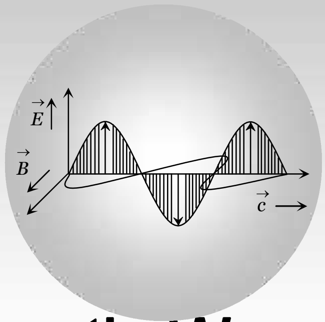


Electromagnetic Waves

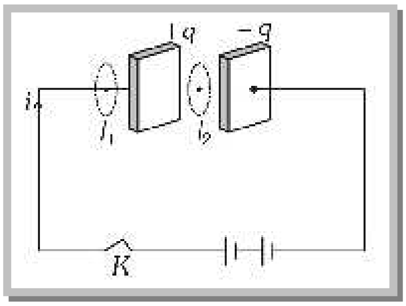
Maxwell's Contribution

(1) **Ampere's Circuital law**

According to this law the line integral of magnetic field along any closed path or circuit is $«_0$ times the total current threading the closed circuit *i.e.*, $\oint \vec{B}.\vec{dl} = «_0 i$

(2) **Inconsistency of Ampere's law**

Maxwell explained that Ampere's law is valid only for steady current or when the electric field does not change with time. To see this inconsistency consider a parallel plate capacitor being charged by a battery. During the charging time varying current flows through connecting wires.



Applying Ampere's law for loop l_1 and l_2 $\oint_{l_1} \vec{B}.\vec{dl} = «_0 i$

But $\oint_{l_2} \vec{B}.\vec{dl} = 0$ (Since no current flows through the region between the plates). But practically it is observed that there is a magnetic field between the plates. Hence Ampere's law fails

i.e. $\oint_{l_1} \vec{B}.\vec{dl} \neq «_0 i$.

(3) **Modified Ampere's Circuital law or Ampere- Maxwell's Circuital law**

Maxwell assumed that some sort of current must be flowing between the capacitor plates during charging process. He named it displacement current. Hence modified law is as follows

$$\oint \vec{B}.\vec{dl} = «_0 (i_c + i_d) \quad \text{or} \quad \oint \vec{B}.\vec{dl} = «_0 (i_c + £_0 \frac{d¤_E}{dt})$$

where i_c = conduction current = current due to flow of charges in a conductor and

i_d = Displacement current = $£_0 \frac{d¤_E}{dt}$ = current due to the changing electric field between the plates of the capacitor

Note : ❑ Displacement current (i_d) = conduction current (i_c).

❑ i_c and i_d in a circuit, may not be continuous but their sum is always continuous.

(4) **Maxwell's equations**

(i) $\oint_s \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$ (Gauss's law in electrostatics) (ii) $\oint_s \vec{B}.\vec{ds} = 0$ (Gauss's law in magnetism)

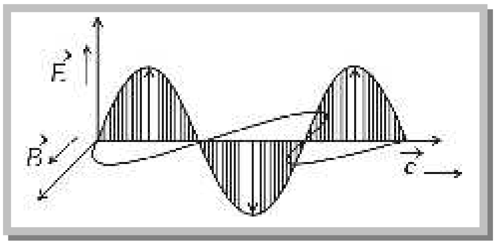
(iii) $\oint \vec{B}.\vec{dl} = -\frac{d\phi_B}{dt}$ (Faraday's law of EMI) (iv) $\oint \vec{B}\ \vec{dl} = \mu_o(i_c + \varepsilon_o \frac{d\phi_E}{dt}$ (Maxwell- Ampere's Circuital law)

EM Waves

(1) **Definition**

A changing electric field produces a changing magnetic field and vice versa which gives rise to a transverse wave known as electromagnetic wave. The time varying electric and magnetic field are mutually perpendicular to each other and also perpendicular to the direction of propagation of this wave.

The electric vector is responsible for the optical effects of an EM wave and is called the *light vector*.



(2) **History of EM waves :**

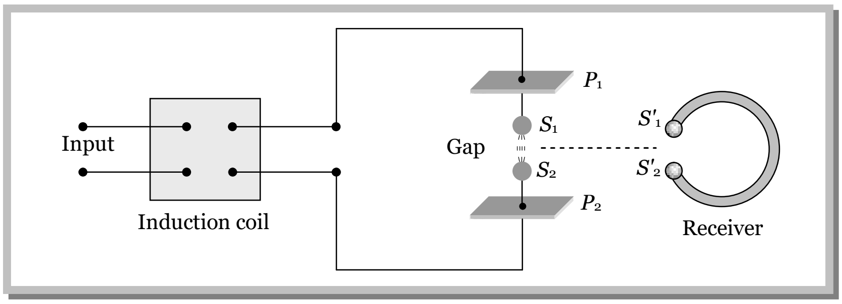
(i) **Maxwell :** Was the first to predict the EM wave.

(ii) **Hertz :** Produced and detected electromagnetic waves experimentally at wavelengths of 6 *m*.

Experimental setup

Hertz experiment based on the fact that a oscillating charge is accelerating continuously, it will radiate electromagnetic waves continuously. In the following figure

- The metallic plates (P_1 and P_2) acts as a capacitor.
- The wires connecting spheres S_1 and S_2 to the plates provide a low inductance.



When a high voltage is applied across metallic plates these plates get discharged by sparking across the narrow gap. The spark will give rise to oscillations which in turn send out electromagnetic waves. Frequency of these wave is given by $\nu = \frac{1}{2\pi\sqrt{LC}}$

The succession of sparks send out a train of such waves which are received by the receiver.

(iii) **J.C. Bose :** Produced EM waves of wavelength ranging from 5*mm* to 25 *mm*.

(iv) **Marconi :** Successfully transmitted the EM waves up to a few *kilometer*. Marconi discovered that if one of the spark gap terminals is connected to an antenna and the other terminal is Earthed, the electromagnetic waves radiated could go upto several kilometers.

