BASED QUESTIONS

Questions 1-7 are Case Study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.

1

Directions of Electromagnetic Waves

In an electromagnetic wave both the electric and magnetic fields are perpendicular to the direction of propagation, that is why electromagnetic waves are transverse in nature. Electromagnetic waves carry energy as they travel through space and this energy is shared equally by the electric and magnetic fields. Energy density of an electromagnetic waves is the energy in unit volume of the space through which the wave travels.

(i) The electromagnetic waves propagated perpendicular to both $\vec{E}$ and $\vec{B}$. The electromagnetic waves travel in the direction of

(a) $\vec{E}\cdot\vec{B}$ (b) $\vec{E}\times\vec{B}$

(c) $\vec{B}\cdot\vec{E}$ (d) $\vec{B}\times\vec{E}$

(ii) Fundamental particle in an electromagnetic wave is

(a) photon (b) electron

(c) phonon (d) proton

(iii) Electromagnetic waves are transverse in nature is evident by

(a) polarisation (b) interference

(c) reflection (d) diffraction

(iv) For a wave propagating in a medium, identify the property that is independent of the others.

(a) velocity (b) wavelength

(c) frequency (d) all these depend on each other

(v) The electric and magnetic fields of an electromagnetic waves are

(a) in opposite phase and perpendicular to each other

(b) in opposite phase and parallel to each other

(c) in phase and perpendicular to each other

(d) in phase and parallel to each other.

2

Speed of Electromagnetic Wave

Maxwell showed that the speed of an electromagnetic wave depends on the permeability and permittivity of the medium through which it travels. The speed of an electromagnetic wave in free space is given by $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$.

The fact led Maxwell to predict that light is an electromagnetic wave. The emergence of the speed of light from purely electromagnetic considerations is the crowning achievement of Maxwell's electromagnetic theory. The speed of an electromagnetic wave in any medium of permeability μ and permittivity ε will be $\frac{c}{\sqrt{K\mu_r}}$ where K is the dielectric constant of the medium and μ_r is the relative permeability.

(i) The dimensions of $\frac{1}{2}\varepsilon_0 E^2$ (ε_0 : permittivity of free space; E = electric field) is

(a) MLT^{-1} (b) ML^2T^{-2} (c) $ML^{-1}T^{-2}$ (d) ML^2T^{-1}

(ii) Let $[\varepsilon_0]$ denote the dimensional formula of the permittivity of the vacuum. If M = mass, L = length, T = time and A = electric current, then

(a) $[\varepsilon_0] = M^{-1}L^{-3}T^2A$ (b) $[\varepsilon_0] = M^{-1}L^{-3}T^4A^2$

(c) $[\varepsilon_0] = MLT^{-2}A^{-2}$ (d) $[\varepsilon_0] = ML^2T^{-1}$

(iii) An electromagnetic wave of frequency 3 MHz passes from vacuum into a dielectric medium with permittivity $\varepsilon = 4$. Then

(a) wavelength and frequency both remain unchanged

(b) wavelength is doubled and the frequency remains unchanged

(c) wavelength is doubled and the frequency becomes half

(d) wavelength is halved and the frequency remains unchanged.

(iv) Which of the following are not electromagnetic waves?

(a) cosmic rays (b) γ-rays (c) β-rays (d) X-rays

(v) The electromagnetic waves travel with

(a) the same speed in all media

(b) the speed of light $c = 3 \times 10^8$ m s^{-1} in free space

(c) the speed of light $c = 3 \times 10^8$ m s^{-1} in solid medium

(d) the speed of light $c = 3 \times 10^8$ m s^{-1} in fluid medium.

3

Momentum and Pressure of an Electromagnetic Wave

An electromagnetic wave transports linear momentum as it travels through space. If an electromagnetic wave transfers a total energy U to a surface in time t, then total linear momentum delivered to the surface is $p = \frac{U}{c}$.

When an electromagnetic wave falls on a surface, it exerts pressure on the surface. In 1903, the American scientists Nichols and Hull succeeded in measuring radiation pressures of visible light where other had failed, by making a detailed empirical analysis of the ubiquitous gas heating and ballistic effects.

