Electromagnetic Waves

8

BASIC EQUATIONS OF ELECTRICITYAND MAGNETISM

The whole concept of electricity and magnetism can be explained by the four basic equations we have deal so far.

(1) $\oint E \cdot ds = \frac{Q}{\epsilon_0}$

(Gauss law for electrostatic)

(2) $\oint B \cdot ds = 0$

(Gauss law for magnetism)

(3) $\oint B \cdot dl = \mu_0 i$

(Ampere's law for Magnetism)

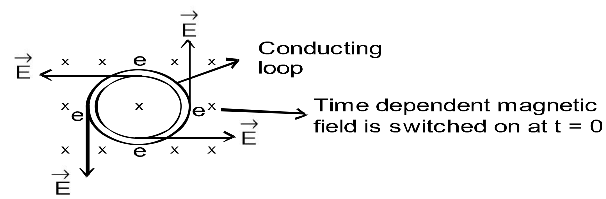
(4) $\oint E \cdot dl = 0$

(Ampere's law for electrostatics)

The above stated equation are true for non-time varying fields

FARADAYS LAW FOR TIME VARYING MAGNETIC FIELD

To understand the concept of faradays law we consider a circular conducting loop placed in a region where time dependent magnetic field is present



From the earlier concept we know that an induced emf will be produced in the conducting loop due to which current will flow in the loop.

For current to flow a force must act on the electron which will move then from static state. This force cannot be due to magnetic field (since magnetic force does not act on stationary charge). Hence this force must be due to an electric field which has been generated due to changing Magnetic field.

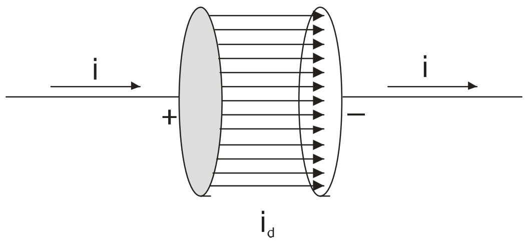
Note :- This electric field is non conservative in nature.

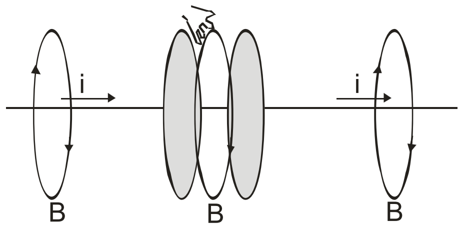
Faraday stated this fact in his equation

$$\oint E \cdot dl = -\left(\frac{d\varphi_B}{dt}\right)$$

CONCEPT OF DISPLACEMENT CURRENT

(i) Let us consider a circuit containing the capacitor as shown in fig. 21.1





(ii) According to Ampere's circuital law, the line integral of magnetic field along any closed path is μ_0 times the total current enclosed by the closed path. Mathematically

$$\oint \vec{B}.\vec{dl} = \mu_0 I$$

In this law it is assumed that conduction current flows through the connecting wires charging the condenser plates but no current flows in the space in between the plates. Actually it is not true.

(iii) When the circuit is closed, conduction current flows from the plate P of the capacitor to the other plate Q through the conducting wires. Maxwell suggested that due to time varying electric field between the plates, an electric current, called displacement current (I_D), also flows across the space between the plates of the capacitor.

(iv) Thus, there is a continuous flow of current in a capacitive circuit also, through the conducting wire there is flow of conduction current I_C and through the space across the plates of capacitor, there is flow of displacement current I_D.

(v) Maxwell pointed out that in Ampere's circuital law, the current I should be treated as total current i.e., the sum of the conduction current I_C and displacement current I_D and modified the law as

$$\oint \vec{B}.\vec{dl} = \mu_0 \left(I_C + I_D\right)$$

It is called the Ampere-Maxwell's circuital law.