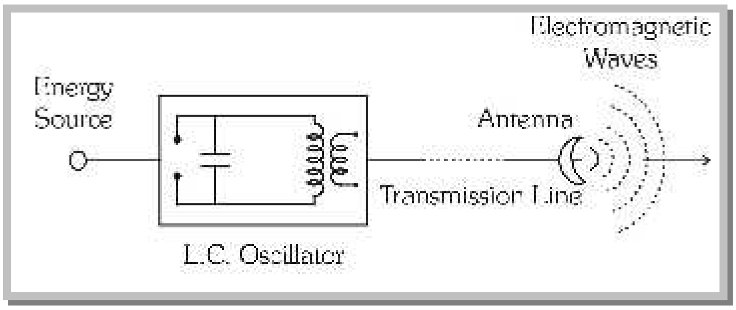
(3) **Source of EM waves**

A charge oscillating harmonically is a source of EM waves of same frequency.

(4) **Production of EM waves**

A simple *LC* oscillator and energy source can produce waves of desired frequency.

Frequency of oscillating discharge in *LC* circuit = Frequency of EM waves $= \frac{1}{2\pi\sqrt{LC}}$



Note : ❑ In an atom an electron circulating around the nucleus in a stable orbit, although accelerating does not emit electromagnetic waves; it does so only when it jumps from a higher energy orbit to a lower energy orbit.

❑ Electromagnetic waves (*X*-rays) are also produced when fast moving electrons are suddenly stopped by a metal target of high atomic number.

❑ Most efficient antennas are those which have a size comparable to the wavelength of the of electromagnetic wave they emit or receive.

(5) **Nature of EM waves**

The EM Waves are transverse in nature. They do not require any material medium for their propagation.

(6) **Properties of EM waves**

(i) Speed : In free space it's speed $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = \frac{E_0}{B_0} = 3 \times 10^8\ m/s.$

In medium $v = \frac{1}{\sqrt{\mu \varepsilon}}$; where μ_0 = Absolute permeability, ε_0 = Absolute permittivity

E_0 and B_0 = Amplitudes of electric field and magnetic field vectors.

(ii) Energy : The energy in an EM waves is divided equally between the electric and magnetic fields.

Energy density of electric field $u_e = \frac{1}{2}\varepsilon_0 E^2$, Energy density of magnetic field $u_B = \frac{1}{2}\frac{B^2}{\mu_0}$

It is found that $u_e = u_B$. Also $u_{av} = u_e + u_B = 2u_e = 2u_B = \varepsilon_0 E^2 = \frac{B^2}{\mu_0}$

(iii) Intensity (*I*) : The energy crossing per unit area per unit time, perpendicular to the direction of propagation of EM wave is called intensity. $I = u_{av} \times c = \frac{1}{2}\varepsilon_0 E^2 c = \frac{1}{2}\frac{B^2}{\mu_0}.c$

(iv) Momentum : EM waves also carries momentum, if a portion of EM wave of energy u propagating with speed c, then linear momentum $= \dfrac{\text{Energy } (u)}{\text{Speed } (c)}$

Note : ❑ When the incident EM wave is completely absorbed by a surface, it delivers energy u and momentum u / c to the surface.

❑ When a wave of energy u is totally reflected from the surface, the momentum delivered to surface is $2u/c$.

(v) Poynting vector$(\vec{S})$. : In EM waves, the rate of flow of energy crossing a unit area is described by the poynting vector. It's unit is $watt/m^2$ and $\vec{S} = \frac{1}{«_o}(\vec{E} \times \vec{B}) = c^2 £_0 (\vec{E} \times \vec{B})$. Because in EM waves $\vec{E}$ and $\vec{B}$ are perpendicular to each other, the magnitude of $\vec{S}$ is $|\vec{S}| = \frac{1}{«_0} E\,B \sin 90^o = \frac{EB}{«_0} = \frac{E^2}{«\,C}$.

Note : ❑ The direction of the poynting vector $\vec{S}$ at any point gives the wave's direction of travel and direction of energy transport the point.

(vi) Radiation pressure : Is the momentum imparted per second pre unit area. On which the light falls.

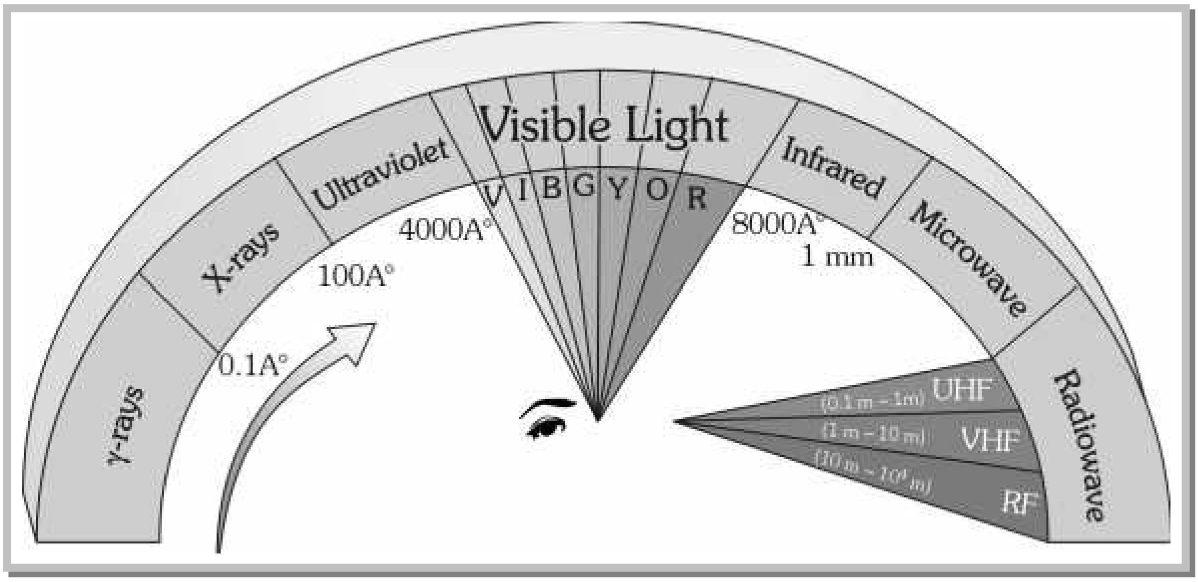
For a perfectly reflecting surface $P_r = \frac{2S}{c}$; S = Poynting vector; c = Speed of light

For a perfectly absorbing surface $P_a = \frac{S}{c}$.