(i) The pressure exerted by an electromagnetic wave of intensity I (W m^{-2}) on a non-reflecting surface is (c is the velocity of light)

(a) Ic (b) Ic^2 (c) I/c (d) I/c^2

(ii) Light with an energy flux of 18 W/cm^2 falls on a non-reflecting surface at normal incidence. The pressure exerted on the surface is

(a) 2 N/m^2 (b) 2×10^{-4} N/m^2

(c) 6 N/m^2 (d) 6×10^{-4} N/m^2

(iii) Radiation of intensity 0.5 W m^{-2} are striking a metal plate. The pressure on the plate is

(a) 0.166×10^{-8} N m^{-2} (b) 0.212×10^{-8} N m^{-2}

(c) 0.132×10^{-8} N m^{-2} (d) 0.083×10^{-8} N m^{-2}

(iv) A point source of electromagnetic radiation has an average power output of 1500 W. The maximum value of electric field at a distance of 3 m from this source (in V m^{-1}) is

(a) 500 (b) 100 (c) $\frac{500}{3}$ (d) $\frac{250}{3}$

(v) The radiation pressure of the visible light is of the order of

(a) 10^{-2} N m^2 (b) 10^{-4} N/m (c) 10^{-6} N/m^2 (d) 10^{-8} N

4

Electromagnetic Spectrum

All the known radiations from a big family of electromagnetic waves which stretch over a large range of wavelengths. Electromagnetic wave include radio waves, microwaves, visible light waves, infrared rays, UV rays, X-rays and gamma rays. The orderly distribution of the electromagnetic waves in accordance with their wavelength or frequency into distinct groups having widely differing properties is electromagnetic spectrum.

(i) Which wavelength of the Sun is used finally as electric energy?

(a) radio waves (b) infrared waves

(c) visible light (d) microwaves

(ii) Which of the following electromagnetic radiations have the longest wavelength?

(a) X-rays (b) γ-rays

(c) microwaves (d) radiowaves

(iii) Which one of the following is not electromagnetic in nature?

(a) X-rays (b) gamma rays

(c) cathode rays (d) infrared rays

(iv) Which of the following has minimum wavelength ?

(a) X-rays (b) ultraviolet rays

(c) γ-rays (d) cosmic rays

(v) The decreasing order of wavelength of infrared, microwave, ultraviolet and gamma rays is

(a) microwave, infrared, ultraviolet, gamma rays

(b) gamma rays, ultraviolet, infrared, microwave

(c) microwave, gamma rays, infrared, ultraviolet

(d) infrared, microwave, ultraviolet, gamma rays.

5

Radiations by Electromagnetic Waves

Electrons oscillating in a circuit give rise to radiowaves. A transmitting antenna radiates most effectively the radiowaves of wavelength equal to the size of the antenna. The infrared waves incident on a substance set into oscillation all its electrons, atoms and molecules. This increases the internal energy and hence the temperature of the substance.

(i) If v_g, v_X and v_m are the speeds of gamma rays, X-rays and microwaves respectively in vacuum, then

(a) $v_g > v_X > v_m$ (b) $v_g < v_X < v_m$ (c) $v_g > v_X > v_m$ (d) $v_g = v_X = v_m$

(ii) Which of the following will deflect in electric field?

(a) X-rays (b) γ-rays (c) cathode rays (d) ultraviolet rays

(iii) γ-rays are detected by

(a) point contact diodes (b) thermopiles (c) ionization chamber (d) photocells

(iv) The frequency of electromagnetic wave, which best suited to observe a particle of radius 3×10^{-4} cm is the order of

(a) 10^{15} Hz (b) 10^{14} Hz (c) 10^{13} Hz (d) 10^{12} Hz

(v) We consider the radiation emitted by the human body. Which one of the following statements is true?

(a) The radiation emitted is in the infrared region. (b) The radiation is emitted only during the day.

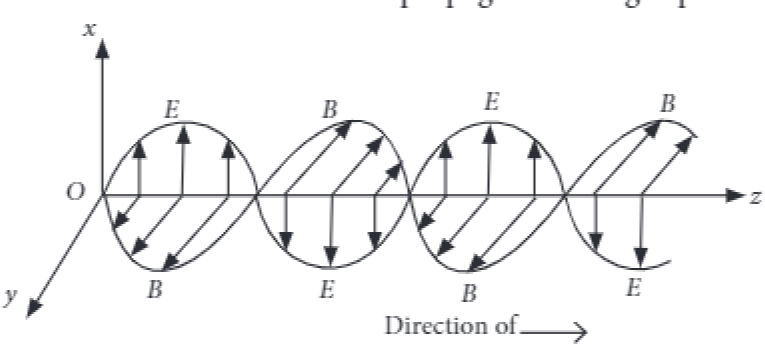
(c) The radiation is emitted during the summers and absorbed during the winters.

