5. ELECTROMAGNETIC WAVES

SYNOPSIS

Introduction :

i) The magnetic field due to a conductor carrying current (i_c) is determined by using the Ampere's circuital law $\int \vec{B}.d\vec{l} = \mu_0 i_c$

ii) When a time varying current is applied to a condenser, there is a flow of electricity. So there must be a magnetic field created between the plates of the condenser.

iii) But Maxwell observed that the Amperes circuital law can not be applied between the plates of the condenser, as in the case of a conductor.

iv) Maxwell observed the inconsistancy of the Amperes law in a circuit carrying time varying current with a gap.

v) To remove the inconsistancy he suggested the existance of an additional current called dis-placement current. (i_d)

vi) Conduction current "i_c" is produced by the time varying magnetic field

$$i_c \propto \frac{dB}{dt} \text{ and } i_c = \frac{dq}{dt}$$

Displacement current "i_d" is produced by the time varying electric field $i_d \propto \frac{dE}{dt}$.

1. Maxwells Displacement Current:

i) Maxwell proposed the existance of "displacement current".

ii) The rate of change of electrical flux produces a current called displacement current "i_d".

iii) The displacement current is due to change in electric field.

iv) Maxwell made the laws of electricity and magnetism symmetrical with the help of displacement current.

v) Unlike conduction current displacement current exists where there is rate of change of electrical flux.

vi) At points where there is an accumulation of charge and hence a discontinuity in conduction current, displacement current helps us to make the total current continuous across the discontinuity.

vii) The displacement current is found between the plates of a condenser during its charging or discharging.

viii) It is also found between the plates of a condenser when AC is applied.

ix) It is called current because it produces a magnetic field.

2. Electrical Flux :

i) ϕ_E = Electrical flux

= Electrical lines of force passing through an area A and perpendicular to the surface
= (Strength of electric field E) (Area A) = EA

When the direction of $\overline{E}$ is not perpendicular to the surface A and makes an angle θ with the normal to A $\phi_E = EA\cos\theta$ or $\overline{E}.\overline{A} = \int \overline{E}.\overline{ds}$

ii) Units of electrical flux is N - m^2 /Coulomb. and Volt meter.

3. Displacement Current :

i) $\boxed{i_d = \epsilon_0 \dfrac{d\phi_E}{dt}}$

ii) $\boxed{i_d = \epsilon_0 A \dfrac{dE}{dt}}$ where $\dfrac{dE}{dt}$ is variable electrical field

4. Displacement current in the gap between the condenser plates :

i) When a charging current "i" which is constant is given, "i_d" the displacement current = charging current "i".

ii) When a variable electrical field is applied to the gap $\boxed{i_d = A \epsilon_0 \dfrac{dE}{dt}}$.

iii) When a variable potential difference is applied to the plates of a condenser of capacity C $\boxed{i_d = C\dfrac{dv}{dt}}$.

iv) If AC is applied to the plates of a condenser variable magnetic field with the same frequency is produced.

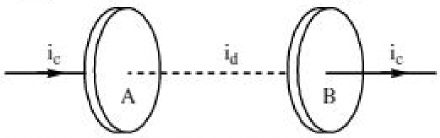
v) $i_c = i_d$; $i_c = \dfrac{V}{X_c} = V\omega C$

$$i_c = C.\frac{dv}{dt} = C.\frac{d}{dt}(V_0 \text{Sin}\ \omega t) = C.V_0\ \omega \text{Cos}\ \omega t$$

$\therefore V_0\ \omega C$ gives peak value of i_d.

$V\omega C$ gives instantant value of i_d.

$V_{rms}\ \omega C$ gives rms value of i_d.



vi) **CONDENSER PLATES**

A and B are condenser plates i_c is conduction current in lead wires i_d is the displacement current Conduction Current i_c = displacement current i_d

vii) Kirchoff's law of current is valid at each plate of the condenser if we take the total current as the sum of the conduction and displacement currents.

viii) **Ampere - Maxwell's law or Amperes Law is modified by Maxwell.**

ix) $\int \vec{B}.d\vec{l} = \mu_0 (i_c + i_d)$

$$\int \vec{B}.d\vec{l} = \mu_0 \left(i_c + \epsilon_0 \frac{d\phi_E}{dt} \right)$$

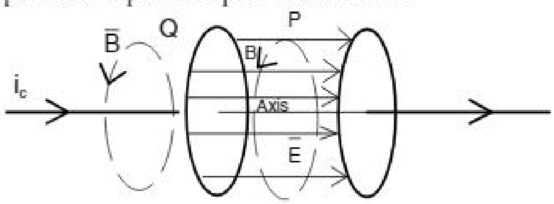
i_c = The conduction current found in a conductor carrying current

i_d = Displacement current which is found between the plates of a condenser which is a discontinuous.

x) Using the above formula the magnetic field $\overline{B}$ produced due to displacement current can be determined.

