UNIT – I
ELECTROSTATICS – I
PART- A

1. Define scalar and vector.

Scalar : A quantity that is characterized only by magnitude is called a scalar.

Vector :A quantity that is characterized both by magnitude and direction is called a vector.

2. Define Gradient.

The gradient of any scalar function is the maximum space rate of change of that function. If the scalar V represents electric potential, ∇V represents potential gradient.

$\nabla V = \frac{\partial V}{\partial x}\bar{a}_x + \frac{\partial V}{\partial y}\bar{a}_y + \frac{\partial V}{\partial z}\bar{a}_z$. This operation is called the gradient.

3. Define divergence and curl

Divergence:

The divergence of a vector 'A' at any point is defined as the limit of its surface integrated per unit volume as the volume enclosed by the surface shrinks to zero. $\nabla .A = Lt_{V\to 0}\frac{1}{v}\oiint_S A.\bar{n}\,ds$.

$\nabla .A = \frac{\partial A_X}{\partial x} + \frac{\partial A_Y}{\partial y} + \frac{\partial A_Z}{\partial z}$. This operation is called divergence. Divergence of a vector is a scalar quantity

Curl:

The curl of a vector 'A' at a any point is defined as the limit of its cross product with normal over a closed surface per unit volume as the volume shrinks to zero.

$$\nabla \times A = Lt_{V\to 0}\frac{1}{v}\oiint_S \bar{n} \times A\,ds.$$

4. Show that the vector $\bar{H} = 3y^4z\,\bar{a}_x + 4x^3z^2\,\bar{a}_y + 2x^3y^2\,\bar{a}_z$ is solenoidal.

$$\nabla .H = \left(\frac{\partial}{\partial x}\bar{a}_x + \frac{\partial}{\partial y}\bar{a}_y + \frac{\partial}{\partial z}\bar{a}_z\right).(3y^4z\,\bar{a}_x + 4x^3z^2\,\bar{a}_y + 2x^3y^2\,\bar{a}_z)$$

$$= \frac{\partial}{\partial x}(3y^4z) + \frac{\partial}{\partial y}(4x^3z^2) + \frac{\partial}{\partial z}(2x^3y^2) = 0 + 0 + 0 = 0;$$ Hence $\bar{H}$ is solenoidal.

5. Determine the angle between A = $2\bar{a}_x + 4\bar{a}_y$ and B=$6\bar{a}_y - 4\bar{a}_z$. (Nov 2016)

$$\theta = Cos[\bar{A}.\bar{B}/(|\bar{A}|.|\bar{B}|)]$$

$$|\bar{A}| = \sqrt{2^2 + 4^2} = 4.47$$

$$|\bar{B}| = \sqrt{6^2 + 4^2} = 7.21$$

$$\bar{A}.\bar{B} = 2*6 + 4*4 = 28$$

θ=0.5182°

6. Define Stoke's Theorem and divergence theorem (Nov 2013, May 2014, Nov 2016)

Stoke's Theorem

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

$$\oint H.dl = \iint_S \nabla x H dS$$

Divergence theorem

The volume integral of the divergence of a vector field over a volume is equal to the surface integral of the normal component of this vector over the surface bounding the volume.

$$\iiint_v \nabla . A dV = \oiint_S A.dS$$

7. Write down the expression for conversion of Cylindrical to Cartesian system.

The Cylindrical co-ordinates (r , Φ , z) can be converted into Cartesian co-ordinates(x, y, z).

Given	Transform
r	x = r cosθ
Φ	y = r sinθ
z	z = z

8. What is the physical significance of curl of a vector field?

The curl of a vector is an axial vector whose magnitude is the maximum circulation of A per unit area as the area tends to zero and whose direction is the direction normal direction of the area when the area is oriented to make the circulation maximum.

9. Write down the expression for conversion of Cartesian to Spherical system.

The Cartesian co-ordinates (x, y, z) can be converted into Spherical co-ordinates (r, θ, Φ).

Given	Transform
x	r = $\sqrt{x^2 + y^2 + z^2}$
y	θ = $\cos^{-1}\left(\frac{z}{\sqrt{x^2 + y^2 + z^2}}\right)$
z	Φ = $\tan^{-1}(y/x)$

10. Write down the expression for conversion of Spherical to Cartesian system.

The Spherical co-ordinates (r, θ, Φ) can be converted into Cartesian co-ordinates (x, y, z).