Note : ❑ The radiation pressure is real that's why tails of comet point away from the sun.

EM Spectrum

The whole orderly range of frequencies/wavelengths of the EM waves is known as the EM spectrum.



Uses of EM spectrum

Radiation	Uses
¥-rays	Gives informations on nuclear structure, medical treatment *etc.*
X-rays	Medical diagnosis and treatment study of crystal structure, industrial radiograph.
UV- rays	Preserve food, sterilizing the surgical instruments, detecting the invisible writings, finger prints etc.
Visible light	To see objects
Infrared rays	To treat, muscular strain for taking photography during the fog, haze etc.
Micro wave and radio wave	In radar and telecommunication.

Earth's Atmosphere

The gaseous envelope surrounding the earth is called it's atmosphere. The atmosphere contains 78% N_2, 21% O_2, and traces of other gases (like helium, krypton, CO_2 etc.)

(1) **Division of earth's atmosphere**

Earth atmosphere has been divided into regions as shown.

(i) *Troposphere* : In this region, the temperature decreases with height from 290 *K* to 220 *K*.

(ii) *Stratosphere* : The temperature of stratosphere varies from 220 *K* to 200 *K*.

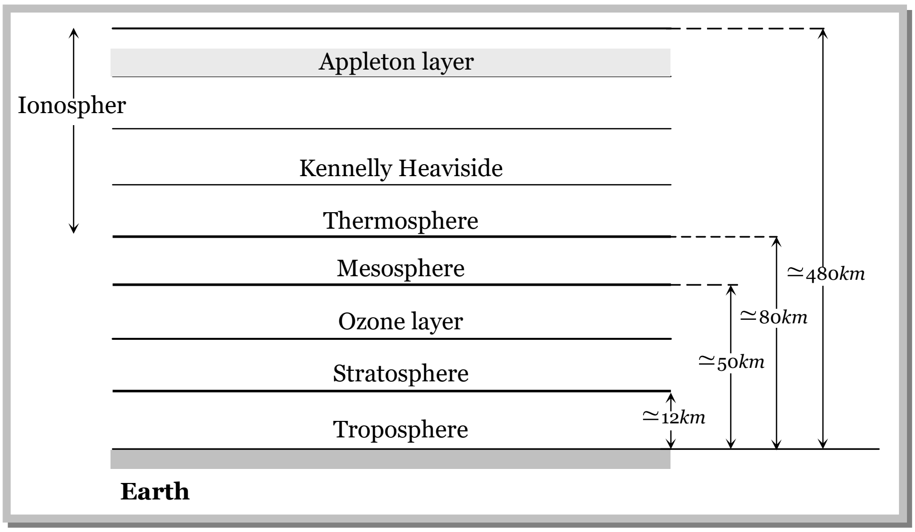
(iii) *Mesosphere* : In this region, the temperature falls to 180 *K*.

(iv) *Ionosphere* : Ionosphere is partly composed of charged particles, ions and electrons, while the rest of the atmosphere contains neutral molecules.

(v) Ozone layer absorbs most of the ultraviolet rays emitted by the sun.

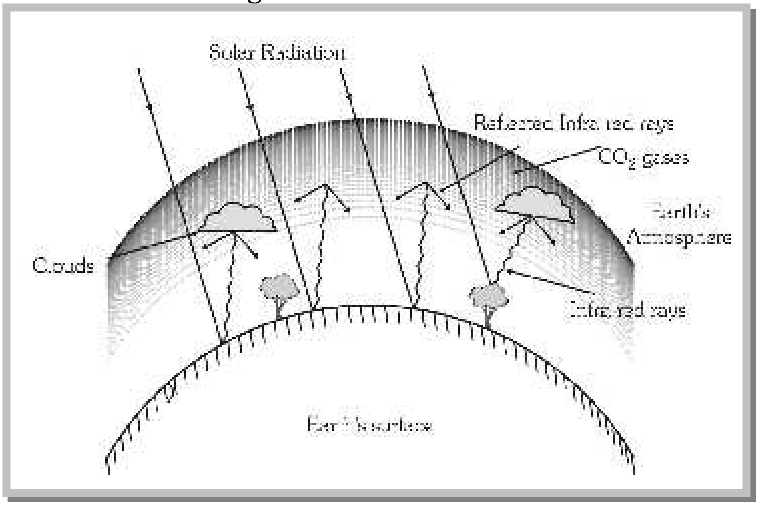
(vi) Kennelly heaviside layer lies at about 110*km* from the earth's surface. In this layer concentration of electron is very high.

(vii) The ionosphere plays a vital role in the radio communication.



(2) **Green house effect**

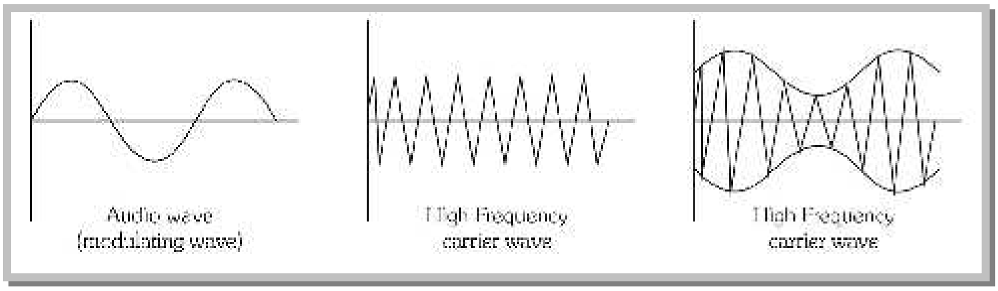
The warming of earth's atmosphere due to the infrared radiations reflected by low lying clouds and carbon dioxide in the atmosphere of earth is called green house effect.