(vi) The displacement current is defined as

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$$

where f_E is the electric flux linked between the plates of the capacitor at any instant. Therefore Ampere-Maxwell circuital law may be expressed as

$$\oint \vec{B}.\vec{dl} = \mu_0 \left(I_C + \varepsilon_0 \frac{d\phi_E}{dt} \right)$$

Solved Examples

Ex. 1 In a plane electromagnetic wave, the electric field oscillates sinusoidal at a frequency 2×10^{10} Hz and amplitude 48 V/m. The amplitude of oscillating magnetic field will be:

(A) $\frac{1}{16}\times10^{-8}$ Wb/m^2

(B) 16×10^{-8} Wb/m^2

(C) 12×10^{-7} Wb/m^2

(D) $\frac{1}{12}\times10^{-7}$ Wb/m^2

Sol. (B) Oscillating magnetic field

$$B = \frac{E}{c} = \frac{48}{3\times10^8} = 16 \times 10^{-8}\ \text{Wb/m}^2$$

Solved Examples

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

(A) 1.062A (B) 1.062×10^{-2}A

(C) 1.062×10^{-3}A (D) 1.062×10^{-4}A

Sol. (D) $I_D = \varepsilon_0 \frac{\partial \phi_E}{\partial t} = \varepsilon_0 \frac{EA}{t} = \frac{\varepsilon_0 VA}{dt}$

or $I_D = \frac{8.85\times10^{-12}\times400\times60\times10^{-4}}{2\times10^{-3}\times10^{-6}}$

$= 1.062 \times 10^{-4}A$

Ex. 3 In an electric circuit, there is a capacitor of reactance $100\,\Omega$ connected across the source of 220V. The displacement current will be:

(A) 2.2A (B) 0.22A

(C) 4.2A (D) 2.4A

Sol. (A) Displacement current and conduction current are equal.

$\therefore I_D = \frac{E}{Z} = \frac{220}{100} = 2.2A$

(vii) The conduction current and the displacement current are always equal, i.e., $I_C = I_D$

(viii) Like conduction current, the displacement current is also the source of magnetic field.

MAXWELL'S EQUATIONS AND ORENTZ FORCE

The existence of electro-magnetic waves that propagate through the space in the form of varying electric and magnetic fields has been predicted by the four basic laws of electromagnetism which are called Maxwell's equations.

(i) Gauss's law in electrostatics: It states that the total electric flux through any closed surface is equal to $\frac{1}{\varepsilon_0}$ times the net charge enclosed by

Mathematically, $\oint \vec{E}.\vec{dl} = \frac{q}{\varepsilon_0}$

This equation is called Maxwell's first equation.

(ii) Gauss law in magnetism: It states that the net magnetic flux crossing any closing surface is always zero.

Mathematically, $\oint \vec{B}.\vec{ds} = 0$

This equation is called Maxwell's second equation. A direct consequence of this equation is that the magnetic monopoles do not exist.

(iii) Faradays' law of electromagnetic induction: It states that the induced emf produced in a circuit is numerically equal to the rate of change of magnetic flux through it.

Mathematically, $\varepsilon = -\frac{d\phi_B}{dt}$

But $q\,\varepsilon = \oint \vec{E}.\vec{dl} =$ Line integral of electric field.

$\therefore \oint \vec{E}.\vec{dl} = -\frac{d\phi_B}{dt}$

This equation is called Maxwell's third equation.

The negative sign in this equation indicates that the induced emf produced opposes the rate of change of magnetic flux.

Solved Examples

Ex. 4 A point source of electromagnetic radiation has an average power output of 800W. The maximum value of electric field at a distance 3.5m from the source will be:

(A) 56.7 V/m (B) 62.6 V/m

(C) 39.3 V/m (D) 47.5 V/m

Sol. (B) Intensity of electromagnetic wave given is by

$I = \frac{P_{av}}{4\pi r^2} = \frac{E^2 m}{2\mu_0 c}$

$E_m = \sqrt{\frac{\mu_0 c P_{av}}{2\pi r^2}}$

$= \sqrt{\frac{(4\pi\times10^{-7})\times(3\times10^{8})\times800}{2\pi\times3.5^2}}$

$= 62.6$ V/m

Ex. 5 In the above problem, the maximum value of magnetic field will be:

(A) 2.09×10^{-5} T (B) 2.09×10^{-6} T

(C) 2.09×10^{-7} T (D) 2.09×10^{-7} T

Sol. (C) The maximum value of magnetic field is given by

$$B_m = \frac{E_m}{c} = \frac{62.6}{3\times10^8}$$

$= 2.09 \times 10^{-7}$ T

(iv) Maxwell-Ampere circuital law: It states that the line integral of magnetic field along a closed path is equal to μ_0 times the total current (i.e., sum of conduction and displacement currents threading the surface bounded by that closed path)

Mathematically,

$$\oint \vec{B}.\vec{dl} = \mu_0\left(I_C + \varepsilon_0 \frac{d\phi_E}{dt}\right)$$

This equation is called Maxwell's fourth equation.

(v) Lorentz: The vector sum of electric force and magnetic force on any charged particle is called the Lorentz force.

$$\vec{F} = q[\vec{E} + (\vec{v}\times\vec{B})]$$

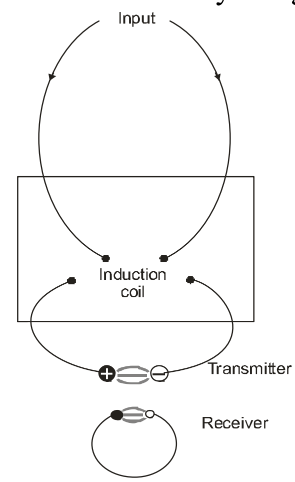
The above five equations give a complete description of all electromagnetic interactions.

PRODUCTION OF ELECTROMAGNETIC WAVES

(i) According to Maxwell, an accelerated charge sets up a magnetic field in its neighborhood. The magnetic field, in turn, produces an electric field in that region. Both these fields vary with time and act as sources for each other.

(ii) As oscillating charge is accelerated continuously, it will radiate electromagnetic waves continuously.

(iii) In 1988, Hertz demonstrated the production of electromagnetic apparatus is shown schematically in fig.



(iv) An induction coil is connected to two spherical electrodes with a narrow gap between them. It acts as a transmitter. The coil provides short voltage surges to the spheres making one positive and the other negative. A spark is generated between the spheres when the voltage between them reaches the breakdown voltage for air. As the air in the gap is ionised, it conducts more rapidly and the discharge between the spheres becomes oscillatory.

(v) The above experiment arrangement is equivalent to an LC circuit, where the inductance is that of the loop and the capacitance is due to the spherical electrodes.

(vi) Electromagnetic waves are radiated at very high frequency ($\approx$100 MHz) as a result of oscillation of free charges in the loop.

(vii) Hertz was able to detect these waves using a single loop of wire with its own spark gap (the receiver).

(viii) Sparks were induced across the gap of the receiving electrodes when the frequency of the receiver was adjusted to match that of the transmitter.

HISTORY OF ELECTROMAGNETIC WAVES

(i) In year 1865, Maxwell predicted the electromagnetic waves theoretically. According to him, an accelerated charge sets up a magnetic field in its neighborhood.

(ii) In 1887, Hertz produced and detected electromagnetic waves experimentally at wavelength of about 6m.

(iii) Seven year later, J.C. Bose became successful in producing electromagnetic waves of wavelength in the range 5 mm to 25 mm.

(iv) In 1896, 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.

(v) The antenna and the earth wires form the two plates of a capacitor which radiates radio frequency waves. These waves could be received at a large distance by making use of an antenna earth system as detector.

(vi) Using these arrangements; in 1899 Marconi first established wireless communication across the English Channel i.e. across a distance of about 50 km.

PROPERTIES OF ELECTROMAGNETIC WAVES

(i) The electric and magnetic fields satisfy the following wave equations, which can be obtained from Maxwell's third and fourth equations.

$$\frac{\partial^2 E}{\partial x^2} = \mu_0 \varepsilon_0 \frac{\partial^2 E}{\partial t^2}$$

(ii) Electromagnetic waves travel through vacuum with the speed of light c, where

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8 \text{ m/s}$$

(iii) The electric and magnetic fields of an electromagnetic wave are perpendicular to each other and also perpendicular to the direction of wave propagation. Hence, these are transverse waves.