Given	Transform
r	x = rsinθ.cosΦ
θ	y = r sinθ.sin Φ
Φ	z = rcosθ

11. Transform the Cartesian co-ordinates x = 2, y = 1, z = 3 into spherical co-ordinates.

Given	Transform
x = 2	r = $\sqrt{x^2 + y^2 + z^2} = \sqrt{4+1+9}$ = 3.74
y = 1	θ = $\cos^{-1}\left(\frac{z}{\sqrt{x^2 + y^2 + z^2}}\right)$ = cos-1($\frac{3}{\sqrt{14}}$)=36.7 ^{o}
z = 3	Φ = $\tan^{-1}(y/x) = \tan^{-1}(1/2)$ = 26.56 ^{o}

The spherical co-ordinates are (3.74, 36.7 ^{o} , and 26.56 ^{o}).

12. **Define electric flux, electric flux density and electric field intensity.**

Electric flux: The lines of electric force are known as electric flux. It is denoted by Ψ.

Ψ = Q (charge) Coulomb.

Electric flux density: Electric flux density or displacement density is defined as the electric flux per unit area.

D = Q/A

Electric field intensity: Electric field intensity is defined as the electric force per unit positive charge. It is denoted by E.

$$E = \frac{F}{Q} \qquad = \frac{Q}{4\pi\varepsilon r^2} \text{ V/m.}$$

13.Given two vectors P=3i+5j+2k and Q=2i-4j+3k.Determine the angular separation between them.

P. Q= IPIIQI cosθ, P.Q=-8, IPI=6.1644 IQI=5.38516, Cosθ=-0.2409, θ=103.94.

14.Two vector quantities A=4i+3j+5k and B=i-2j-2k.are oriented in two different directions. Determine the angular separation between them.

$$A.B = IAI\ IBI\ \cos\theta$$

$$\theta = \cos^{-1}\frac{A.B}{IAI\ IBI} = 67.84^{o}$$

15.What are the different sources of Electromagnetic fields?

Electromagnetic fields are present everywhere in our environment but are invisible to the human eye. Electric fields are produced by the local build-up of electric charges in the atmosphere associated with thunderstorms. The earth's magnetic field causes a compass needle to orient in a North-South direction and is used by birds and fish for navigation.

16.How is the unit vectors defined in cylindrical co-ordinate systems?

A vector A in cylindrical coordinates can be written as (A_ρ, A_φ, A_z)

Where a_ρ, a_ϕ and a_z are unit vectors in the ρ, ϕ and z directions.

17.State the condition for the vector to be solenoidal and irrotational.

A.B=0 and AX B=0

18.State Gauss's law and Coulomb's law .

Gauss's law: The electric flux passing through any closed surface is equal to the total charge enclosed by that surface. $\Psi = Q$

Coulomb's law.

Coulomb's law states that the force between two very small charged objects separated by a large distance compared to their size is proportional to the charge on each object and inversely proportional to the square of the distance between them.

$$F \alpha\ Q_1Q_2$$

$$F \alpha\ \frac{1}{r^2}$$

$$F \alpha\ \frac{Q_1Q_2}{r^2} = \frac{Q_1Q_2}{4\pi\varepsilon r^2}\overline{a_{12}} \text{ Newton.}$$

19.Name a few application of Gauss's law in electrostatics.

Gauss's law is applied to determine the electric field intensity from a closed surface. (e.g) Electric field can be determined for shell, two concentric shell or cylinders, etc.

20.What is the electric field intensity at a distance of 20cm from a charge of 20μc/m² lying on the z=0 plane. in vacuum?(Nov/Dec 2014)

$$E = \frac{\rho_s}{2\varepsilon_0}a_z \quad = \frac{20x10^{-6}}{2x8.854x10^{-12}}a_z \quad = 1.12 \text{ x } 10^6 a_z \text{V/m.}$$

21. Points P and Q are located at (0,2,4) and (-3,1,5). Calculate the distance vector from P to Q.

$R_{pq}=r_q - r_p$ = (-3,1,5) – (0,2,4) = (-3,-1,1)

22. Given $\overline{A}$ =4 $\overline{a_x}$ +6 $\overline{a_y}$ - 2 $\overline{a_z}$ and $\overline{B}$ =-2 $\overline{a_x}$ +4 $\overline{a_y}$ +8 $\overline{a_z}$. Show that the vectors are orthogonal.

