19ECT211 Electromagnetic Fields

Question Bank

UNIT I STATIC ELECTRIC FIELD

TWO MARK QUESTIONS & ANSWERS

1. State Stokes's theorem.

Stokes's theorem states that the circulation of a vector field $\vec{A}$ around a closed path is equal to the surface integral of curl of $\vec{A}$ over the open surface S bounded by the path L.

$$\oint \vec{A} \cdot \vec{dl} = \int (\vec{\nabla} \times \vec{A}) \cdot \vec{dS}$$

2. State Coulomb's law.

Coulombs law states that the force between any two point charges is directly proportional to the product of their magnitudes and inversely proportional to the square of the distance between them. It is directed along the line joining the two charges.

$$F = Q1Q2 / 4\pi\varepsilon r^2$$

3. State Gauss law for electric fields.

The total electric flux Ψ passing through any closed surface is equal to the total charge enclosed by that surface.

$$\Psi = Q_{enc}$$

$$\oint \vec{D}.\vec{dS} = \int \rho_v dv \quad \text{(Integral form)}$$

$$\vec{\nabla} \cdot \vec{D} = \rho_v \quad \text{(Point form)}$$

4. State Divergence Theorem.

The divergence theorem states that the total outward flux of a vector field $\vec{A}$ through the closed surface S is the same as the volume integral of the divergence of $\vec{A}$.

$$\oint \vec{A} \cdot \vec{dS} = \int \vec{\nabla} \cdot \vec{A}\, dv$$

5. Define electric field intensity.

Electric field intensity is defined as the electric force per unit positive charge. Its unit is V/m.

$$\vec{E} = \vec{F} / Q$$

$$\vec{E} = (Q/4\pi\varepsilon r^2)\ \widehat{ar}$$

6. Define electric potential.

Potential at any point is defined as the work done in moving a unit positive charge from infinity to that point in an electric field.

Its unit is Volts.

$$V = \frac{Q}{4\pi\varepsilon r}$$

7. Define Gradient

The gradient of a scalar field V is a vector that represents both the magnitude and the direction of the maximum space rate of increase of V.

$$\textit{Gradient of } V = \nabla V = \frac{\partial V}{\partial x}\widehat{a_x} + \frac{\partial V}{\partial y}\widehat{a_y} + \frac{\partial V}{\partial z}\widehat{a_z}$$

8. Write the relationship between electric field (E) and potential (V)

The relation between Electric field intensity and potential is given by

$$\vec{E} = -\vec{\nabla}V$$

Where $\vec{E}$ – Electric field intensity, V – Potential.

9. Define line, surface and volume charge densities.

Line charge density : It is the charge per unit length at a point on the line charge.

$$\rho_l = \frac{dQ}{dl}$$

Surface charge density: It is the charge per surface area at a point on the surface charge

$$\rho_s = \frac{dQ}{dS}$$

Volume charge density: It is the charge per volume at a point on the volume of the charge

$$\rho_v = \frac{dQ}{dv}$$

10. Define electric flux and electric flux density.

The total number of lines of electric force in an electric field is called as electric flux. Its unit is Coulombs(C).

Electric flux density is defined as electric flux per unit area. Its unit is C/m^2

$$\vec{D} = Q/4\pi r^2\,\hat{a}_r$$

11. Name few applications of Gauss law in electrostatics.

- Gauss law is applied to find the electric field intensity due to symmetric charge distributions such as line charge, sheet of charge.
- Electric Field can be determined for shell, two concentric shell or cylinders etc.

12. Define potential difference.

Potential difference is defined as the work done in moving a unit positive charge from one point to another point in an electric field. Its unit is Volts.

Potential difference $\quad V = -\int_B^A \vec{E} \cdot \vec{dl}$

13. What is the physical significance of div D?

The divergence of a vector field A at a given point is a measure of how much the field diverges or emanates from that point. It also gives the limit of field's source strength per unit volume/source density.

14. State the principles of superposition of force.

The principle of superposition states that if there are N charges $Q_1, Q_2, \ldots Q_n$ at points with position vectors $r_1, r_2, \ldots r_N$, the resultant force F on a charge located at point r is the vector sum of the forces exerted on Q by each of the charges.