5. Measurement of Magnetic field in the gap :

A variable current is applied to a parallel plate condenser.



i) Consider a point Q above the condenser lead. In the lead conduction current i_c flows. Magnetic $\bar{B}$ is determined from $\int \vec{B}.\vec{dl} = \mu_0 (i_c + i_d)$ as $i_d = 0$ at Q $\int \vec{B}.\vec{dl} = \mu_0 i_c$

ii) a) Consider a point P between the plates of a condenser. Variable electric field is created between the plates and perpendicular to them.

b) Consider each line of force to be an imaginary conductor carrying current. This produces magnetic field around it but not on it. The magnetic field produced at a point P is the cumulative effect of the bundle of currents (lines of force) contained by the circle passing through P. The plane of the circle is parallel to the plates with its centre on their axes. From the law

$$\int \vec{B}.\vec{dl} = \mu_0 (i_c + i_d)$$

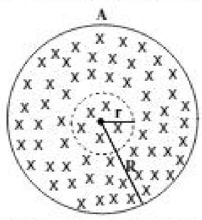
But $i_c = 0$

$$\therefore \int \vec{B}.\vec{dl} = \mu_0 i_d$$

As the electrical field is variable, the magnetic field produced is also variable.

6. Magnetic field between the plates at different points with respect to the axis of the plates :

i) The magne tic field at different distances from the axis can be estimated using displacement current



ii) The figure A shows the cross section of Electrical field between the plates of a condenser having the plates of radius R.

iii) The electric field is acting into the paper.

iv) The magnetic field at a distance "r" from the axis 'B' is obtained,

$$\int \vec{B}.\vec{dl} = \mu_0 i_d$$

$$B\, 2\pi r = \mu_0 \frac{i_d}{\pi R^2}.\pi r^2$$

$$\boxed{\therefore B = \frac{\mu_0}{2\pi} i_d \frac{r}{R^2}}$$

v) The magnetic field along the axis (r = 0). $\therefore B = 0$.

vi) The magnetic field at a distance R from the axis $\boxed{B = \frac{\mu_0}{2\pi}\frac{i_d}{R}}$ this is maximum value.

vii) If 'Q' the charge on the condenser $i_d = \frac{dQ}{dt}$.

7. MAXWELL'S EQUATIONS :

i) Gauss' law for electricity, with the usual notation $\boxed{\int \vec{E}.d\vec{A} = q_{net}/\varepsilon_0}$ .... **(1)**

a) It establishes a relation between the net charge enclosed in a closed volume to the total electric flux associated with its surface area.

b) It shows that isolated charge do exist and electric lines of force start from positive charge and terminate at negative charge.

ii) Gauss' law for magnetism,

$$\boxed{\int \vec{B}.d\vec{A} = 0} \quad ......\ (2)$$

a) The right hand side of Eq. (2) confirms that equal number of magnetic lines of force enter and leave a certain volume, as they are closed curves.

b) It shows that isolated magnetic monopoles do not exist.

iii) Faraday's law,

$$\boxed{\int \vec{E}.d\vec{l} = -\frac{d\phi_B}{dt}} \quad ......\ (3)$$

This law shows that a time varying magnetic field induces an electrical field.

iv) Ampere-Maxwell law, which relates the magnetic field induced due to the changing electric flux as well as to the current due to flow of charges, as

$$\boxed{\int \vec{B}.d\vec{l} = \mu_0 i_c + \mu_0 \varepsilon_0 \frac{d\phi_E}{dt} = \mu_0 (i_c + i_d)} \quad ....\ (4)$$

The above four equations viz., Eqns. (1) to (4) are known as the **Maxwell's equations.**

v) **Lorentz Force:** The force acting on a charge 'q' moving in a region where electric and magnetic fields similar to EM wave are existing simul-taneously is $\boxed{\overline{F} = q\left[\overline{E} + \overline{V} \times \overline{B}\right]}$.

vi) The Maxwells equations along with the Lorentz force give the complete description of all magnetic interactions.