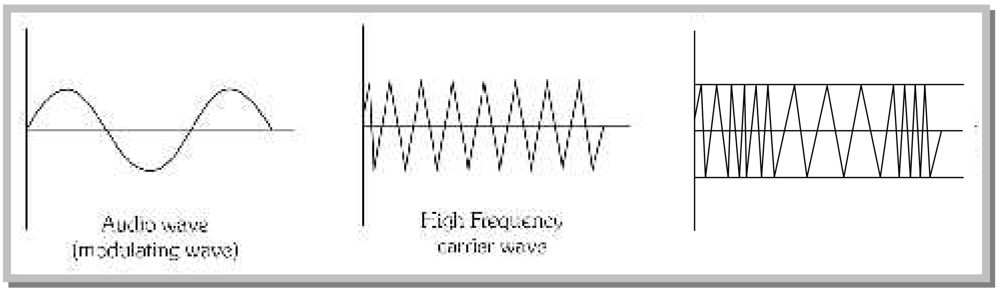
(3) **Modulation and demodulation**

The audio waves can be heard only over short distances. To overcomes this difficulty, an audio wave (low frequency) to be transmitted is superimposed on the carrier wave (high frequency). This process of superimposing is called modulation.

The process of separating the audio frequency wave from the carrier wave is called demodulation.



Amplitude modulation (Amplitude of carrier wave modifies in accordance with the amplitude of modulating wave)



Frequency modulation (frequency of carrier wave changes in accordance with the amplitude of modulating wave)

(4) **Role of earth's atmosphere in propagation of radio waves**

(i) **Radio waves classification :**

(a) Very low frequency (VLF) $\rightarrow$ 10 KHz to 30 KHz

(b) Low frequency (LF) $\rightarrow$ 30 KHz to 300 KHz

(c) Medium frequency (MF) or medium wave (MW) $\rightarrow$ 300 KHz to 3000 KHz

(d) High frequency (HF) or short wave (SW) $\rightarrow$ 3 MHz to 30 MHz

(e) Very high frequency (VHF) $\rightarrow$ 30 *MHz* to 300 *MHz*

(f) Ultra high frequency (UHF) $\rightarrow$ 300 *MHz* to 3000 *MHz*

(g) Super high frequency or micro waves $\rightarrow$ 3000 *MHz* to 300, 000 *MHz*

(ii) **Amplitude modulated transmission :** Radio waves having frequency less than or equal to 30 MHz form an amplitude modulation band (or AM band). The signals can be transmitted from one place to another place on earth's surface in two ways

(a) Ground wave propagation : The radio waves following the surface of the earth are called ground waves.

(b) Sky wave propagation : The amplitude modulated radio waves which are reflected back by the ionosphere are called sky waves.

(iii) **Frequency modulated (FM) transmission :** Radio waves having frequencies between 80 MHz and 200 MHz form a frequency modulated bond. T.V. signals are normally frequency modulated.

Note : ❑ Ionosphere cannot reflect back the waves of frequencies greater than 40 *MHz* as these waves easily penetrate through the ionosphere.

(5) **T.V. Signals :**

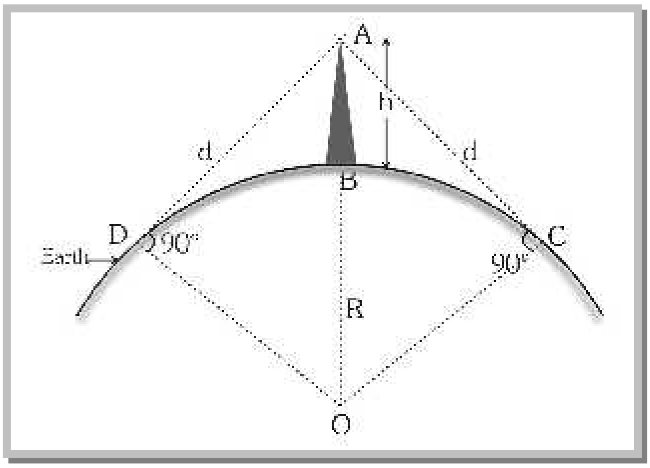
(i) T.V. signals are normally frequency modulated. So T.V. signals can be transmitted by using tall antennas.

(ii) Distance covered by the T.V. signals $d = \sqrt{2hR}$

(h = Height of the antenna, R = Radius of earth)

(iii) Area covered $A = \pi d^2 = 2\pi hR$

(iv) Population covered = area $\times$ population density.



Example

Example: 1 A flash light is covered with a filter that transmits red light. The electric field of the emerging beam is represented by a sinusoidal plane wave $E_x = 36\sin(1.20\times10^7 z - 3.6\times10^{15} t)\, V/m$ **.** The average intensity of the beam will be

(a) $0.86\ W/m^2$ (b) $1.72\ W/m^2$ (c) $3.44\ W/m^2$ (d) $6.88\ W/m^2$

Solution : (b) $I_{av} = \frac{c\varepsilon_0 E_0^2}{2} = \frac{3\times10^8\times8.85\times10^{-15}\times36^2}{2} = 1.72\ W/m^2$

Example: 2 What should be the height of transmitting antenna if the T.V. telecast is to cover a radius of 128 *Km*

(a) 1560 *m* (b) 1280 *m* (c) 1050 *m* (d) 79 *m*

Solution : (b) Height of transmitting antenna $h = \frac{d^2}{2\,\text{Re}} = \frac{(128\times10^3)^2}{2\times6.4\times10^6} = 1280\ m$

Example: 3 A T.V. tower has a height of 100 *m*. How much population is covered by T.V. broadcast, if the average population density around the tower is $1000\ /Km^2$

(a) 39.5×10^5 (b) 19.5×10^6 (c) 29.5×10^7 (d) 9×10^4

Solution : (a) Radius of the area covered by T.V. telecast $d = \sqrt{2hR_e}$

Total population covered $= \pi d^2 \times$ population density $= 2\pi hR_e \times$ Population density

$$= 2 \times 3.14 \times 100 \times 6.4 \times 10^6 \times \frac{1000}{10^6} = 39.503 \times 10^5$$

***Example*: 4** An electromagnetic radiation has an energy 14.4 *KeV*. To which region of electromagnetic spectrum does it belong

(a) Infra red region (b) Visible region (c) *X*-rays region (d) γ -ray region

Solution : (c) $\lambda = \frac{hc}{E} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{14.4 \times 10^3 \times 1.6 \times 10^{-19}} = 0.8 \times 10^{-10}\, m = 0.8\,\mathring{A}$. This wavelength belongs to *X*-ray region.