15. What is the relation between D and E in free space?

The relation between D and E is given by

$$\vec{D} = \varepsilon_o \vec{E} \quad C/m^2$$

$\vec{D}$ - Electric flux density

$\vec{E}$ - Electric fnsity

ε_o - permittivity of free space

16. Explain the conservative property of electric field.

The work done in moving a point charge around a closed path in a electric field is zero. Such a field is said to be conservative.

$$\oint \vec{E} \cdot \vec{dl} = 0$$

17. Define electric dipole and dipole moment. (May/June 2016)

The two point charges of equal magnitude and opposite sign, separated by a very small distance is called as electric dipole.

The product of electric charge and distance is known as dipole moment. It is donated by m.

m= Qd

where Q is the charge and d is the distance between point charges.

18. Define divergence.

The divergence of $\vec{A}$ at a given point P is the outward flux per unit volume as the volume shrinks about P.

Divergence of $\vec{A}$ is given by,

$$\vec{\nabla} \cdot \vec{A} = \lim_{\Delta v \to 0} \frac{\oint \vec{A} \cdot \vec{dS}}{\Delta v}$$

Divergence of a vector field is a scalar.

19. Define curl

The curl of $\vec{A}$ is an axial or rotational vector whose magnitude is the maximum circulation of $\vec{A}$ per unit area as the area tends to zero and whose direction is the normal direction of the area.

Curl of $\vec{A}$ is given by,

$$\vec{\nabla} \times \vec{A} = \left(\lim_{\Delta v \to 0} \frac{\oint \vec{A} \cdot \vec{dl}}{\Delta S} \right)_{max} \hat{a}_n$$

20. Define Scalar quantity.

A scalar is a quantity which is characterized by its magnitude. The direction is not required to describe the scalar. The examples of scalar are temperature, mass, volumes, speed, charge etc.

21. Define vector quantity.

A vector is a quantity which is characterized by both magnitude and direction. The examples of vector are forces, velocity, electric field intensity, acceleration etc.

22. Name three co-ordinate systems used in electromagnetic engineering.

1. Cartesian co-ordinate system
2. Cylindrical co-ordinate system
3. Spherical co-ordinate system

23. How to represent a point and vector in Cartesian systems?

A point in Cartesian system is represented by three co-ordinates namely x co-ordinate in x direction, y co-ordinate in y-direction and z co-ordinate in z-direction.

Co-ordinates (x, y, z)

Vector $\vec{A} = A_x\hat{a}_x + A_y\hat{a}_y + A_z\hat{a}_z$

24. What is electrostatic force?

The force between any two particles due to existing charges is known as electrostatic force, repulsive for like and attractive for unlike.

25. What is meant by equipotential surface?

It is an imaginary surface in an electric field of a given charge distribution in which all the points on the surface area at the same electric potential.

26. What is energy density?

Electrostatic energy density is the energy stored per unit volume as volume tends to zero. Its unit is J/m^3. It is given by w_E as

$$w_E = \frac{1}{2}\vec{D} \cdot \vec{E} = \frac{1}{2}\varepsilon_o E^2 = \frac{1}{2\varepsilon_o} D^2$$

27. Write the equation for energy stored in electrostatic field in terms of field quantities. (Apr/May 2017)

$$W_E = \frac{1}{2}\int D \cdot E \, dv = \frac{1}{2}\int \varepsilon_o E^2 \qquad \text{Joules}$$