(d) The radiation emitted lies in the ultraviolet region and hence it is not visible.

6

Oscillating Charge

A stationary charge produces only an electrostatic field while a charge in uniform motion produces a magnetic field, that does not change with time. An oscillating charge is an example of accelerating charge. It produces an oscillating magnetic field, which in turn produces an oscillating electric fields and so on. The oscillating electric and magnetic fields regenerate each other as a wave which propagates through space.



(i) 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.)

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

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

(ii) 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

(a) $\frac{2E_0}{c}\hat{j}\cos kz\cos\omega t$ (b) $\frac{2E_0}{c}\hat{j}\sin kz\cos\omega t$ (c) $\frac{2E_0}{c}\hat{j}\sin kz\sin\omega t$ (d) $-\frac{2E_0}{c}\hat{j}\sin kz\sin\omega t$

(iii) A plane em wave of frequency 25 MHz travels in a free space along x-direction. At a particular point in space and time, $E = (6.3\,\hat{j})$ V/m. What is magnetic field at that time?

(a) 0.095 μT (b) 0.124 μT (c) 0.089 μT (d) 0.021 μT

(iv) A plane electromagnetic wave travelling along the x-direction has a wavelength of 3 mm. The variation in the electric field occurs in the y-direction with an amplitude 66 V m^{-1}. The equations for the electric and magnetic fields as a function of x and t are respectively

(a) $E_y = 33\cos\pi\times10^{11}\left(t-\frac{x}{c}\right)$, $B_z = 1.1\times10^{-7}\cos\pi\times10^{11}\left(t-\frac{x}{c}\right)$

(b) $E_y = 11\cos2\pi\times10^{11}\left(t-\frac{x}{c}\right)$, $B_y = 11\times10^{-7}\cos2\pi\times10^{11}\left(t-\frac{x}{c}\right)$

(c) $E_x = 33\cos\pi\times10^{11}\left(t-\frac{x}{c}\right)$, $B_x = 11\times10^{-7}\cos\pi\times10^{11}\left(t-\frac{x}{c}\right)$

(d) $E_y = 66\cos2\pi\times10^{11}\left(t-\frac{x}{c}\right)$, $B_z = 2.2\times10^{-7}\cos2\pi\times10^{11}\left(t-\frac{x}{c}\right)$

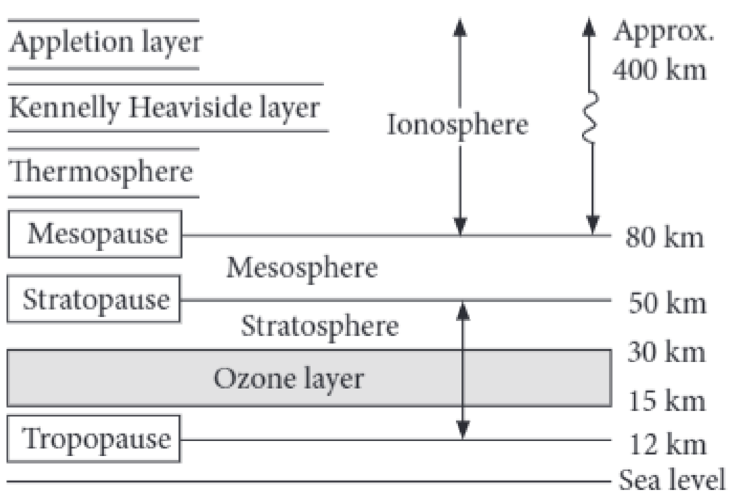
(v) A plane electromagnetic wave travels in free space along x-axis. At a particular point in space, the electric field along y-axis is 9.3 V m^{-1}. The magnetic induction (B) along z-axis is

(a) 3.1×10^{-8} T (b) 3×10^{-5} T (c) 3×10^{-6} T (d) 9.3×10^{-6} T

7

Sources of Electromagnetic Waves

Radio waves are produced by the accelerated motion of charges in conducting wires. Microwaves are produced by special vacuum tubes. Infrared waves are produced by hot bodies and molecules also known as heat waves. UV rays are produced by special lamps and very hot bodies like Sun.