$\vec{A}.\vec{B}$=(4*-2)+(6*4)+(-2*8)= -8+24-16 = 0. Therefore, $\vec{A},\vec{B}$ are orthogonal.

23. Express in matrix form the unit vector transformation from the rectangular to cylindrical co-ordinate system.

$$\begin{bmatrix} a_\rho \\ a_\phi \\ a_z \end{bmatrix} = \begin{bmatrix} cos\varphi & sin\varphi & 0 \\ -sin\varphi & cos\varphi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}$$

24. What are the practical applications of electromagnetic fields?

Electric fans, electric motors, magnetic tape, mobiles and telephones.

25. Write the expression for differential displacement and volume in spherical co-ordinates.

Differential displacement

dl = $\sqrt{(dr)^z + (rd\theta)^2 + (r\sin\theta d\Phi)^2}$

Differential volume

dv = $r^2 \sin\theta \ dr \ d\theta \ d\phi$

PART -B

1. **Explain the method of converting a vector from (i) Spherical to Cartesian system.(ii) Cylindrical to Cartesian system**
2. **State and prove Divergence theorem. Transform $4\bar{a}_x$-$2\bar{a}_y$-$4\bar{a}_z$ at (2, 3, 5) to cylindrical coordinates.**
3. **Write short notes on the following (i) Gradient (ii) Divergence (iii) Curl and (iv) Strokes theorem.**
4. **Derive an expression for Electric field intensity due to a line charge which has a uniform linear charge density of ρ_LC/m. Also extend it to a conductor of infinite length**
5. **State and prove the Gauss law and explain the applications of Gauss Law.**
6. **Show that over the closed surface of a sphere of radius b,ds = 0.**
7. **Show that the vector F= $(6xy+z^2)a_x + (3x^2 - z)a_y + (3xz^2 - y)a_z$ is irrotational and find its scalar potential.**
8. **Verify the divergence theorem for a vector field D = $(3x^2)a_x + (3y + z)a_y + (3z - x)a_z$ in the region bounded by the cylinder $x^2+y^2 = 9$ and the planes x = 0, y = 0, z = 0 and z = 2.**
9. **A novel printing technique is based upon electrostatic deflection principle, Justify. 8. (a) Derive expression for electric field intensity due to uniformly charged circular disc of σ C/m². Find the force on a charge Q_1 of 20 µC at (0, 1, 2) m due to Q_2 of 300 µC at (2, 0, 0) m.**
10. **Three point charge in free space are located as follows: 50 nC at (0,0)m; 40 nC at (3, 0)m; -60nC at (0,4)m. Find the electric field intensity at (3, 4)m.**
11. **A charge is distributed along a finite straight line with constant density ρ C/m along X axis. Develop an expression for E at an arbitrary point P.**

12. A charge Q_1=100nC is located in vacuum at P_1 (-0.03, 0.01, 0.04) m. Find the force on Q_1 due to (i) Q_2=120 µC at P_2(0.03, 0.08, -0.02)m (ii) Q_3=120µC at P_3 (-0.09, -0.06, 0.10)m (iii) Q_2 and Q_3. Explain divergence and curl of a vector.

UNIT – II
ELECTROSTATICS – II
PART- A

1. What do you understand by linear, surface and volume charge densities?

Linear Charge density: It is the charge per unit length (Col / m) at a point on the line of charge.

$$\rho_l = Lt_{\Delta l \to 0} \left(\frac{\Delta Q}{\Delta l}\right)$$

Surface charge density: It is the charge per surface area (C/m^2) at a point on the surface of the charge.

$$\rho_s = Lt_{\Delta s \to 0} \left(\frac{\Delta Q}{\Delta s}\right)$$

Volume charge density: It is the charge per volume (C/m^3) at a point on the volume of the charge.

$$\rho_V = Lt_{\Delta v \to 0} \left(\frac{\Delta Q}{\Delta v}\right)$$

2. Define potential and potential difference.

Potential: Potential at any point as the work done in moving a unit positive charge from infinity to that point in an electric field = $\frac{Q}{4\pi\varepsilon r}$ Volts.