***Example*: 5** A point source of electromagnetic radiation has an average power output of 800 *W*. The maximum value of electric field at a distance 3.5 *m* form the source will be

(a) 56.7 *V/m* (b) 62.6 *V/m* (c) 39.3 *V/m* (d) 47.5 *V/m*

Solution : (b) Intensity of electromagnetic wave given is by $I = \frac{P_{av}}{4\pi r^2} = \frac{E_m^2}{2\mu_0 c}$

$$E_m = \sqrt{\frac{\mu_0 c P_{av}}{2\pi r^2}} = \sqrt{\frac{(4\pi \times 10^{-7}) \times (3 \times 10^8) \times 800}{2\pi \times 3.5^2}} = 62.6 \quad V/m$$

***Example*: 6** In the above problem, the maximum value of magnetic field will be

(a) $2.09 \times 10^{-5}\, T$ (b) $2.09 \times 10^{-6}\, T$ (c) $2.09 \times 10^{-7}\, T$ (d) $2.09 \times 10^{-8}\, T$

Solution : (c) The maximum value of magnetic field is given by $B_m = \frac{E_m}{c} = \frac{62.6}{3 \times 10^8} = 2.09 \times 10^{-7}\, T$

***Example*: 7** A plane electromagnetic wave of wave intensity $6\, W/m^2$ strikes a small mirror area $40\, cm^2$, held perpendicular to the approaching wave. The momentum transferred by the wave to the mirror each second will be

(a) $6.4 \times 10^{-7}\, kg-m/s^2$ (b) $4.8 \times 10^{-8}\, kg-m/s^2$ (c) $3.2 \times 10^{-9}\, kg-m/s^2$ (d) $1.6 \times 10^{-10}\, kg-m/s^2$

Solution : (d) In one second $p = \frac{2U}{c} = \frac{2S_{av}A}{c} = \frac{2 \times 6 \times 40 \times 10^{-4}}{3 \times 10^8} = 1.6 \times 10^{-10}\, kg-m/s^2$

***Example*: 8** The charge on a parallel plate capacitor is varying as $q = q_0 \sin 2\pi nt$. The plates are very large and close together. Neglecting the edge effects, the displacement current through the capacitor is

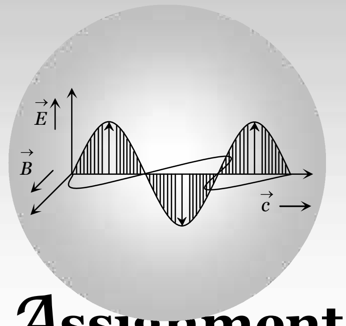
(a) $\frac{q}{\varepsilon_0 A}$ (b) $\frac{q_0}{\varepsilon_0} \sin 2\pi nt$ (c) $2\pi n q_0 \cos 2\pi nt$ (d) $\frac{2\pi n q_0}{\varepsilon_0} \cos 2\pi nt$

Solution : (c) $I_D = \frac{dq}{dt} = \frac{d}{dt} q_0 \sin 2\pi nt = 2\pi n q_0 \cos 2\pi nt$

***Example*: 9** The value of magnetic field between plates of capacitor, at distance of 1*m* from centre where electric field varies by $10^{10}\, V/m/s$ will be

(a) $5.56\, T$ (b) $5.56\, \mu T$ (c) $5.56\, mT$ (d) $5.56\, nT$

Solution : (d) $B = \frac{\mu_0 \varepsilon_0 r}{2} \frac{dE}{dt} = \frac{1}{2 \times 9 \times 10^{16}} \times 10^{10} = 5.56 \times 10^{-8}\, T$ $\left(\because c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \right)$



Assignment

Electromagnetic waves

Basic Level

1. The speed of electromagnetic wave in vacuum depends upon the source of radiation
(a) Increases as we move from ¥-rays to radio waves (b) Decreases as we move from ¥-rays to radio waves
(c) Is same for all of them (d) None of these

2. Which of the following radiations has the least wavelength
(a) ¥ -rays (b) -rays (c) ~-rays (d) X-rays

3. The maximum distance upto which TV transmission from a TV tower of height h can be received is proportional to
(a) $h^{1/2}$ (b) h (c) h (d) h^2

4. In short wave communication, waves of which of the following frequencies will be reflected back by the ionospheric layer having electron density 10^{11} per m^3
(a) 2.8 MHz (b) 10 MHz (c) 12 MHz (d) 18 MHz

5. Which of the following are not electromagnetic waves
(a) Cosmic rays (b) Gamma rays (c) -rays (d) X-rays

6. Ozone is found in
(a) Stratosphere (b) Ionosphere (c) Mesosphere (d) Troposphere

7. The electromagnetic waves travel with a velocity
(a) Equal to velocity of sound (b) Equal to velocity of light (c) Less than velocity of light (d) None of these

8. The ozone layer absorbs
(a) Infrared radiations (b) Ultraviolet radiations (c) X-rays (d) ¥-rays

9. Electromagnetic radiation of highest frequency is
(a) Infrared radiations (b) Visible radiation (c) Radio waves (d) ¥-rays

10. Which of the following shows green house effect
(a) Ultraviolet rays (b) Infrared rays (c) X-rays (d) None of these

11. Which of the following waves have the maximum wavelength
(a) X-rays (b) I.R. rays (c) UV rays (d) Radio waves

12. Electromagnetic waves are transverse in nature is evident by
(a) Polarization (b) Interference (c) Reflection (d) Diffraction