(iv) The instantaneous magnitude of $\vec{E}$ and $\vec{B}$ in an electromagnetic wave are related by the expression

$$\frac{E}{B} = c$$

(v) Electromagnetic waves carry energy. The rate of flow of energy crossing a unit area is described by the Pointing vector $\vec{S}$

where $\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}$

(vi) Electromagnetic waves carry momentum and hence can exert pressure (P) on surfaces, which is called radiation vector $\vec{S}$, incident on a perfectly absorbing surface $P = \frac{S}{c}$ and if incident on a perfectly reflecting surface $P = \frac{2S}{c}$

(vii) The electric and magnetic fields of a sinusoidal plane electromagnetic wave propagating in the positive x-direction can also be written as

$$E = E_m \sin(kx - \omega t)$$
$$B = B_m \sin(kx - \omega t)$$

where w is the angular frequency of the wave and k is wave number which are given by

$$w = 2 w f \qquad \text{and } k = \frac{2\pi}{\lambda}$$

(viii) The intensity of a sinusoidal plane electro-magnetic wave is defined as the average value of Pointing vector taken over one cycle.

$$S_{av} = \frac{E_m B_m}{2\mu_0} = \frac{E_m^2}{2\mu_0 c} = \frac{c}{2\mu_0} = B_m^2$$

(ix) The fundamental sources of electromagnetic waves are accelerating electric charges. For example radio waves emitted by an antenna arise from the continuous oscillations (and hence acceleration) of charges within the antenna structure.

(x) Electromagnetic waves obey the principle of superposition.

(xi) The electric vector of an electromagnetic field is responsible for all optical effects. For this reason electric vector is called a light vector.

Solved Examples

Ex. 6 In an electromagnetic wave, the amplitude of electric field is 1V/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}

Sol. (B) Average energy density is given by

$$u_E = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\varepsilon_0\left(\frac{E_0}{\sqrt{2}}\right)^2 = \frac{1}{4}\varepsilon_0 E_0^2$$

$$= \frac{1}{4}\times 0.85\times 10^{-12}\times(1)^2$$

$= 2.2 \times 10^{-12}$ J/m^3

Ex. 7 To establish an instantaneous displacement current of 2A in the space between two parallel plates of 1μF 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

Sol. (D)

$$I_D = \varepsilon_0\frac{d\phi_E}{dt} = \varepsilon_0\frac{d}{dt}(EA) = \varepsilon_0 A\frac{d}{dt}\left(\frac{V}{d}\right)$$

$$I_D = \frac{\varepsilon_0 AdV}{d}\frac{dV}{dt} = C\frac{dV}{dt}$$

$$\therefore \frac{dV}{dt} = \frac{I_D}{C} = \frac{2}{10^{-6}} = 2\times 10^6 \text{ V/s}$$

ENERGY DENSITY AND INTENSITY

We know that electric and magnetic field have energy and since EM wave have both these components hence it carries energy with it.

We know that energy density associated with E.F. $= \frac{1}{2}\in_0 E^2$

We know that energy density associated with M.F. $= \frac{B^2}{2\mu_0}$

Thus total energy of EM wave is given by

$$U = U_E + U_B \text{ or } \frac{1}{2}\in_0 E^2 + \frac{B^2}{2\mu_0}$$

putting the values of E.F. and M.F.

$$U = \frac{1}{2}\in_0 E_0^2$$

$$\sin^2\omega(t-x/c) + \frac{B_0^2\sin^2\omega(t-x/c)}{2\mu_0}$$

If we take the average value over a long period of time

$$\left[\sin^2\omega\left(t-\frac{x}{c}\right)\right]_{Av} = \frac{1}{2}$$

$$\therefore \boxed{U_{av} = \frac{1}{4}\in E_0^2 + \frac{1}{4\mu_0}B_0^2}$$

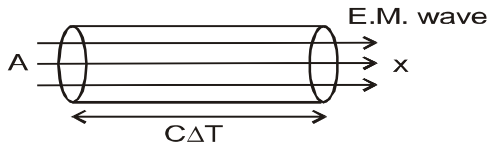
The above equation can also be written as

$$U_{av}\ \frac{\in_0 E_0^2}{2} = \text{ or } U_{av} = \frac{B_0^2}{2\mu_0}$$

Intensity:

Energy crossing per unit area per unit time perpendicular to the direction of propagation is called intensity of wave.