8. PRODUCTION OF ELECTOMAGNETIC WAVES :

i) a) Stationary charges produce only electric field

b) Moving charges produce both electric field $\overline{E}$ and magnetic field $\overline{B}$.

ii) Only accelerated charges radiates energy in the form of em waves. So it is the source of an emwave.

iii) An oscillating charge produces an oscallating or time varying magnetic field.

iv) This time varying magnetic field is a source of time varying electrical field.

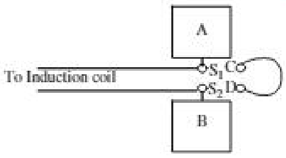
v) The oscillating electric and magnetic fields regenerate each other and propagate through space as waves called electro magnetic waves.

vi) An electric charge oscillating harmonically with frequency ν produces electromagnetic waves of the same frequency ν.

vii) Maxwell predicated the existence of em waves theoretically.

viii) After 20 years later their existence was confirmed experimentally by Hertz.

ix) In 1888, Hertz demonstrated the production of electromagnetic waves by oscillating charge.



From the diagram

a) A and B are two metallic plates called condensing plates.

b) Due to high voltage from induction coil the space between S_1 and S_2 becomes conductive and discharge takes place.

c) Due to the accelerated charges between S_1 and S_2 E-M waves are originated from S_1 S_2

d) Due to induced electricity in the detector CD spark is produced between CD.

e) When CD and S_1 S_2 are perpendicular no spark is produced since there is no induction.

f) When CD is parallel to S_1S_2 due to induced current spark is produced.

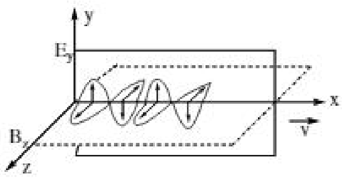
g) Hence it can be concluded that electromagnetic waves are tranverse in nature.

h) Finally Maxwell concluded that light is an em wave.

i) Frequency $\boxed{\nu = \frac{1}{2\pi\sqrt{LC}}}$.

9. Nature of electromagnetic waves :

Electric and magnetic fields oscillate sinusoidally in space and time in an electromagnetic wave, giving rise to and sustaining each other. The oscillating electric and magnetic fields $\bar{E}$ and $\bar{B}$ are perpendicular to each other and to the direction of propagation of the electromagnetic wave. If $\bar{E}$ is along the y-axis and $\bar{B}$ is along the z-axis, the direction of propagation is along $\bar{E}\times\bar{B}$ i.e., along the x-axis.



The electric and magnetic fields shown in the above figure are mathematically represented by

i) $\bar{E} = E_y\,\hat{j} = E_0 \sin\,[kx\text{-}wt]\,\hat{j} = E_0 \sin$

$$2\pi\left(\frac{x}{\lambda} - vt\right)\hat{j} = E_0 \sin\,2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)\hat{j}$$

$$E_x = E_z = 0$$

ii) $\bar{B} = B_z\,\hat{k} = B_0 \sin\,[kx - wt]\,\hat{k}$

$$= B_0 \sin\,2\pi\left(\frac{x}{\lambda} - vt\right)\hat{k} \quad = B_0 \sin 2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)\hat{k} \qquad B_x = B_y = 0$$

iii) E_0 and B_0 are the amplitudes of the electric fields.

iv) $\bar{E}$ and $\bar{B}$ are the instanteneous values.

v) The planes in which $\bar{E}$ vector and $\bar{B}$ vector exist perpendicular to each other at a given instant.

vi) These two planes are perpendicular at all instants but the orientation of planes are variable w.r.t. time. This is the reason to get an unpolarised light.

vii) $k=\frac{2\pi}{\lambda}$ is the magnitude of the wave vector $\overline{k}$.

viii) The magnitudes of $\overline{E}$ and $\overline{B}$ are related by $\boxed{\frac{E}{B}=c \text{ or } \frac{E_0}{B_0}=c}$

ix) Electromagnetic waves travel through vacuum with the speed of light c,

where $c=\frac{1}{\sqrt{\mu_0 \epsilon_0}}=3 \times 10^8$ m/s

where μ_0 = permeability of free space

ϵ_0 = permittivity of free space

x) The speed of em waves or light in any other medium of permittivity ϵ and permeability μ is C_{medium}

$$C_{med}=\frac{1}{\sqrt{\mu \epsilon}}=\frac{1}{\sqrt{\mu_r \mu_0 \varepsilon_r \epsilon_0}}=\frac{c_0}{\sqrt{\mu_r \varepsilon_r}}$$

$$\boxed{\sqrt{\mu_r \epsilon_r}=\frac{C_0}{C_{med}}=\text{the refractive index}=n}$$