D – Electric flux density

E – Electric field intensity

PART B QUESTIONS

1. Derive divergence theorem and stokes theorem.
2. Find the electric field intensity of a straight uniformly charged wire of length 'L'm and having a linear charge density of +ρ C/m at any point at a distance of 'h' m.
3. State and Prove Gauss's law. And explain applications of Gauss's law. 4.Verify stokes theorem for a vector field $F = r^2 \cos\varphi\, \mathrm{a_r} + \mathrm{z}\sin\varphi\, \mathrm{a_z}$ around a closed path L defined by 0 ≤ r ≤3 , 0 ≤ φ ≤ 45º and z=0.
5. If V=$\left[2x^2y + 20z - \frac{4}{x^2+y^2}\right]$ volts, find E and D at P (6,-2.5, 3).
6. Explain briefly about gradient, divergence and curl.
7. Explain coulomb's Law. Three equal positive charges of 4* 10^{-9} coulomb each are located at three corners of a square, side 20cm. determine the electric field intensity at the vacant corner point of the square.
8. Derive the expression for potential due to an electric dipole at any point P. Also find electric field intensity at the same point.
9. Two point charges 1.5 nC at (0, 0, 0.1) and -1.5 nC at (0, 0,-0.1) are in free space. Treat the two charges as a dipole at the origin and find potential at P (0.3, 0, and 0.4).
10. Derive an expression for electric field intensity due to an infinite uniformly charged sheet.
11. i. Define electric potential. Derive an expression for potential due to point charge.
    ii. Derive the relation between potential and electric field intensity.
12. Explain applications of Gauss law.
13. Derive an expression for Electric field on the axis of a uniformly charged circular disc.
14. Define potential difference and electric field. Give the relation between potential and electric field intensity. Also derive an expression for potential due to infinite uniformly charged line and potential due to electric dipole**.**
15. Given two vectors A=3ax+4ay+-5az and B=-6ax+2ay+45az , determine the unit vector normal to the plane containing two vectors A and B.
16. i. Using gauss law find the electric filed intensity for the uniformly charged sphere of radius 'a' find the E everywhere.
    ii. Derive the equation for the scalar electric potential

UNIT II – DIELECTRICS AND STEADY ELECTRIC CURRENT

1. Write poisson's and laplace 's equations. (May/June 2010)
Poisson's equation:
$\Delta^2 V = - \rho v / \varepsilon$
Laplace's equation:
$\Delta^2 V = 0$
2. Write the point form of continuity equation and explain its significance.

$$\nabla . J = -\frac{\partial \rho_v}{\partial t}$$

Since the charge is conserved, the outward flux of J must therefore be equal to the rate of loss of charge within the volume.
3. State point form of Ohm's law.
Point form of ohms law states that the field strength within a conductor is proportional to the current density.
$J = \sigma E$

4. Define current.
The current is defined as electric charge passing through the area per unit time and is measured in amperes.
5. What is the significance of displacement current?
The concept of displacement current was introduced to justify the production of magnetic field in empty space. It signifies that a changing electric field induces a magnetic field. In empty space the conduction current is zero and the magnetic fields are entirely due to displacement current.

6. Distinguish between conduction and displacement currents.
The current through a resistive element is termed as conduction current whereas the current through a capacitive element is termed as displacement current.

7. Differentiate between Conduction Current and Convection current. (Nov/Dec2007)
Conduction current is defined as the current flowing because of actual motion of charges through a conductor. Convection current does not involve conductors. It occurs when current floes through an insulating medium such as liquid, gas or a vacuum.

8. What is meant by displacement current?
Displacement current is a result of time varying electric field such as the current through a capacitor when an alternating voltage source is applied to its plates.

9. Define current density.
The current density is defined as the current passing through the unit surface area, when the surface is held normal to the direction of the current.
Current density is measured in amperes per square meters.
10. Give the expression for capacitance of a parallel plate capacitor. (April/May 2008)

$C = (A\ \xi r\ \xi_0)/d$
11. What are the significant physical differences between Poisson's and laplace's equations.
Poisson's and laplace's equations are useful for determining the electrostatic potential V in regions whose boundaries are known.
When the region of interest contains charges poisson's equation can be used to find the Potential.
When the region is free from charge laplace equation is used to find the potential.

12. How is electric energy stored in a capacitor?

In a capacitor, the work done in charging a capacitor is stored in the form of electric energy.

13. What are dielectrics?

Dielectrics are materials that may not conduct electricity through it but on applying electric field induced charges are produced on its faces .The valence electron in atoms of a dielectric are tightly bound to their nucleus.

14. What is a capacitor?

A capacitor is an electrical device composed of two conductors carrying equal but opposite charges. The plates are separated by a dielectric medium.

15. Define dielectric strength.

The dielectric strength of a dielectric is defined as the maximum value of electric field that can b applied to the dielectric without its electric breakdown.

16. What meaning would you give to the capacitance of a single conductor?

A single conductor also possess capacitance. It is a capacitor whose one plate is at infinity.

17. Why water has much greater dielectric constant than mica?

Water has a much greater dielectric constant than mica because water has a permanent dipole moment, while mica does not have.

18. What are polar and nonpolar dielectrics.

Nonpolar dielectric molecules do not possess dipoles until the application of the electric field. Ex: Hydrogen, Oxygen.