Energy contained in the volume :



$$U = U_{av} \times \text{vol} = \frac{1}{2} \in_0 E^2 (AC\Delta T)$$

$$\text{intensity} = \frac{U}{A\Delta T} = \frac{\in_0 E^2 C}{2}$$

$$\therefore \quad \boxed{I = \frac{1}{2}\in_0 CE_0^2 \quad \text{or} \quad \frac{1}{2\mu_0} B_0^2}$$

Solved Examples

Ex.8 The intensity of light from a source is $500/\pi$ W/m^2. Find the amplitude of electric field in this wave-

(A) $\sqrt{3} \times 10^2$ N/C (B) $2\sqrt{3} \times 10^2$ N/C

(C) $\frac{\sqrt{3}}{2} \times 10^2$ N/C (D) $2\sqrt{3} \times 10^1$ N/C

Sol. (B) $I = \frac{1}{2} \in_0 C E_0^2$

$$E_0 = \sqrt{\frac{2I}{\in_0 C}} \text{ or } \sqrt{\frac{2 \times 500 \times 10^9 \times 36\pi}{\pi \times 10^8 \times \pi \times 3}}$$

$$E_0 = 2\sqrt{3} \times 10^2 \text{ N/C}$$

Ex.9 A point source of 2 watts is radiating uniformly in all direction in vacuum. Find the amplitude of electric field at a distance 2m from it-

(A) 3×10^{-4} (B) 3×10^{-2}

(C) $\sqrt{3} \times 10^{-4}$ (D) $\sqrt{3} \times 10^{-2}$

Sol. (C) $I = \frac{P}{A}$ or $\frac{2}{4\pi \times 4} = \frac{1}{8\pi}$ W/m^2

$$I = \frac{1}{2} \in_0 E_0^2 c$$

$$E_0 = \sqrt{\frac{2I}{\in_0 C}} \text{ or } \sqrt{\frac{2 \times 1 \times 36\pi}{8\pi \times 3 \times 10^8}} \times 10^{-4} \text{N/C}$$

Ex.10 In a EM wave the amplitude of electric field is 10 V/m. The frequency of wave is 5 Ч 10^4 Hz. The wave is propagating along Z-axis. Then the average energy density of Magnetic field is-

(A) 2.21×10^{-10} J/m^3

(B) 2.21×10^{-8} J/m^3

(C) 2×10^{-8} J/m^3

(D) 2×10^{-10} J/m^3

Sol. (A) $U_B = \frac{B_0^2}{4\mu_0}$

Also $\frac{E_0}{B_0} = C \therefore B_0 = \frac{E_0}{C}$

Hence $B_0 = \frac{E_0}{\frac{1}{\sqrt{\mu_0 \in_0}}}$

$\therefore \quad U_B = \frac{E_0^2 \mu_0 \in_0}{4\mu_0}$

or $\frac{100 \times 8.84 \times 10^{-12}}{4}$

$\therefore U_B = 2.21 \times 10^{-10}$ J/m^3

ELECTROMAGNETIC SPECTRUM

(i) The orderly distribution of electromagnetic waves (on the basis of wavelength or frequency) in the form of distinct groups having widely differing properties is called the electromagnetic spectrum.