During the propagation of light the effect of μ_r is negligible there four $n=\sqrt{\epsilon_r}$

xi) The Poynting vector $\vec{S}=\vec{E}\times\vec{H}=\frac{\vec{E}\times\vec{B}}{\mu_0}$ represents the direction of energy flow per unit area per sec along the direction of wave propagation.

xii) Its unit is Wm^{-2}

xiii) The medium offers opposition to the propagation of wave. Such a hinderance is called **Wave Impedance (Z)** and its value in a medium is given by

$$Z=\frac{E}{H}=\sqrt{\frac{\mu}{\varepsilon}}=\sqrt{\frac{\mu_r}{\varepsilon_r}}\sqrt{\frac{\mu_0}{\varepsilon_0}} \quad [E=CB]$$

$$\{\because \mu=\mu_r\mu_0 \text{ and } \varepsilon=\varepsilon_r\varepsilon_0\}$$

where μ_r and ε_r are relative permeability and relative permittivity of medium.

xiv) a) For vacuum or free space

$$Z=\sqrt{\frac{\mu_0}{\varepsilon_0}}=376.6\Omega$$

b) For a conducting medium the impedence

$$\boxed{Z_e=\sqrt{\frac{\mu\,\omega}{\sigma}}}$$

μ –permeability of medium.

ω–angular frequency of incident e.m. wave.

σ – conductivity of medium.

c) For Higher frequencies Z_e is larger hence the em wave is reflected. so good conductors are good reflecters.

d) For perfect conductor σ is very very high hence Z_e is zero.

For a transparent medium refractive index

$$\boxed{n = \frac{\text{Im pedence in free space}}{\text{Im pedence in medium}}} = \frac{Z_{\text{free space}}}{Z_{\text{medium}}}.$$

xv) In free space the E & B are related as

$$\frac{E}{B} = \frac{E}{\mu_0 H} = \frac{1}{\mu_0}\sqrt{\frac{\mu_0}{\varepsilon_0}} \Rightarrow \frac{E}{B} = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = c \Rightarrow E = Bc$$

10. Energy density in free space :

i) The electrostatic energy density is equal to magnetostatic energy density.

ii) Average Electric Energy Density = Average Magnetic Energy Density

$$= \frac{1}{4}\varepsilon_0 E_0^2 = \frac{1}{4}\mu_0 H_0^2 = \frac{B_0^2}{4\mu_0}$$

iii) Total average energy density $\boxed{= \frac{1}{2}\varepsilon_0 E_0^2}$

(over one cycle)

Total Energy density in free space $\boxed{\frac{1}{2}\varepsilon_0 E^2 + \frac{B^2}{2\mu_0}}$

Energy density in a medium

iv) Electric Energy Density $= \frac{1}{2}\varepsilon E^2$

v) Magnetic Energy Density $= \frac{B^2}{2\mu}$

vi) Total Energy Density $= \frac{1}{2}\varepsilon E^2 + \frac{B^2}{2\mu}$

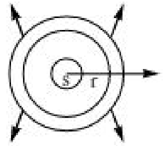
INTESITY OF RADIATION :

vii) The intensity of radiation is defined as the amount of energy passing through unit area in unit time.

$$\boxed{I = \frac{\text{Energy / time}}{\text{Area}} = \frac{\text{Power}}{\text{Area}}}$$

$$\boxed{I = uc = \epsilon_0 \, c \, E_{rms}^2}$$

viii) The intensity of the electromagnetic radiation from an isotropic point source at a distance r is $\boxed{I = \frac{P}{4\pi r^2}}$



P = Power of the Source.

MOMENTUM and RADIATION PRESSURE

ix) Electromagnetic waves have linear momentum as well as energy. When electromagnetic waves strike a surface, a pressure is exerted on the surface called radiation pressure.

x) When electro magnetic waves are incident on a surface and the total energy transferred to the surface in a time t is U, then the magnitude of the momentum delivered to the surface is

$\boxed{p = \frac{U}{c}}$ (Complete absorption)

where c = velocity of light

xi) When the sun shines on the hands of a person, he feels the absorption of electromagnetic waves (hands get warm).

xii) When the radiation incident on a surface is entirely reflected back along its original path, the magnitude of the momentum delivered to the surface is $\boxed{p = \frac{2U}{c}}$ where c = velocity of light

xiii) When radiation is incident on a surface, Radiation pressure $\boxed{p_r = \frac{I}{c}}$ (total absorption) $\boxed{p_r = \frac{2I}{c}}$ (total reflection back along the incident path)

xiv) Electromagnetic waves obey the principle of superposition.