Polar dielectric molecules possess built in dipoles that are randomly oriented. Ex: water, sulfur dioxide, Hydrocloric acid

20. Define polarization

Polarization is defined as the dipole moment per unit volume.

$$P = \lim_{\Delta v \to 0} (\sum Q\, d)/\Delta v$$

21. Write the expression for capacitance of a co-axial cable.

$C = 2\pi\varepsilon_o\varepsilon_r / \ln(b/a)$

22. What is energy stored in a capacitor?

If the dielectric is free space then there is increase in the stored energy if free space replaced by other dielectric having $\xi r > 1$.

$W = ½ CV^2$

23. Write the boundary conditions at the interface between two perfect dielectrics. (May/June 2010)

i)The tangential component of electric field is continuous i.e)Et1=Et2

ii) The normal component of electric flux density is continuous i.e) Dn1=Dn2

24. What is meant by Method of images?

The image theory states that a given charge configuration above an infinite grounded perfect conducting plane may be replaced by the charge configuration itself, its image, and an equipotential surface in place of the conducting plane.

25. What is the use of Method of images?

Method of images is used in solving problems of one or more point charges in the presence of boundary surfaces.

26. Define dipole moment

When the dipole is formed due to polarization, there exists an electric dipole moment p.

$$p = Q\,d$$

Q – Magnitude of charge

d – Distance vector from negative to positive charge

27. Define dielectric constant

The dielectric constant (or relative permittivity) ε_r is the ratio of the permittivity of the dielectric to that of free space.

28. State Uniqueness theorem.

If a solution to Laplace's equation can be found that satisfies the boundary conditions, then the solution is unique.

PART B

1. Derive the continuity equation of current.
2. Derive an expression for the boundary conditions.
3. Given the potential $V = 100\,(x^2 - y^2)$ and a point P(2, -1,3) that is stipulated to lie on a conductor to free space boundary, find V, E, D and surface charge density at P and also the equation of the conductor surface.
4. Derive an expression for the boundary condition for perfect dielectric materials.
5. Define capacitance and derive capacitance for parallel plate capacitor.
6. Derive Poisson's and Laplace's equations.
7. Explain the solution of Laplace equation with example and application of Poisson's and Laplace's equations.
8. Solve the laplace's equation for the potential field in the homogenous region between the two concentric conducting spheres with radius 'a' and 'b' where b>a V=0 at r = b and V =V0 at r=a .find the capacitance between the two concentric spheres.
9. A cylindrical capacitor consists of an inner conductor of radius 'a' and an outer conductor of radius b. The space between the conductors filled with a dielectric whose permittivity ε, the length of the capacitor is L. Determine the capacitance
10. Derive an expression for the capacitance of a spherical capacitor with conducting shells of radius a and b.
11. Derive the expressions for the energy stored and energy density in a capacitor.

UNIT-III STEADYMAGNETIC FIELD

1. What is magnetic field intensity?

Magnetic Field intensity at any point in the magnetic field is defined as the force experienced by a unit north pole of one Weber strength, when placed at that point. Unit: N/Wb (or) A/m. It is denoted as H.

2. Define magnetic flux density.

The total magnetic lines of force i.e. magnetic flux crossing a unit area in a plane at right angles to the direction of flux is called magnetic flux density.

3. What is the relationship between B and H?

$$B = \mu H$$

μ – Permeability

4. State Ampere's circuit law.

Ampere's circuit law states that the line integral of magnetic field intensity around a closed path is equal to the net current enclosed by the path.

$$\oint H \, . \, dl = I$$

5. State Biot –Savarts law.

It states that the differential magnetic field intensity dH produced at a point P by the differential current element Idl is proportional to the current element and sine of the angle between the element and line joining P and inversely proportional to the square of the distance between them.

$$dH = \frac{Idl \ sin\theta}{4\pi r^2}$$

6. Define magnetic vector potential.

It is defined as that quantity whose curl gives the magnetic flux density.

$B = \nabla \times A$

Where A is the magnetic vector potential.

$$A = \frac{\mu}{4\pi} \iiint_v \frac{I}{r} \, dl$$

7. Write down the expression for magnetic field at the centre of the circular coil.

H = I/2a

8. State Gauss law for magnetic field.

The total magnetic flux passing through any closed surface is equal to zero.

$$\oint B . ds = 0$$

9. Write the expression of H due to infinite long conductor.

H = I / 2πh

10. Write the expression of H due to circular loop.

$H = Ia^2 / 2(h^2+a^2)^{3/2}$

11. Define magnetic field strength.

The magnetic field strength (H) is a vector having the same direction as magnetic flux density. H=B/μ

12. Describe what are the sources of electric field and magnetic field?

Stationary charges produce electric field that are constant in time, hence the term electrostatics. Moving charges produce magnetic fields hence the term magnetostatics.