The following table gives a complete and detailed picture of electromagnetic spectrum

(ii) Various parts of electromagnetic pectrum

S.No.	Radiation	Discover	How produced	Wave length range	Frequency range	Energy range	Properties	Application
1.	γ&Rays	Henry Becquerrel and Madam Curie	Due to decay of radioactive nuclei	10^{-14} m to 10^{-10}m.	3×10^{22} Hz to 3×10^{18} Hz	10^{7}eV $- 10^{4}$ eV	(a) High penetrating power (b) Uncha-rged (c) Low ionising power	(a) Gives information on nuclear structure (b) Medical treatment etc.
2.	X-Rays	Roentgen	Due to collisions of high energy electrons with heavy targets	6×10^{-10} m to10^{-9} m	5×10^{19} Hz to 3×10^{17} Hz	2.4×10^{5} eV to 1.2×10^{3} eV	(a) Low penetrating power (b) other properties similar to γ&rays except wavelength	(a) Medical diagnosis and treatment (b) Study of crystal structure (c) Indus-trial radiography
3.	Ultraviolet Rays	Ritter	By ionised gases, sun are lamp spark etc.	6×10^{-10}m to 3.8×10^{-7} m	3×10^{17} Hz to 5×10^{19} Hz	2×10^{3} eV to 3eV	(a) All properties (b) Photo-electric effect	(a) To detect adulteration, (b) Sterili-zation of water due to its des-tructive act-ion on bacteriaa
4.	Visible light (a)Violet	Newton	Outer orbit electron transitions in atoms, gas disch-arge tube, incandes-cent	3.8×10^{-7} m to 7.8×10^{-7} m 3.9×10^{-7} m to 4.55 $\times10^{-7}$ m	8×10^{14} Hz to 4×10^{14} Hz 7.69×10^{14} Hz to 6.59×10^{14} Hz	3.2 eV to 1.6eV	(a) Sensitive to human eye	(a) To see objects (b) To study molecular structure

	(b) Blue			4.55×10^{-7} m to 4.92×10^{-7} m	6.59×10^{14} Hz to 6.10×10^{14} Hz			
	(c) Green			4.92×10^{-7} m to 5.77×10^{-7} m	6.10×10^{14} Hz to 5.20×10^{14} Hz			
	(d) Yellow			5.77×10^{-7} m to 5.97×10^{-7} m	5.20×10^{14} Hz to 5.03×10^{14} Hz			
	(e)Orange			5.97×10^{-7} m to 6.22×10^{-7} m	5.03×10^{14} Hz to 4.82×10^{14} Hz			
	(f) Red			6.22×10^{-7} m to 7.80×10^{-7} m	4.82×10^{14} Hz to 3.84×10^{14} Hz			
5.	Infra-Red waves	William Herschell	(a) Rearr-angement of outer orbital's electrons in atoms and molecules (b)Change of molecu-lar vibrati-onal and rotational energies. (c) By bodies at high temp-erature	7.8×10^{-7} m to 10^{-3} m	4×10^{14} Hz to 3×10^{11} Hz	1.6 eV to 1.6^{-3}eV	(a) Thermal effect (b) All prop-erties similar of those of light except λ	(a) Used in industry, me dicine and astro nomya (b) Used for fog or have photography
6.	Microwav es	Hertz	special electronic devices such as klystron tube	10^{-7} m to 0.3m	3×10^{11} Hz to 10^{9} Hz	10^{-3}eV to 10^{-5}eV	(a) Pheno mena of reflection, refraction and diffraction	(a) Radar and telecom - munication (b) Analysis of fine details of molecular structure

7.	Radio waves	Marconi	Oscillating circuits	0.3m to few kms.	10^9 Hz to few Hz	10^{-3}ev to ≈ 0	(a) Exhibit waves like properties more than particle like properties	(a) Radio communication (b) Radar, Radio and sate llite communi cation (Microw aves)
(A)	Subparts of Radio spectrum Super High (a)SHF Ultra High (b) (UHF) Very High (c) (VHF)			0.1m to 0.1m 0.1m to 1m 1m to 10m	3×10^{10} Hz to 3×10^9 Hz 3×10^9 Hz to 3×10^8 Hz 3×10^8 Hz to 3×10^7 Hz			Radar and television broad cast short distance communication, Television communication
(B)	High frequency Medium frequency Low Frequency Very low frequency			10m to 100m 100m to 1000m 1000m to 10000m 10000m to 30000m	3×10^7 Hz to 3×10^6 Hz 3×10^6 Hz to 3×10^5 Hz 3×10^5 Hz to 3×10^4 Hz 3×10^4 Hz to 3×10^4 Hz			Medium distance communication Marine and navigation use, long range communication. Long distance communication.