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

11. ELECTROMAGNETIC SPECTRUM :

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

12. Propagation of Radio waves :

i) Low frequency waves - the AM band :

a) Radiowaves having wavelengths of 10m or more (frequency less than 30MHz) are said to constitute the AM band.

b) The lower atmosphere is transparent to these waves, but the ionosphere reflects them back.

c) 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 ground wave) and after reflection from ionosphere (called sky wave).

d) Waves having frequencies upto about 1500 KHz (Wavelengths above 200m) are mainly transmitted through ground because low frequency sky waves lose their energy very quickly than the ground waves.

e) Therefore, higher frequencies are mainly transmitted through sky.

f) These two regions of the AM band are called medium wave and short wave bands respectively.

ii) High frequency waves - Television transmission

a) Above a frequency of about 30MHz, the ionosphere does not reflect the wave toward the earth.

b) The television signals have frequencies in the range 100-200 MHz. Therefore TV transmission via the sky is not possible.

c) Only direct reception via the ground is possible.

d) Therefore, in order to have larger coverage, the transmission has to be done through very tall antennas.

e) The height of transmitting antenna for T.V. telecast is given by $h = \frac{d^2}{2R_e}$ where 'd' is the radius of the area to be covered for T.V. telecast and R_e is the radius of earth.

iii) Micro waves :

a) The frequency range is 1 GHz to 30GHz.

b) Discovered by Hertz.

c) Used in Radar and tele communications.

d) To analyse the fine details of the molecular structure.

e) Produced by special tubes called Klystrons.

f) Basing on the micro waves, speed guns are designed which are used to time fast balls, and in Tenni's serves and automobiles.

g) Micro waves produce heat when absorbed by matter.

h) Micro wave owen is a domestic appliance to cook the food items.

i) The water molecules vibrate in the frequencies of the order of micro wave frequencies.

j) Frequency of water molecules is 3GHz.

k) The frequency of micro wave is selected to match the resonant frequencyof wate molecule.

l) When such waves pass through water. The KE of the waves are efficiently transferred to the water molecules. This rises the temperature of the water.

m) This rises the temperature of food Containing water.

n) The food materials are to be placed in porcelain container.

o) The molecules in the porcelain vibrate with much smaller frequencies. Because large molecules vibrate with much smaller frequencies

p) So it can not absorb micro waves as they are of smaller frequencies. Hence the container is uneffected and it is cool.

q) When a metal container is used, it may accumulate some charges and there is a danger of getting shock when touched.

r) The heat developed the container may some times melt it.

s) The heat is directly delivered to water molecules which is shared by the entire food unlike in the conventional heating

t) In the convertional heating the heat is shared by the burner and the vessels.

LECTURE SHEET

Straight Objective Type Questions

(Displacement current)

1. A parallel plate condenser has two circular metal plates of radius 10cm seperated by certain distance of 1m. The condenser is being charged with a variable electric field at the rate of 5×10^{13} v/s. The displacement current is

   1) 0.139 A 2) 1.39 A 3) 13.9 A 4) 139 A

2. A parallel plate condenser has conducting plates of radius 12cm seperated by a distance of 5mm. It is charged with a constant charging current of 0.16 A, the rate at which the potential difference between the plates change is

   1) 1×10^9 Vs^{-1} 2) 2×10^{10} Vs^{-1} 3) 3×10^{12} Vs^{-1} 4) 2×10^9 Vs^{-1}

3. The voltage between the plates of a parallel plate conductor of capacity $2\mu F$ is charging at a rate of 10V/sec. The displacement current

   1) 2mA 2) 2μA 3) 20μA 4) 2A

4. A parallel plate condensor of capacity $10\mu F$ is connected to an A.C. supply voltage $e = 4 \sin(100\pi t)$. The maximum displacement current.

   1) 4π mA 2) $4\pi\ \mu A$ 3) 2.8π mA 4) $2.8\pi\ \mu A$

5. A parallel plate condenser of capacity $1000\mu F$ is connected to a resistance of 10Ω in series and an AC supply of peak voltage 2V and frequency $50/\pi$ is applied. The maximum displacement current is

   1) 0.02 A 2) 0.2 A 3) 2.0 A 4) 0.1 A

Magnetic field produced between the plates of a parallal plate condenser :

6. A condenser has two conducting plates of radius 10cm seperated by a distance of 5mm. It is charged with a constant current of 0.15 A. The magnetic field at a point 2cm from the axis in the gap is