Potential Difference: Potential difference is defined as the work done in moving a unit positive charge from one point in an electric field. V= $\frac{Q}{4\pi\varepsilon}\left(\frac{1}{r_A} - \frac{1}{r_B}\right)$ Volts.

3. Find the electric potential at a point (4 , 3) m due to a charge of 10^{-9} C located at the origin in free space.

V= $\frac{Q}{4\pi\varepsilon_O r}$; r = $\sqrt{4^2+3^2}$ = 5m. V= $\frac{10-9}{4\pi x 8.854\, x 10-12 x(5)}$ = 1.8V

4. Define Capacitance.

The capacitance of two conducting planes is defined as the ratio of magnitude of charge on either of the conductor to the potential difference between conductors. It is given by, $C = \frac{Q}{V}$ Farad.

5. What is meant by conduction current?

Conduction current is nothing but the current flows through the conductor. Conduction current density is given by

$$Jc = \sigma E \text{ Amp / m}^2.$$

6. Write the Poisson's equation and Laplace equation.

Poisson equation; $\nabla^2 V = -\rho/\varepsilon$

Where , ρ – Volume charge density, ε - Permittivity of the medium, ∇ - Laplacian operator.

$$\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial Y^2}+\frac{\partial^2 V}{\partial z^2} = -\rho/\varepsilon$$

Laplace equation: $\nabla^2 V = 0$; $\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial Y^2}+\frac{\partial^2 V}{\partial z^2} = 0$

7. Give the relationship between potential gradient and electric field.

$$E = -\nabla V \text{ ; } E = -\left(\frac{\partial}{\partial x}\bar{a}_x + \frac{\partial}{\partial y}\bar{a}_y + \frac{\partial}{\partial z}\bar{a}_z \right) V.$$

8. Define dipole and dipole moment.

Dipole or electric dipole is nothing but two equal and opposite point charges are separated by a very small distance. The product of electric charge and distance (spacing) is known as dipole moment. It is denoted by m where Q is the charge and l is the length (m) =Q. l C/m

9. What is the physical significance of divD?

$\nabla . D = \rho_v$. The divergence of a vector flux density is electric flux per unit volume leaving a small volume. This is equal to the volume charge density.

10. Determine the capacitance of a parallel plate capacitor with two metal plates of size 30cm x 30cm separated by 5mm in air medium.

Given data: A = 0.3 X0.3 = 0.09m^2; d=5 x 10^{-3}m.

$\varepsilon_o = 8.854 \times 10^{-2}$;C= $\frac{A}{2}\varepsilon_o$= $\frac{0.09 \times 8.854 \times 10^{-12}}{5 \times 10^{-3}}$ = 15.9nF

11. Express the value of capacitance for a co-axial cable.

C= $\frac{2\pi\varepsilon_o \varepsilon_r}{\ln \frac{b}{a}}$; Where b – outer radius: a – inner radius.

12. Find the energy stored in a parallel plate capacitor of 0.5m by 1m has a separation of 2cm and a voltage difference of 10V.

C= $\varepsilon_o \frac{A}{d}$ = $\frac{8.854 \times 10^{-12} \times 0.5 \times 1}{2 \times 10^{-2}}$ =2.2135x10^{-10}F

Energy stored in a capacitor E=1/2 CV^2 =1/2 X 2.2135 X 10^{-10} X10^2=1.10675 X 10^{-8}Joules.

13. State the boundary conditions at the interface between two perfect dielectrics.

The tangential component of electric field E is continuous at the surface. That is E is the same just outside the surface as it is just inside the surface.$E_{t1} = E_{t2}$

The normal component of electric flux density is continuous if there is no surface charge density. Otherwise D is discontinuous by an amount equal to the surface charge density.

$D_{n1} = D_{n2}$

14. What is meant by Displacement current density?

Displacement current is nothing but the current flows through the Capacitor.

Displacement current density is given by $J_d = \frac{\partial D}{\partial t}$ Amp / m^2

15. What is meant by conservative property of Electric field?

The line integral of electric field along a closed path is zero. Physically this implies that no net work is done in moving a charge along a closed path in an electrostatic field. Thus an electrostatic field is said to have conservative property.