13. If $\vec{E}$ and $\vec{B}$ are the electric and magnetic field vectors of e.m. waves then the direction of propagation of e.m. wave is along the direction of
(a) $\vec{E}$ (b) $\vec{B}$ (c) $\vec{E} \times \vec{B}$ (d) None of these

14. Biological importance of Ozone layer is
(a) It stops ultraviolet rays (b) Ozone rays reduce green house effect
(c) Ozone layer reflects radio waves (d) Ozone layer controls O_2 / H_2 radio in atmosphere

15. What is ozone hole
(a) Hole in the ozone layer (b) Formation of ozone layer
(c) Thinning of ozone layer in troposphere (d) Reduction in ozone thickness in stratosphere

16. Which rays are not the portion of electromagnetic spectrum
(a) X-rays (b) Microwaves (c) ~-rays (d) Radio waves

17. Radio wave diffract around building although light waves do not. The reason is that radio waves
(a) Travel with speed larger than c (b) Have much larger wavelength than light

(c) Carry news (d) Are not electromagnetic waves

18. The frequencies of X-rays, ¥-rays and ultraviolet rays are respectively a, b and c. Then

(a) $a < b, b > c$ (b) $a > b, b > c$ (c) $a > b, b < c$ (d) $a < b, b < c$

19. Radio waves and visible light in vacuum have

(a) Same velocity but different wavelength (b) Continuous emission spectrum

(c) Band absorption spectrum (d) Line emission spectrum

20. Energy stored in electromagnetic oscillations is in the form of

(a) Electrical energy (b) Magnetic energy (c) Both (a) and (b) (d) None of these

21. Heat radiations propagate with the speed of

(a) ~-rays (b) -rays (c) Light waves (d) Sound waves

22. If a source is transmitting electromagnetic wave of frequency 8.2×10^6 Hz, then wavelength of the electromagnetic waves transmitted from the source will be

(a) 36.6 m (b) 40.5 m (c) 42.3 m (d) 50.9 m

23. In an apparatus, the electric field was found to oscillate with an amplitude of 18 V/m. The magnitude of the oscillating magnetic field will be

(a) 4×10^{-6} T (b) 6×10^{-8} T (c) 9×10^{-9} T (d) 11×10^{-11} T

24. According to Maxwell's hypothesis, a changing electric field gives rise to

(a) An e.m.f. (b) Electric current (c) Magnetic field (d) Pressure radiant

25. In an electromagnetic wave, the electric and magnetising fields are $100\ V m^{-1}$ and $0.265\ A m^{-1}$. The maximum energy flow is

(a) $26.5\ W/m^2$ (b) $36.5\ W/m^2$ (c) $46.7\ W/m^2$ (d) $765\ W/m^2$

26. The 21 cm radio wave emitted by hydrogen in interstellar space is due to the interaction called the hyperfine interaction is atomic hydrogen. the energy of the emitted wave is nearly

(a) 10^{-17} *Joule* (b) 1 *Joule* (c) 7×10^{-8} *Joule* (d) 10^{-24} *Joule*

27. TV waves have a wavelength range of 1-10 *meter*. Their frequency range in *MHz* is

(a) 30-300 (b) 3-30 (c) 300-3000 (d) 3-3000

28. The velocity of all radio waves in free space is $3 \times 10^8\ m/s$. The frequency of a radio wave of wavelength 150 m, is

(a) 45 *MHz* (b) 2 *MHz* (c) 2 *KHz* (d) 20 *KHz*

29. Maxwell's equations describe the fundamental laws of

(a) Electricity only (b) Magnetism only (c) Mechanics only (d) Both (a) and (b)

30. An electric charge moving with a uniform velocity has

(a) Only an electric field around it (b) Only a magnetic field around it

(c) Both electric and magnetic field around it (d) Neither an electric field nor a magnetic field around it

31. Which of the following rays has minimum frequency

(a) U.V. rays (b) X-rays (c) Microwaves (d) Infrared rays

32. Which one of the following electromagnetic radiations have the smallest wavelength

(a) Ultraviolet waves (b) X-rays (c) ¥-rays (d) Microwaves

33. The oscillating electric and magnetic vectors of an electromagnetic wave are oriented along

(a) The same direction but differ in phase by 90° (b) The same direction and are in phase

(c) Mutually perpendicular directions and are in phase (d) Mutually perpendicular directions and differ in phase by 90°

34. Energy of E.M. waves is due to their

(a) Wavelength (b) Frequency

(c) Electric and magnetic field (d) None of these

35. In which one of the following regions of the electromagnetic spectrum will the vibrational motion of molecules give rise to absorption

(a) Ultraviolet (b) Microwaves (c) Infrared (d) Radio waves

36. An electromagnetic wave travels along z-axis. Which of the following pairs of space and time varying fields would generate such a wave

(a) E_x, B_y (b) E_y, B_x (c) E_z, B_x (d) E_y, B_z

37. Which of the following rays has the maximum frequency

(a) Gamma rays (b) Blue light (c) Infrared rays (d) Ultraviolet rays

38. Radio waves of constant amplitude can be generated with

(a) FET (b) Filter (c) Rectifier (d) Oscillator

39. A signal emitted by an antenna from a certain point can be received at another point of the surface in the form of

(a) Sky wave (b) Ground wave (c) Sea wave (d) Both (a) and (b)

40. Speed *c* of E.M. waves through vacuum is given by

(a) $c = \sqrt{«_0 £_0}$ (b) $c = \frac{1}{\sqrt{«_0 £_0}}$ (c) $c = \sqrt{\frac{«_0}{£_0}}$ (d) $c = \sqrt{\frac{£_0}{«_0}}$

41. Approximate height of ozone layer above the ground is

(a) 60 to 70 *km* (b) 59 *km* to 80 *km* (c) 70 *km* to 100 *km* (d) 100 *km* to 200 *km*

42. The electromagnetic waves do not transport

(a) Energy (b) Charge (c) Momentum (d) Information

43. An electromagnetic radiation of wavelength ª and frequency ¬ propagating in air with velocity *c*, is incident on a glass plate and is transmitted through. Which of the following statements is true for the wave inside the glass plate