   1) 6×10^{-8} T 2) 3×10^{-8} T 3) 6×10^{-6} T 4) 3×10^{-6} T

7. A potential difference varying at the rate of 6×10^{2} Vs^{-1} is applied to the plates of a condenser of capacity $2\mu F$. The magnetic field at the edge of the plate in the gap if the radius of plate is 10cm is

   1) 2.4×10^{-9} T 2) 3×10^{-12} T 3) 3.33×10^{-9} T 4) 2.4×10^{-6} T

Wave equation :

8. The refractive index of a medium of di-electric constant 2 and relative permeability 1.28 is

   1) 2.56 2) 0.8 3) 1.6 4) 1.3

9. An electromagnetic wave of frequency 3 MHz passes from Vacuum into a dielectric medium with permittivity $\in = 4.0$. Then

   1) wave length doubled and frequency remains unchanged
   2) wave length is doubled and frequency be comes half
   3) wave length is halved and frequency remains unchanged
   4) wave length and frequency both remain unchanged

Relation between B&E :

10 In a crossed field, the magnetic field induction is 2.0T and electric field intensity is 20×10^3v/m. At which velocity the electron will travel in a straight line without the effect of electric and magnetic fields ?

1) $\frac{20}{1.6} \times 10^3 ms^{-1}$ 2) 10×10^3 ms^{-1} 3) 20×10^3 ms^{-1} 4) 40×10^3 ms^{-1}

11. A Plane electro magnetic wave of frequency 25 MHz travels in free space along the x-direction. At a particular point in space and time $\overline{E} = 6.3\,\hat{j}$. The magnetic field $\overline{B}$ at this point is

1) $4.2 \times 10^{-8}\ \hat{k}$ T 2) $2.1 \times 10^{-8}\ \hat{k}$ T 3) $18.9 \times 10^{8}\ \hat{k}$ T 4) $2.1 \times 10^{-8}\ \hat{k}$ T

12. In an apparatus the electric field was found to oscillate with an amplitude of 18Vm^{-1}. The rms of the oscillating magnetic field is

1) 6×10^{-8} T 2) 4.23×10^{-8} T 3) 9×10^{-8} T 4) 7.0×10^{-8} T

Momentum and force :

13. Light with energy flux of 18w/cm^2 falls on a non reflecting surface of area 20cm^2 at normal incidence the momentum delivered in 30 minutes is

1) 1.2×10^{-6} kgms^{-1} 2) 2.16×10^{-3} kgms^{-1} 3) 1.8×10^{-3} kgms^{-1} 4) 3.2×10^{-3} kgms^{-1}

14. The incident intensity of an a horizontal surface at sea level from sun is about1 kw/m^2. Assuming that 50% of this intensity is reflected and 50% is absorbed, then the radiation pressure on his horizontal surface

1) 5×10^{-6}pascal 2) 10×10^{-6}pascal 3) 2.5×10^{-6}pascal 4) 1.25×10^{-6}pascal

Energy density :

15. An electromagnetic radiation point source operates at a 250 W power with a 10% efficiency. The average energy density at a point distant 10 m from the source is

1) 0.85 Jm^{-3} 2) 1.7×10^{-11} Jm^{-3} 3) 3.3×10^{-11} Jm^{-3} 4) 6.6×10^{-11} Jm^{-3}

Intensity :

16. The sun radiates electromagnetic energy at the rate of 3.9×10^{26}W. Its radius is 6.96×10^8m. The intensity of sun light at the solar surface will be(in W/m^2)

1) 1.4×10^4 2) 2.8×10^5 3) 64×10^6 4) 5.6×10^7

17. The amplitude of magnetic field at a region carried by an electromagnetic wave is $0.1\mu T$. The intensity of wave is

1) 4n Wm^{-2} 2) 1.2 Wm^{-2} 3) 4 Wm^{-2} 4) $1.2\mu\, W m^{-2}$

18. A long straight wire of resistance R, radius 'a' and length 'L' carries a constant current "I". The poynting vector for the wire is

1) $\frac{IR}{2\pi a l}$ 2) $\frac{IR^2}{a l}$ 3) $\frac{I^2 R}{a l}$ 4) $\frac{I^2 R}{2\pi a l}$

Numerical Value Type Questions

19. A parallel plate condenser of capacity 1nF is connected to a battery of emf 2v through a resistance of 1MΩ. The displacement current after 10^{-3} sec in μA is

20. The electric field for an electromagnetic wave in free space is $\overline{E} = \overline{i}\,30\cos(kz - 5\times10^8 t)$ where magnitude of E is in V/m. The magnitude of wave vector, k is (velocity of em wave in free space = 3×10^8 m/s) in rad /m is

21. The intensity of electromagnetic wave at a distance of 1 Km from a source of power 12.56 kw. is $n\times10^{-1}W/m^2$. The value of 'n'

22. A condenser of capacity 50PF is connected to an AC suppy of 220V–50Hz. The rms value of magnitic field at a distance of 5cm from the axis is $n\times10^{-12}$T. The value of 'n' is.