13. Write the expression for field intensity due to a toroid carrying a filamentary current I

H=NI / 2πR

14. Distinguish between solenoid and toroid.

Solenoid is a cylindrically shaped coil consisting of a large number of closely spaced turns of insulated wire wound usually on a non magnetic frame. If a long slender solenoid is bent into the form of a ring and there by closed on itself it becomes a toroid.

15. Define scalar magnetic potential

Magnetic scalar potential V_m is defined as related H according to,

$$H = -\nabla V_m \quad \text{if } J = 0$$

16. Write Poisson's Equation for Magnetic field

$$\nabla^2 A = -\mu_o J$$

17. State Stoke's theorem.

The line integral of a vector around a closed path is equal to the normal component of the curl over any closed surface bounded by the contour.

$$\oint H \,.\, dl = \oint (\nabla \times H)\, dS$$

18. Write the application of ampere's law.

To find infinitely long straight conductor, co-axial cable and infinite sheet of current.

19. What are the magnetic field quantities?

H, B, Φ, V_m and A.

20. State Lorentz force equation.

The force on a moving particle arising from combined electric and magnetic fields is obtained easily by superposition **F = Q (E + (v x B)).**

21. What is the force on a moving charge?

The force on a moving particle arising from combined electric and magnetic fields is obtained easily by superposition **F = Q (E + (v x B)).**

22. Give the applications of Lorentz force equation.

To find force on a differential current element in a uniform magnetic field, force and torque in a closed circuit.

23. Mention the importance of Lorentz force equation.

Lorentz force equation relates mechanical force to the electrical force. If the mass of the charge is m, then **F = ma = Q (E + (v x B)) Newton.**

24. Write the expression for torque in vector form.

The torque T on the loop is the vector product of the force F and the moment arm r.

T = r x F

25. What do you mean by magnetic moment?

Product of area of cross section of the loop and the current through that loop.

M = IA

26. What is a solenoid?

A solenoid is a cylindrically shaped coil consisting of a large number of turns wound on a non-magnetic frame.

27. Write down the expression for the torque experienced by a current carrying loop situated in a magnetic field.

T = BIA

Where

B = Magnetic flux density

I = Current through the loop

A = Area of the loop

PART B

1. Find the magnetic flux density at a point on the axis of a circular loop of a radius b that carries a current I.
2. Obtain the expression for magnetic field intensity due to infinite long straight wire carrying a steady current I.
3. State and explain Biot-savart's law. Derive the expressions for magnetic field intensity at the centre of the square loop.
4. Derive the expression for magnetic field due to an infinitely long coaxial cable.
5. Derive the expression for H due to finite length wire carrying a steady current I.
6. State and prove Ampere's circuital law. Explain about any two applications of Ampere's circuital law.
7. Derive magnetic vector potential**.**
8. Derive an expression for magnetic gauss law in point form and integral form.

UNIT -IV TIME-VARYING FIELDS AND MAXWELL's EQUATIONS

1. State Lorentz force equation. (Apr/May 2015, Nov/Dec 2013)

The force on a moving particle arising from combined electric and magnetic fields is obtained easily by superposition,

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

$\vec{v}$ is the velocity, B is magnetic flux density**,** E is electric field intensity

2. Define Magnetization. (Nov/Dec 2011)

The magnetization is defined as the magnetic dipole moment per unit volume. Unit is amperes per meter.

$$\vec{M} = \lim_{\Delta v \to 0} \frac{1}{\Delta v} \sum_{i=1}^{n} m_i$$

3. Define mutual inductance. (Apr/May 2015)

Mutual inductance between two coils is the ratio of the flux linkage of one coil to the current in the other coil.