(a) The velocity of wave remains *c* but wavelength changes

(b) The frequency ¬ and wavelength ª remain unchanged but the velocity changes

(c) The wavelength ª remain unchanged but frequency changes

(d) The frequency ¬ remains unchanged but the wavelength changes

44. An electric charge oscillating with a frequency of 1 *kilo* cycles/*second* can radiate electromagnetic waves of wavelength

(a) 100 *km* (b) 200 *km* (c) 300 *km* (d) 400 *km*

45. If a free electron is placed in the path of a plane electromagnetic wave, it will start moving along

(a) Centre of earth (b) Equator of earth (c) Magnetic field (d) Electric field

46. A plane electromagnetic wave is incident on a material surface. If the wave delivers momentum *p* and energy *E*, then

(a) $p = 0, E = 0$ (b) $p \neq 0, E \neq 0$ (c) $p \neq 0, E = 0$ (d) $p = 0, E \neq 0$

47. An electric field $\vec{E}$ and magnetic field $\vec{B}$ exist in a region. If these fields are not perpendicular to each other, then the electromagnetic wave

(a) Will not pass through the region (b) Will pass through region

(c) May pass through the region (d) Nothing is definite

48. Which of the following has zero average value in a plane electromagnetic wave

(a) Kinetic energy (b) Magnetic field (c) Electric field (d) Both (b) and (c)

49. In a plane E.M. wave, the electric field oscillates sinusoidal at a frequency of 2.0×10^{10} *Hz* and amplitude $48\ V m^{-1}$. The wavelength of the wave is

(a) $24 \times 10^{-10} m$ (b) $1.5 \times 10^{-2} m$ (c) $4.16 \times 10^{8} m$ (d) $3 \times 10^{8} m$

50. Beyond which frequency, the ionosphere bends any incident electromagnetic radiation but do not reflect it back towards the earth

(a) 50 *MHz* (b) 40 *MHz* (c) 30 *MHz* (d) 20 *MHz*

51. Radio waves with frequencies higher than television signals are

(a) Ultrasonic waves (b) Sound waves (c) Light waves (d) Microwaves

52. Radio waves do not penetrate in the band of

(a) Ionosphere (b) Mesosphere (c) Troposphere (d) Stratosphere

53. A radar sends the waves towards a distant object and receives the signal reflected by object. These waves are

(a) Sound waves (b) Light waves (c) Radio waves (d) Microwaves

54. In electromagnetic wave, the average energy density is associated to

(a) Electric field only (b) Magnetic field only

(c) Equally with electric and magnetic fields (d) Average energy density is zero

55. A laser beam is sent to the moon and reflected back to earth by a mirror placed on the moon by an astronaut. If the moon is 384000 *km* from earth, how long does it take the light to make the round trip

(a) 5 *minutes* (b) 2.5 *minutes* (c) 2.5 *s* (d) 500 *s*

56. An electromagnetic wave, going through vacuum is described by $E = E_0 \sin(kx - \mu\, t)$. Which of the following is independent of wavelength

(a) k (b) μ (c) k/μ (d) $k\mu$

57. The energy contained in a small volume through which an electromagnetic wave is passing, oscillates with

(a) Zero frequency (b) One-fourth frequency of wave
(c) One-third frequency of wave (d) Double frequency of wave

58. (P-151) An electromagnetic wave going through vacuum is described by $E = E_0 \sin(kx - \mu\, t)$; $B = B_0 \sin(kx - \mu\, t)$. Which of the following equation is true

(a) $E_0 k = B_0 \mu$ (b) $E_0 \mu = B_0 k$ (c) $E_0 B_0 = \mu k$ (d) None of these

59. An LC resonant circuit contains a 400 pF capacitor and a 100 «H inductor. It is set into oscillation coupled to an antenna. The wavelength of the radiated electromagnetic waves is

(a) 377 mm (b) 377 $metre$ (c) 377 cm (d) 3.77 cm

60. A brilliant arc lamp delivers a luminous flux of 100 W to a 1 cm^2 absorber. The force due to radiation pressure is

(a) $3.3 \times 10^{-4}\, N$ (b) $16.5 \times 10^{-7}\, N$ (c) $3.3 \times 10^{-6}\, N$ (d) $3.3 \times 10^{-7}\, N$

61. Waves used for telecommunication are

(a) Visible light (b) Infrared (c) Ultraviolet (d) Microwaves

62. To double the covering range of a TV transmitter tower, its height should be made

(a) Two times (b) Four times (c) $\sqrt{2}$ times (d) 8 times

63. A radio receiver antenna that is 2 m long is oriented along the direction of the electromagnetic wave and receives a signal of intensity $5 \times 10^{-16}\, W/m^2$. The maximum instantaneous potential difference across the two ends of the antenna is

(a) 1.23 «V (b) 1.23 mV (c) 1.23 V (d) 12.3 mV

64. The transmitting antenna of a radio-station is mounted vertically. At a point 10 km due north of the transmitter the peak electric field is 10^{-3} $volt/metre$. The magnitude of the radiation magnetic field is

(a) 3.33×10^{-10} $Tesla$ (b) 3.33×10^{-12} $Tesla$ (c) 10^{-3} $Tesla$ (d) 3×10^{5} $Tesla$

65. Tick the correct statement

(a) E.M. radiations act as waves when they move place to place
(b) E.M. radiations behave as photons when interacting with material substances
(c) The main factor which makes the microwave range unsuitable for vision is associated with corpuscular nature of e.m. radiation
(d) All of the above

66. Television signals broadcast from the moon can be received on the earth while the TV broadcast from Delhi cannot be received at places about 100 km distant from Delhi. This is because

(a) There is no atmosphere around the moon
(b) Of strong gravity effect on TV signals
(c) TV signals travel straight and cannot follow the curvature of the earth
(d) There is atmosphere around the earth

67. An LC current contains inductance L = 1 «H and capacitance C = 0.01 «F. The wavelength of electromagnetic wave generated is nearly