23. The velocity of electromagnetic wave in a medium is 2×10^8m/sec. If the ralative permiability is '1' the relative permiability of medium is ($C_0=3\times10_8$m/sec)

24. In an electromagnetic wave in vacuum. The electric and magnetic fields are $40\pi V/m$ and 0.4×10^{-7}T. The poynting vector in W/m is

KEY SHEET (LECTURE SHEET)

1) **3**	2) **4**	3) **1**	4) **1**	5) **2**	6) **1**	7) **1**	8) **3**	9) **3**	10) **2**
11) **2**	12) **2**	13) **2**	14) **1**	15) **4**	16) **3**	17) **2**	18) **4**	19) **0.74**	
20) **1.66**	21) **0.01**	22) **69.08**		23) **2.28**	24) **4.0**				

PRACTICE SHEET

Straight Objective Type Questions

(Displacement current)

1. A parallel plate condenser consists of two circular plates each of radius 2cm seperated by a distance of 0.1 mm. A time varying potential difference of 5×10^{13} v/s is applied across the plates of the condenser. The displacement current is
   1) 5.50 A 2) 5.56×10^2 A 3) 5.56×10^3 A 4) 2.28×10^4 A

2. A parallel plate condenser has conducting plates of radius 8cm seperated by a distance of 2.0 mm. It is charged by an external source, with a constant charging current of 0.15 A. The displacement current is
   1) 0.10 A 2) 0.15 A 3) 0.20 A 4) 0.30 A

3. A Parallel plate condenser of capacity 100 pF is connected to 230 V of AC supply of 300rad/sec frequency. The rms value of displacement current
   1) $6.9\mu A$ 2) $2.3\mu A$ 3) $9.2\mu A$ 4) $4.6\mu A$

Magnetic field produced between the plates of a parallel plate condenser

4. The diameter of the plates of a condenser is 10cm and it is charged by an external source with a steady current of 0.1 A. The maximum magnetic field induced in the gap is
   1) $4\ \mu T$ 2) $8\ \mu T$ 3) $40\ \mu T$ 4) $0.4\ \mu T$

5. A condenser is charged using a constant current. The ratio of the magnetic fields at a distance of $\frac{R}{2}$ and R from the axis is (R is the radius of plate)
   1) 1 : 1 2) 2 : 1 3) 1 : 2 4) 1 : 4

6. The magnetic field between the plates of radius 12 cm separated by distance of 4mm of a parallel plate capacitor of capacitance 100 pF. along the axis of plates having conduction current of 0.15 A is
   1) zero 2) 1.5 T 3) 15 T 4) 0.15 T

Wave equation :

7. A wave is propagating in a medium of dielectric constant 2 and relative permeability 50. The wave impedance is

   1) $5\,\Omega$ 2) $376.6\,\Omega$ 3) $3776\,\Omega$ 4) $1883\,\Omega$

8. The relative permeability of glass is 3/8 and the dielectric constant of glass is 8. The refractive index of glass is

   1) 1.5 2) 1.1414 3) 1.732 4) 1.6

Relation between B&E :

9. A plane e.m. wave of frequency 40 MHz travels along X-axis. At same pint at same instant, the electric field E has maximum value of 750 N/C in Y - direction. The magnitude and direction of magnetic field is

   1) $2.5\,\mu T$ along X-axis 2) $2.5\,\mu T$ along Y-axis 3) $2.5\,\mu T$ along Z-axis 4) $5\,\mu T$ along Z-axis

10. The amplitude of the sinusoidally oscillating electric field of a plane wave is 60v/m. Then theamplitude of the magnetic field is

    1) $12 \times 10^7 T$ 2) 6×10^7 T 3) 6×10^7 T 4) 2×10^7 T

Moment of force :

11. Light with energy flux of $24 wm^{-2}$ is incident on a well polished disc of radius 3.5cm for one hour. The momentum transfered to the disc is

    1) $1.1\,\mu kg\, ms^{-1}$ 2) $2.2\,\mu kg\, ms^{-1}$ 3) $3.3\,\mu kg\, ms^{-1}$ 4) $4.4\,\mu kg\, ms^{-1}$