$M_{12} = N_2\,\Phi_{12} / I_1$ and

$M_{21} = N_1\,\Phi_{21} / I_2$

4. Define magnetic dipole moment (Nov/Dec 2013)

The magnetic dipole moment is the product of current and area of the loop. Its direction is normal to the loop. Unit is A.m^2

Magnetic dipole moment $\vec{m}$ **= I S** $\hat{a}_n$

(Or) m = Qm L

for a bar magnet where Qm is the pole strength and L is length of the bar

5. Write the expression for torque in vector form. (April/May 2015)

The torque T or mechanical moment of force on the loop is the vector product of the force F and the moment arm r.

$$\vec{T} = \vec{r} \times \vec{F}$$

6. What is a solenoid?

A solenoid is a cylindrically shaped coil consisting of a large number of turns wound on a non-magnetic frame.

7. Write down the expression for the torque experienced by a current carrying loop situated in a magnetic field.

T = BIA

Where

B = Magnetic flux density

I = Current through the loop

A = Area of the loop

8. State the expression of H due to infinite sheet of current.

H = ½ K x $\mathbf{a_N}$

Where **K** = current density

$\mathbf{a_N}$ = unit vector normal from the current sheet to the point at which H to be obtained.

9. What are the different types of magnetic materials?

- Diamagnetic
- Paramagnetic
- Ferromagnetic
- Antiferromagnetic
- Ferrimagnetic

10. What is a diamagnetic material?

A material is diamagnetic if $\mu_r \leq 1$. The permanent magnetic moment of each atom is zero. E.g. Copper, Lead, Silicon, Diamond.

11. What is a Paramagnetic material and give examples.

A material is paramagnetic if $\mu_r \geq 1$. It has nonzero permanent magnetic moment.

E.g. Potassium, Oxygen, Tungsten

12. Define self inductance.

Self inductance is defined as the ratio of the total flux linkage to the current. The flux linkage is the product of the number of turns and the flux linking each of them.

$L = N\Phi / I$ Henry

13. Give the formula for inductance of a solenoid and toroid.

Inductance of a solenoid : $L = (\mu_o \mu_r N^2 A) / L$ Henries
Inductance of a toroid : $L = (\mu_o \mu_r N^2 A) / 2\pi R$ Henries

14. Write the expression for energy stored in an inductor.

$W_H = ½ LI^2$ Joules
Where L = Inductance and I = Current

15. Write down the magnetic boundary conditions.

- The normal components of flux density B is continuous across the boundary.
- The tangential component of field density H is continuous across the boundary.

16. Define magnetic torque and give its equation.

When a current loop is placed parallel to a magnetic field, forces act on the loop that tends to rotate it. The tangential force multiplied by the radial distance at which it acts is called torque or mechanical moment on the loop.

$$T = BIA \sin\theta$$

17. Find the relative permeability of the material whose magnetic susceptibility is 49.

Magnetic susceptibility $\chi_m = 49$
Relative permeability $\mu_r = 1 + \chi_m$
$\mu_r = 1+49 = 50$.

18. Distinguish between solenoid and toroid.

Solenoid is a cylindrically shaped coil consisting of a large number of closely spaced turns of insulated wire wound usually on a non magnetic frame. If a long slender solenoid is bent into the form of a ring and there by closed on itself it becomes a toroid.

19. What is the expression for energy density and energy stored in magnetic field? (Apr/May 2015)

Energy density in magnetic field is given by
$W = ½ BH$ or $W = ½ \mu H^2$
Magnetostatic energy is given by
$W_m = 1/2 \int B \cdot H \, dv$

20. Mention the equation of force between two current elements. (May/June 2016)

Force between two current elements I_1dl and I_2dl is expressed as

$$d(d\mathbf{F}_1) = \frac{\mu_o I_1 \, d\mathbf{l}_1 \times (I_2 \, d\mathbf{l}_2 \times \mathbf{a}_{R_{21}})}{4\pi R_{21}^2}$$

21. A current of 3 A flowing in the inductor of 100mH. What is the energy stored in the inductor. (May/June 2016)

I = 3 A

L= 100mH

Use the Formula : $W= \frac{1}{2} LI^2$ Jules

$W = \frac{1}{2} * 100*10^{-3}*(3)^2$

W = 0.45 **J**

22. Differentiate diamagnetic, paramagnetic and ferromagnetic material (May/June 2016)

diamagnetic	paramagnetic	ferromagnetic
$\chi_m < 0$, $\mu_r <= 1$	$\chi_m > 0$, $\mu_r >= 1$	$\chi_m >> 0$, $\mu_r >> 1$
Linear & nonmagnetic	Linear & nonmagnetic	NonLinear & magnetic
Zero permanent magnetic moment	Non Zero permanent magnetic moment	Large permanent magnetic moment