(i) Solar radiation is
(a) transverse electromagnetic wave
(b) longitudinal electromagnetic waves
(c) both longitudinal and transverse electromagnetic waves
(d) none of these.

(ii) What is the cause of greenhouse effect?
(a) Infrared rays (b) Ultraviolet rays (c) X-rays (d) Radiowaves

(iii) Biological importance of ozone layer is
(a) it stops ultraviolet rays (b) It layer reduces greenhouse effect
(c) it reflects radiowaves (d) none of these.

(iv) Ozone is found in
(a) stratosphere (b) ionosphere (c) mesosphere (d) troposphere

(v) Earth's atmosphere is richest in
(a) ultraviolet (b) infrared (c) X-rays (d) microwaves

ASSERTION & REASON

For question numbers 8-20, two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false and R is also false

8. **Assertion (A) :** The electric field and magnetic field have equal average values in linearly polarised plane em wave.
Reason (R) : The electric energy and magnetic energy have equal average values in linearly polarised plane em wave.

9. **Assertion (A) :** Light can travel in vacuum whereas sound cannot do so.
Reason (R) : Light has an electromagnetic wave nature whereas sound is mechanical wave.

10. **Assertion (A) :** The microwaves are better carriers of signals than radio waves.
Reason (R) : The electromagnetic waves do not required any material medium for propagation.

11. **Assertion (A) :** Velocity of light is constant in all media.
Reason (R) : Light is an electromagnetic wave which has constant velocity in all media.

12. **Assertion (A) :** X-rays in vacuum travel faster than light waves in vacuum.
Reason (R) : The energy of X-rays photon is less than that of light photon.

13. **Assertion (A) :** In an electromagnetic wave, magnitude of magnetic field vector is much smaller than the magnitude of electric field vector.
Reason (R) : Energy of electromagnetic waves is shared equally by the electric and magnetic fields.

14. **Assertion (A) :** The electromagnetic waves are transverse in nature.
Reason (R) : These waves propagate in straight lines.

15. **Assertion (A) :** Light is a transverse wave but not an electromagnetic wave.
Reason (R) : Maxwell showed that speed of electromagnetic waves is related to the permittivity of the medium through which it travels.

16. **Assertion (A) :** Electromagnetic waves exert pressure called radiation pressure.
Reason (R) : Electromagnetic waves carries energy.

17. **Assertion (A) :** Infrared waves sometimes referred as heat waves.
Reason (R) : Infrared waves heat up the earth surface.

18. **Assertion (A) :** X-ray astronomy is possible only from satellites orbiting the earth.
Reason (R) : Efficiency of X-rays telescope is large as compared to any other telescope.

19. **Assertion (A) :** Radio waves cannot be diffracted by the buildings.
Reason (R) : The wavelength of radio waves is very small.

20. **Assertion (A) :** When a charged particle moves in a circular path. It produces electromagnetic wave.
Reason (R) : Charged particle has acceleration.

HINTS & EXPLANATIONS

1. (i) (b): Electromagnetic waves propagate in the direction of $\vec{E}\times\vec{B}$.

(ii) (a): Photon is the fundamental particle in an electromagnetic wave.

(iii) (a): Polarisation establishes the wave nature of electromagnetic waves.

(iv) (c): Frequency υ remains unchanged when a wave propagates from one medium to another. Both wavelength and velocity get changed.

(v) (c): The electric and magnetic fields of an electromagnetic wave are in phase and perpendicular to each other.

2. (i) (c): $\frac{1}{2}\varepsilon_0 E^2 = \text{energy density} = \frac{\text{Energy}}{\text{Volume}}$

$$\therefore \left[\frac{1}{2}\varepsilon_0 E^2\right] = \frac{\text{ML}^2\text{T}^{-2}}{\text{L}^3} = [\text{ML}^{-1}\text{T}^{-2}]$$

(ii) (b): As $\varepsilon_0 = \frac{q_1 q_2}{4\pi F R^2}$ (from Coulomb's law)

$$\varepsilon_0 = \frac{\text{C}^2}{\text{Nm}^2}\ \frac{[\text{AT}]^2}{\text{MLT}^{-2}\text{L}^2} = \text{M}^{-1}\text{L}^{-3}\text{T}^4\text{A}^2$$

(iii) (d): The frequency of the electromagnetic wave remains same when it passes from one medium to another.