12. Light with energy flux $36 w/cm^2$ is incident on a well polished metal squar plate of side 2cm. The force experienced by it is

    1) $0.96\mu N$ 2) $0.24\,\mu N$ 3) $0.12\,\mu N$ 4) $0.36\,\mu N$

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

    1) 6.4×10^{-7} kg-m/s 2) 4.8×10^{-8} kg-m/s 3) 3.2×10^{-9} kg-m/s 4) 1.6×10^{-10} kg-m/s

Energy density :

14. The maximum electric field of a plane electro-magnetic wave is 88 V/m. The average energy density is

    1) $3.4\times10^{-8} Jm^{-3}$ 2) $13.7\times10^{-8} Jm^{-3}$ 3) $6.8\times10^{-8} Jm^{-3}$ 4) $1.7\times10^{-8} Jm^{-3}$

15. The rms value of the electric field of a plane electromagnetic wave is 314V/m. The average energy density of electric field and the average energy density are

    1) $4.3\times10^{-7}\ Jm^{-3}; 8.6\times10^{-7}\ Jm^{-3}$ 2) $4.3\times10^{-7}\ Jm^{-3}; 8.6\times10^{-7}\ Jm^{-3}$

    3) $2.15\times10^{-7}\ Jm^{-3}; 4.3\times10^{-7}\ Jm^{-3}$ 4) $8.6\times10^{-7}\ Jm^{-3}; 4.3\times10^{-7}\ Jm^{-3}$

16. In an electromagnetic wave the electric and magnetising fields are 100 Vm^{-1} and 0.265 Am^{-1}. The maximum rate of energy flow perunit area in W/m^{-2} is

    1) 26.5 2) 36.5 3) 46.7 4) 765

17. The rms value of the electric field of the light coming from the sun is 720 N/C. The average total energy density of the electromagnetic wave is

    1) $3.3\times10^{-3} J/m^3$ 2) $4.58\times10^{-6} J/m^3$ 3) $6.37\times10^{-9} J/m^3$ 4) $81.35\times10^{-12} J/m^3$

Intensity :

18. The intensity of TV broad cast station of $E = 800 Sin(10^9 t - kx)$V/M is .... and the wave length in meter is ....

    1) $850\ wm^{-2}$; 0.6π 2) $425\ wm^{-2}$; 0.6π 3) $850\ wm^{-2}$; 0.3π 4) $425\ wm^{-2}$; 0.3π

19. The sun delivers $10^3 W/m^2$ of electromagnetic flux incident on a roof of dimensions 8m × 20m, will be

1) 6.4×10^3 W 2) 3.4×10^4 W 3) 1.6×10^5 W 4) 3.2×10^5W

20. A flood 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 in W/m^2 is

1) 0.86 2) 1.72 3) 3.44 4) 6.88

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

1) 1.34 V/m 2) 2.68 V/m 3) 5.36 V/m 4) 9.37 V/m

Numerical Value Type Questions

22. 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 in 10^{-2}amp is

23. An AC rms voltage of 2V having a frequency of 50 KHz is applied to a condenser of capacity of 10 μ F. The maximum value of the magnetic field between the plates of the condenser if the radius of plate is 10cm in μT is

24. The wave emitted by any atom or molecule must have some finite total length which is known as the coherence length. For sodium light, this length is 2.4cm. The number of oscillations in this length will be (Given $\lambda = 5900A^0$) in $nX10^6$Hz. The value of 'n' is

25. Light with an energy flux of 18 w/cm^2 falls on a non-reflecting surface at normal incidence. If the surface has an area of $20cm^2$, the average force exerted on the surface during a 30 minute time span in $K\times10^{-6}$N. The value of 'K' is

26. In a plane electromagnetic wave, the electric field oscillates at a frequency of 2×1010Hz and amplitude 48v/m. The amplitude of oscillating magnetic field will be $n\times10^{-5}Wb/m^2$. The value of 'n' is

27. E.M radiation with energy flux $50W/cm^2$ is incident on a totally absorbingly surface has an area of $0.05m^2$, then the average force due to the radiation pressure on it is $n\times10^{-4}$. The value of 'n' is

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1) **3**	2) **2**	3) **1**	4) **4**	5) **3**	6) **1**	7) **4**	8) **3**	9) **3**	10) **4**
11) **2**	12) **1**	13) **4**	14) **1**	15) **2**	16) **1**	17) **2**	18) **1**	19) **3**	20) **2**
21) **1**	22) **1.06**	23) **12.56**	24) **4.07**	25) **1.20**	26) **0.016**	27) **0.83**			