Part B

1. Derive the Maxwell's equation from Faraday's law.
2. Derive the Maxwell's equation from Ampere's law (or) prove that
3. Derive the Maxwell's four equations for free space.
4. Derive the Maxwell's four equations for static field.
5. Derive the Maxwell's four equations for time varying fields.
6. Derive the Maxwell equation for harmonically time varying fields.
7. Derive the Poynting vector from Maxwell's equation for the general case.
8. Explain brietly about the Motional emf and derive an expression for it.
9. State and prove pointing theorem.
10. Write note on vector and scalar potential.

<u>UNIT- V ELECTROMAGNETIC WAVES</u>

1. Define Faraday's law.

The electromotive force (emf) induced in a circuit is equal to the rate of change of magnetic flux linking the circuit.

$V_{emf} = - N\, d\Psi/dt$ volts

2. Define skin depth

Skin depth is defined as that depth in which the wave has been attenuated to e^{-1} or approximately 37% of its original value. It is a measure of the depth to which an EM wave can penetrate the medium.

$$\delta = \frac{1}{\alpha} = \frac{1}{\sqrt{\pi f \mu \sigma}}$$

3. What is the significance of displacement current?

The concept of displacement current was introduced to justify the production of magnetic field in empty space. It signifies that a changing electric field induces a magnetic field. In empty space the conduction current is zero and the magnetic fields are entirely due to displacement current.

4. Write the expression for power flow in co-axial cable.

Power flow is the product of voltage and current.

W = VI

5. What is the formula for instantaneous power?

Instantaneous power flow per unit area is given by,

$$\vec{P} = \vec{E} \times \vec{H}$$

6. What is the formula for complex pointing vector?

The complex pointing vector is given by,

$$\vec{P} = \frac{1}{2}\vec{E} \times \vec{H}^*$$

7. In a material for which σ=5 s/m and ε_r=1 and E=250 sin 10^{10} t. Find the conduction and displacement current densities.

Ans:

Conduction current density

$Jc = \sigma E$

$Jc = 1250 \sin 10^{10} t$ A/m^2

Displacement current density

$$J_D = \frac{\partial D}{\partial t}$$

$$J_D = \frac{\partial \epsilon E}{\partial t}$$

$$J_D = \frac{\partial}{\partial t}(\epsilon_o \epsilon_r E)$$

$J_D = 22.1 \cos 10^{10} t$ A/m^2

8. Define poynting vector with its unit.

Poynting vector $\vec{P}$ is the cross product of the vector $\vec{E}$ and $\vec{H}$.

$\boldsymbol{\vec{P} = \vec{E} \times \vec{H}}$ Watts / m^2

It represents the instantaneous power density vector associated with Electromagnetic field at a given point.

9. Define displacement current density.

Displacement current density is defined from time varying electric field. Unit is A/m^2

$J_D = dD / dt$

10. Write down the wave equation for E and H.

$$\nabla^2 \boldsymbol{E} - \mu\epsilon \frac{\partial^2 \boldsymbol{E}}{\partial t^2} - \mu\sigma \frac{\partial \boldsymbol{E}}{\partial t} = 0$$

$$\nabla^2 \boldsymbol{H} - \mu\epsilon \frac{\partial^2 \boldsymbol{H}}{\partial t^2} - \mu\sigma \frac{\partial \boldsymbol{H}}{\partial t} = 0$$

11. Mention the properties of uniform plane wave.

i) At every point in space, the electric field E and magnetic field H are perpendicular to each other.

ii) The fields vary harmonically with time and at the same frequency everywhere in space.

12. What is skin effect?

In good conductors, the wave attenuates very rapidly and the fields are confined to the region near the surface of the conductor. This phenomenon is known as skin effect.