EARTH'S ATMOSPHERE AND ELECTROMAGNETIC WAVES

(i) The gaseous envelop surrounding the earth is called earth's atmosphere.

(ii) It mainly consists of nitrogen 78% and oxygen 21% along with a little portion of argon, carbon dioxide, water vapor, hydrocarbons, sulphur compounds and dust particles.

(iii) The density of atmospheric air goes on decreasing gradually as we go up.

(iv) The earth's atmosphere has no sharp boundary. However, it has been divided into various regions as given below:

(a) **Troposphere:** It extends upto a height of 12 km from earth's surface. The temperature in this region decreases from 298K to 220K and conductivity increases. All climatic changes occur in this region.

(b) **Stratosphere:** It extends from 12 km to 50 km after troposphere. At the upper part of this region, approximately 20km thick, most of ozone of atmosphere is concentrated. This layer is called as ozone layer. This layer absorbs very large portion of ultraviolet radiations coming from sun, therefore its temperature increases from 220K to 280K.

(c) Mesosphere: It extends from 50km to 80 km after stratosphere. In this region the temperature decreases from 280K to 180K

(d) Ionosphere: It extends from 80 km to 400 km after mesosphere. The temperature of this region rises from 180K to 700K. In this region ultraviolet radiation coming from sun cause ionisation, therefore this part mostly consists of free electrons and positive ions. The concentration of free electrons is found to be very large in a region beyond 110 km from earth's surface which extends vertically for a few kilometers and is called Kennelly Heaviside layer. Beyond this layer the concentration of free electrons decreases considerably until a height of about 250 km. Beyond it there is another layer of electrons, called Appleton layer.

(v) Greenhouse effect: The atmosphere is transparent to visible radiations, but most ifrared (heat) radiations are not allowed to pass through. The energy from the sun heats the earth which then starts emitting radiations like any other hot body. However, since the earth is much colder than sun, its radiations are mainly in the infra red region. These radiations are unable to cross the lower atmosphere and are reflected back. Low lying clouds also reflect back the infra red radiations. As such, the earth's surface warm at night. This phenomenon is called the Green house effect.

(vi) Propagation of Radio waves:

(a) Low frequency waves-the AM band: Radio waves having wavelengths of 10m or more (frequency less than 30 Mhz) are said to constitute the AM band. The lower atmosphere is transparent to these waves, but the ionosphere reflects them back. A signal transmitted from a certain point can be received at another point in two possible ways-directly along the surface of the earth (called sky wave) and after reflection from ionosphere (called sky wave). Waves having frequencies upto about 1500kHz (Wavelength above 200m) are mainly transmitted through ground because low frequency sky waves lose their energy very quickly than the sky waves. Therefore, higher frequencies are mainly transmitted through sky. These two regions of the AM band are called medium wave and short wave bands respectively.

(b) High frequency waves-Television transmission: Above a frequency of about 40MHz the ionosphere does not reflect the wave toward the earth. The television signals have frequencies in the range 100-200 MHz. Therefore TV transmission via the sky is not possible-only direct reception via the ground is possible. Therefore, in order to have larger coverage, the transmission has to be done through very tall antennas. The height of transmitting antenna for TV telecast is given by $h = \dfrac{d^2}{2R_e}$

where d is the radius of the area to be covered for TV telecast and Re is the radius of earth.

Solved Examples

Ex. 11 A T.V. tower has a height of 100m. 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

Sol. (A) Radius of the area covered by T.V. telecast

$d = \sqrt{2hR_e}$

Total population covered ¾ $\pi d^2 \times$ population density

$= 2\pi hR_e \times$ population density

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

$= 39.503 \times 10^5$

Ex. 12 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-ray region (D) γ-ray region

Sol. (C) $\lambda = \frac{hc}{E} = \frac{6.6\times10^{-34}\times3\times10^8}{14.4\times10^3\times1.6\times10^{-19}}$

This wavelength belongs to X-ray region.