Refractive index of the medium, $n = \sqrt{\frac{\varepsilon}{\varepsilon_0}} = \sqrt{\frac{4}{1}} = 2$

Wavelength of the electromagnetic wave in the medium,

$$\lambda_{\text{med}} = \frac{\lambda}{n} = \frac{\lambda}{2}$$

(iv) (b): β-rays consists of electrons which are not electromagnetic in nature.

(v) (b): The velocity of electromagnetic waves in free space (vacuum) is equal to velocity of light in vacuum (*i.e.*, 3×10^8 m s^{-1}).

3. (i) (c): Pressure exerted by an electromagnetic radiation, $P = \frac{I}{c}$

(ii) (d): $P_{\text{rad}} = \frac{\text{Energy flux}}{\text{Speed of light}} = \frac{18\ \text{W/cm}^2}{3\times10^8\ \text{m/s}}$

$$= \frac{18\times10^4\ \text{W/m}^2}{3\times10^8\ \text{m/s}} = 6\times10^{-4}\ \text{N/m}^2$$

(iii) (a): $P = \frac{I}{c} = \frac{0.5}{3\times10^8} = 0.166\times10^{-8}\ \text{N m}^{-2}$

(iv) (b): Intensity of EM wave is given by $I = \frac{P}{4\pi R^2}$

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

$$\Rightarrow E_0 = \sqrt{\frac{P}{2\pi R^2 \varepsilon_0 c}} = \sqrt{\frac{1500}{2\times3.14(3)^2\times8.85\times10^{-12}\times3\times10^8}}$$

$$= \sqrt{10{,}000} = 100\ \text{V m}^{-1}$$

(v) (c) : The radiation pressure of visible light $= 7 \times 10^{-6}$ N/m^2

4. (i) (b): Infrared rays can be converted into electric energy as in solar cell.

(ii) (d): Radiowaves have longest wavelength.

(iii) (c) : Cathode rays are invisible fast moving streams of electrons emitted by the cathode of a discharge tube which is maintained at a pressure of about 0.01 mm of mercury.

(iv) (c) : γ-rays have minimum wavelength.

(v) (a): $\lambda_{micro} > \lambda_{infra} > \lambda_{ultra} > \lambda_{gamma}$

5. (i) (d): All electromagnetic waves travel in vacuum with the same speed.

(ii) (c) : Cathode rays (beam of electrons) get deflected in an electric field.

(iii) (c) : γ-rays are detected by ionization chamber.

(iv) (b): Size of particle $= \lambda = \frac{c}{\upsilon}$

$$\upsilon = \frac{c}{\lambda} = \frac{3\times10^{10}\text{ cm s}^{-1}}{3\times10^{-4}\text{ cm}} = 3\times10^{14}\text{ Hz}$$

(v) (a): Every body at a temperature $T > 0$ K emits radiation in the infrared region.

6. (i) (d): Given : $\vec{B} = B_0 \sin(kx + \omega t)\hat{j}$ T

The relation between electric and magnetic field is, $c = \frac{E}{B}$ or $E = cB$

The electric field component is perpendicular to the direction of propagation and the direction of magnetic field. Therefore, the electric field component along z-axis is obtained as $\vec{E} = cB_0 \sin(kx + \omega t)\hat{k}$ V/m

(ii) (c) : $\frac{dE}{dz} = -\frac{dB}{dt}$

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

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

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

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

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

E is along y-direction and the wave propagates along x-axis.

$\therefore$ B should be in a direction perpendicular to both x-and y-axis.