13. Give the Maxwell's equation – I in both integral form and point form. (Nov/Dec 2011)

Maxwell's equation – I is derived from the Ampere's circuital law which states that the line integral of magnetic field intensity H on any closed path is equal to the current enclosed by that path.

$$\oint H.dl = I$$

Maxwell's equation – I in integral form is

$$\oint H.dl = \iint_s \left(\sigma E + \varepsilon \frac{\partial E}{\partial t} \right) ds$$

Maxwell's equation – I in point form is

$$\nabla \times H = \sigma E + \varepsilon \frac{\partial E}{\partial t}$$

14. Give the Maxwell's equation – II in both integral form and point form.

Maxwell's equation – II is derived from Faraday's law which states that the emf induced in a circuit is equal to the rate of decrease of the magnetic flux linkage in the circuit.

$$e = -\frac{d\phi}{dt}$$

Maxwell's equation - II in integral form is

$$\oint E.dl = -\mu \iint \frac{\partial H}{\partial t} ds$$

Maxwell's equation – II in point form is

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

15. Give the Maxwell's equation – III in both integral form and point form.

The Maxwell's equation – III is derived from electric Gauss's law which states that the electric flux through any closed surface is equal to the charge enclosed by the surface.

$$\psi = Q$$

Maxwell's equation – III in integral form is

$$\iint_s D.ds = \iiint_v \rho dv$$

Maxwell's equation – III in point form is

$$\nabla \cdot D = \rho$$

16. Give the Maxwell's equation – IV in both integral form and point form.

Maxwell's equation – IV is derived from magnetic Gauss's law which states that, the total magnetic flux through any closed surface is equal to zero.

$$\phi = 0$$

Maxwell's equation – IV in integral form is

$$\iint_s B.ds = 0$$

Maxwell's equation – IV in point form is

$$\nabla \cdot B = 0$$

17. What is meant by conduction current?

Conduction current is the curtrent flowing because of actual motion of charges. It is denoted by i_c. Conduction current density is given by

$$Jc = i_c / A$$

18. Distinguish between conduction and displacement currents.

The current through a resistive element is termed as conduction current whereas the current through a capacitive element is termed as displacement current.

19. Find the frequency at which conduction current density and displacement current density are equal in a medium with σ = 2*10^{-4} mho/m and ξr = 81.

Solution : The ratio of amplitudes of the two current densities is given as 1, so we can write,

$$\frac{|\bar{J}_C|}{|\bar{J}_D|} = \frac{\sigma}{\omega\varepsilon} = 1$$

i.e.

$$\omega = \frac{\sigma}{\varepsilon} = \frac{\sigma}{\varepsilon_0 \varepsilon_r}$$

∴

$$\omega = \frac{2\times10^{-4}}{(8.854\times10^{-12})(81)} = 0.2788\times10^{6} \text{ rad/sec}$$

But

$$\omega = 2\pi f$$

∴

$$f = \frac{\omega}{2\pi} = \frac{0.2788\times10^{6}}{2\pi} = \mathbf{44.372 \text{ kHz}}$$

Hence, the frequency at which the ratio of amplitudes of conduction and displacement current density is unity, is 44.372 kHz.

20. What is the formula for average power?

The average power flow per unit area is given by,

$$\vec{P}_{avg} = \frac{1}{2} Re[\vec{E} \times \vec{H}^*]$$

21. What is the formula for reactive power?

The reactive power flow per unit area is given by,

$$\vec{P}_{react} = \frac{1}{2} Im[\vec{E} \times \vec{H}^*]$$

22. State lenz's law.

The direction of induced emf is such that it opposes the changes in magnetic flux.

23. State poynting's theorem.

It states that the net power flowing out of a given volume V is equal to the time rate of decrease in the energy stored within the volume V minus the ohmic losses.

24. Time varying field is not conservative prove it.

For conservative field it should be zero. But time varying electric field produces a magnetic field and its value is given by faraday's law. So, time varying field is not conservative field.

25. Define a wave.

Wave involves the propagation of energy or information whose magnitude is a function of time and space. Examples are radio waves, TV signals, radar beams and light.

26. What is TEM?

Electromagnetic wave that has no electric or magnetic field components along the direction of propagation, such a wave is called a transverse electromagnetic wave (TEM) wave. Both E or H fields are everywhere normal to the direction of wave propagation.

27. What are the standing waves?

A wave that does not progress is known as standing wave. If two waves having same magnitude travelling in opposite directions combine, then it produces a standing wave.

28. Give the wave equation in free space.

The wave equation in free space in terms of electric field is,

$$\nabla^2 E - \mu\varepsilon \frac{\partial^2 E}{\partial t^2} = 0$$

The wave equation in free space in terms of magnetic field is,

$$\nabla^2 H - \mu\varepsilon \frac{\partial^2 H}{\partial t^2} = 0$$