(a) 0.5 m (b) 5 m (c) 188 m (d) 30 m

68. The ratio of electric field vector E and magnetic field vector H *i.e.*, $\left(\frac{E}{H}\right)$ has the dimensions of

(a) Resistance (b) Inductance
(c) Capacitance (d) Product of inductance and capacitance

69. The frequency modulated waves are

(a) Reflected by atmosphere (b) Absorbed by atmosphere (c) Bend by atmosphere (d) Radio waves

70. A TV tower has a height of 100 m. The average population density around the tower is 1000 per km^2. The radius of the earth is 6.4×10^6 m. the population covered by the tower is

(a) 2×10^6 (b) 3×10^6 (c) 4×10^6 (d) 6×10^6

71. The ionosphere

(a) Reflects back radio waves in the AM band (b) Reflects back radio waves in the FM band
(c) Absorbs radio waves in the AM band (d) Absorbs radio waves in the FM band

72. The wavelength 21 cm emitted by atomic hydrogen in interstellar space belongs to

(a) Radio waves (b) Infrared waves (c) Microwaves (d) ¥-rays

Electromagnetic waves

Advance Level

73. A parallel plate capacitor of plate separation 2 *mm* is connected in an electric circuit having source voltage 400 *V*. if the plate area is 60 *cm*², then the value of displacement current for 10^{-6} sec will be

(a) 1.062 *amp* (b) 1.062×10^{-2} *amp* (c) 1.062×10^{-3} *amp* (d) 1.062×10^{-4} *amp*

74. A long straight wire of resistance *R*, radius *a* and length *l* carries a constant current *I*. The Poynting vector for the wire will be

(a) $\frac{IR}{2®al}$ (b) $\frac{IR^2}{al}$ (c) $\frac{I^2R}{al}$ (d) $\frac{I^2R}{2®al}$

75. In an electromagnetic wave, the amplitude of electric field is 1 *V*/*m*. the frequency of wave is 5×10^{14} *Hz*. The wave is propagating along *z*-axis. The average energy density of electric field, in *Joule*/*m*³, will be

(a) 1.1×10^{-11} (b) 2.2×10^{-12} (c) 3.3×10^{-13} (d) 4.4×10^{-14}

76. To establish an instantaneous displacement current of 2*A* in the space between two parallel plates of 1«*F* capacitor, the potential difference across the capacitor plates will have to be changed at the rate of

(a) 4×10^4 *V* / *s* (b) 4×10^6 *V* / *s* (c) 2×10^4 *V* / *s* (d) 2×10^6 *V* / *s*

77. A laser beam can be focussed on an area equal to the square of its wavelength *A He-Ne* laser radiates energy at the rate of 1*mW* and its wavelength is 632.8 *nm*. The intensity of focussed beam will be

(a) 1.5×10^{13} W/m^2 (b) 2.5×10^{9} W/m^2 (c) 3.5×10^{17} W/m^2 (d) None of these

78. An electric field of 300 *V*/*m* is confined to a circular area 10 *cm* in diameter. If the field is increasing at the rate of 20 *V*/*m-s*, the magnitude of magnetic field at a point 15*cm* from the centre of the circle will be

(a) 1.85×10^{-15} *T* (b) 1.85×10^{-16} *T* (c) 1.85×10^{-17} *T* (d) 1.85×10^{-18} *T*

79. A lamp emits monochromatic green light uniformly in an directions. The lamp is 3% efficient in converting electrical power to electromagnetic waves and consumes 100*W* of power. The amplitude of the electric field associated with the electromagnetic radiation at a distance of 10*m* from the lamp will be

(a) 1.34 *V*/*m* (b) 2.68 *V*/*m* (c) 5.36 *V*/*m* (d) 9.37 *V*/*m*

80. A point source of electromagnetic radiation has an average power output of 800 *W*. The maximum value of electric field at a distance 4.0 *m* from the source is

(a) 64.7 *V*/*m* (b) 57.8 *V*/*m* (c) 56.72 *V*/*m* (d) 54.77 *V*/*m*

81. A lamp radiates power P_0 uniformly in all directions, the magnitude of electric field strength E_0 at a distance *r* from it is

(a) $E_0 = \frac{P_0}{2®£_0 cr^2}$ (b) $E_0 = \sqrt{\frac{P_0}{2®£_0 cr^2}}$ (c) $E_0 = \sqrt{\frac{P_0}{4®£_0 cr^2}}$ (d) $E_0 = \sqrt{\frac{P_0}{8®£_0 cr}}$

82. The wave impedance of free space is

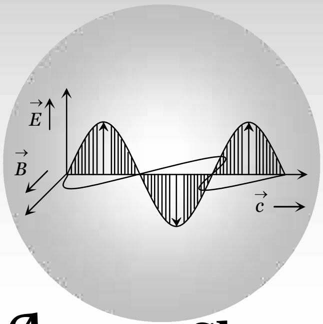
(a) Zero (b) 376.6 Ω (c) 33.66 Ω (d) 3.76 Ω

83. The transmitting antenna of a radio-station is mounted vertically. At a point 10 *km* due north of the transmitter the peak electric field is 10^{-3} Vm^{-1}. The magnitude of the radiated magnetic field is

(a) 3.33×10^{-10} *T* (b) 3.33×10^{-12} *T* (c) 10^{-3} *T* (d) 3×10^{5} *T*

84. A wave is propagating in a medium of electric dielectric constant 2 and relative magnetic permeability 50. The wave impedance of such a medium is

(a) 5 Ω (b) 376.6 Ω (c) 1883 Ω (d) 3776 Ω



Answer Sheet

Assignments

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
c	a	a	a	c	a	b	b	d	b	d	a	c	a	d	c	b	a	a	c
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
c	a	b	c	a	d	a	b	d	c	c	c	c	c	b	a	a	d	d	b
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
a	b	d	c	d	b	c	d	b	b	c, d	a	d	c	c	c	d	a	b,d	d
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
d	b	a	b	d	c	c	a	c	c	a	a	d	d	b	d	b	d	a	d
81	82	83	84																
b	b	b	c																