(iii) (d): Here, $E = 6.3\hat{j}$; $c = 3 \times 10^8$ m/s

The magnitude of B is

$$B_z = \frac{E}{c} = \frac{6.3}{3\times10^8} = 2.1\times10^{-8}\text{ T} = 0.021\ \mu\text{T}$$

(iv) (d): Here : $E_0 = 66$ V m^{-1}, $E_y = 66\cos\omega(t - \frac{x}{c})$,

$\lambda = 3$ mm $= 3 \times 10^{-3}$ m, $k = \frac{2\pi}{\lambda}$

$$\frac{\omega}{k} = c \Rightarrow \omega = ck = 3\times10^8 \times \frac{2\pi}{3\times10^{-3}}$$

or $\omega = 2\pi \times 10^{11}$

$\therefore$ $E_y = 66\cos 2\pi \times 10^{11}(t - \frac{x}{c})$

$$B_z = \frac{E_y}{c} = \left(\frac{66}{3\times10^8}\right)\cos 2\pi\times10^{11}\left(t - \frac{x}{c}\right)$$

$$= 2.2\times10^{-7}\cos 2\pi\times10^{11}\left(t - \frac{x}{c}\right)$$

(v) (a): At a particular point, $E = 9.3$ V m^{-1}

$\therefore$ Magnetic field at the same point $= \frac{9.3}{3\times10^8} = 3.1 \times 10^{-8}$ T

7. (i) (a)

(ii) (a): Greenhouse effect is due to infrared rays.

(iii) (a): Ozone layer absorbs the harmful ultraviolet radiations coming from the sun.

(iv) (a): Ozone layer lies in stratosphere.

(v) (b): The atmosphere of earth is richest in infrared radiation.

8. (b): In case of a linearly polarised plane electromagnetic wave, the average values of electric field and magnetic field are equal and average values of electric energy and magnetic energy are also equal.

9. (a): Light being electromagnetic wave do not require any material medium for its propagation. Hence light can travel in vacuum. On the other hand sound is a mechanical wave and requires a material medium for its propagation. Hence sound cannot travel in vacuum.

10. (b): Microwaves are the electromagnetic waves of wavelength of the order of a few millimetres, which is less than those of T.V. signals. On account of smaller wavelength, the microwaves can be transmitted as beam signals in a particular direction and are much better than radiowaves because microwaves do not spread or bend around the corners of any obstacle coming in their way. Therefore microwaves are better carriers of signals than radiowaves.

11. (d): Velocity of light has different values in different media.
It depends on the refractive index of the medium. Related by formula

$$v_{\text{medium}} = \frac{\text{velocity in vacuum}}{\text{refractive index of medium}}$$

12. (d): All electromagnetic waves including X-rays travels with same velocity in vacuum. The energy of X-rays is greater than energy of the light because energy is inversely proportional to wavelength ($E = hc/\lambda$) and wavelength of X-rays are smaller than light waves.

13. (b): At every instant the ratio of the magnitudes of the electric field to the magnetic field of an em wave is given by $E/B = c$.
From this equation, the magnitude of electric vector is much greater than the magnitude of magnetic vector.

Also electromagnetic waves carry energy which is equally shared by electric and magnetic field.

14. (b): The electromagnetic waves consist of sinusoidally time varying electric and magnetic fields acting at right angles to each other as well as at right angles to the direction of propagation of waves *i.e.*, electromagnetic waves are transverse in nature.

15. (d): The speed of em waves in free space is given by

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

where $\mu_0 = 4\pi \times 10^{-7}$ N s^2/C^2 is permeability constant of vacuum and $\varepsilon_0 = 8.85419 \times 10^{-12}$ $C^2/N\ m^2$ is the permittivity of free space. After substituting these value, the value of c ($= 2.99792 \times 10^8$ m/s) which is same as the speed of light in vacuum. From this it is concluded that light is an electromagnetic wave.

16. (b): Electromagnetic waves transport linear momentum as well as energy. When electromagnetic waves strike a surface, a pressure is exerted on the surface. If the intensity of wave is I, the radiation pressure P (force per unit area) exerted on the perfectly absorbing surface is $P = I/c$.

17. (b): Infrared waves are sometimes called heat waves. This is because water molecules present in most materials readily absorb infrared waves. After absorption, their thermal motion increases, that is, they heat up and heat their surroundings.

18. (c): The earth's atmosphere is transparent to visible light and radio waves, but absorbs X-rays. Therefore X-rays telescope cannot be used on earth surface.

19. (d): For wave to suffer diffraction, the wavelength should be of the order of size of the obstacle. The wavelength of radio waves (short radio waves) is order of the size of the building and the other obstacles coming in their path and hence they easily get diffracted.

20. (a): Accelerated charges radiate electromagnetic waves.