16. A parallel plate capacitor has a charge of 10-3 C on each plate while the potential difference between the plates is 1000V.Calaculate the value of capacitance.

Given data, Q = 10-3C, V = 1000V, $C = \frac{Q}{V} = \frac{10^{-3}}{10^3}$ = 1μF.

17. Give the significant physical difference between Poisson's and Laplace equation.

Poisson equation: $\nabla^2 V = -\rho/\varepsilon$

Where ρ – Volume charge density, ε – Permittivity of the medium, ∇^2 - Laplacian operator.

$$\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial Y^2} + \frac{\partial^2 V}{\partial z^2} = -\rho/\varepsilon$$

Laplace equation: $\nabla^2 V = 0$; $\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial Y^2} + \frac{\partial^2 V}{\partial z^2} = 0$

The Laplace equation is defined only for the region which is free of charges.

18. State the properties of electric flux lines.

i. It must be independent of the medium.
ii. Its magnitude solely depends upon the charge from which it originates,
iii. If a point charge is enclosed in an imaginary sphere of radius R, the electric flux must pass perpendicularly and uniformly through the surface of the sphere and
iv. The electric flux density, the flux per unit area is then inversely proportional to R^2.

19. What is the electric field intensity at a distance of 20 cm from a charge of 2 μC in vacuum?

$E = \frac{Q}{4\pi\epsilon r^2}$ V/m ; $E = \frac{2*10^{-6}}{4\pi*8.854*10^{-12}*0.02^2}$ V/m ;

E = $4.49 * 10^7$ V/m

20. Find the electric field intensity in free space if D=30a_Z C/m^2.

$D = \epsilon E$; $E = \frac{D}{\epsilon}$; $E = \frac{30}{8.854*10^{-12}}$ = $3.388*10^{12}$ V/m

21. What is the practical significance of Lorentz's Force?(April /May 2015)(Nov/Dec 2015)

When an electric charge element is moving in a uniform magnetic field (B) with velocity V, the charge experience a force (dF). This force is called as Lorentz's force.

$dF = dQVBsin\theta$, θ is angle between V and B.

The direction of lorentz's force is maximum if the direction of movement of charge is perpendicular to the orientation of field lines.

22. What is a capacitor and capacitance?

Capacitor is a passive element that stores electrical energy in an electric field. Capacitance is the ability of a body to store an electric charge.

PART – B

1. **Derive the expression for the electric field intensity at a point P which is situated 'h' meter away from the disc along its axis. The disc is charged uniformly with a charge density of ρ_L c/m^2**
2. **Derive the expression for energy and energy density in the static electric field. Deduce an expression for the capacitance of a parallel plate capacitor with two dielectrics of relative permittivity ε_1 and ε_2 respectively interposed between the plates.**
3. **Derive the electrostatic boundary conditions at the interface between two dielectrics and a conductor to dielectric medium.**
4. **Distinguish between electric potential and electric potential difference. Two point charges -4μC and 5μC are located at (2,-1,3) and (0,4,-2) respectively. Find the potential at (1,0,1) assuming zero potential at infinity.**
5. **A capacitor consists of two parallel metal plates 30cm x 30cm surface area, separated by 5mm in air. Determine its capacitance. Find the total energy stored by the capacitor and the energy density if the capacitor is charged to a potential difference of 500V?**
6. **Derive an expression for polarization 'p' and thus obtain electric field intensity and potential of a dipole. Derive an expression for capacitance of concentric spheres.**
7. **Explain the potential at a point in an electric field. Derive the electric field intensity at any point in a field due to a point charge.**
8. **Write Laplace's equation in Cartesian co-ordinates. And obtain the solution when V is function of x only for the boundary condition $V=V_1$ at $x=x_1$ and $V=V_2$ at $x=x_2$. Calculate the potential at a point P(0, 0)m due to point charges Q_1 and Q_2. $Q_1=10^{-12}$ Coulomb is located at (0.5, 0)m and $Q_2=-10^{-11}$ Coulomb is located at (-0.5, 0)m.**
9. **Find the potential at r_A = 5m with respect to r_B = 15m due to point charge Q=500 pC at the origin and zero reference at infinity. Find the capacitance of a parallel plate capacitor with dielectric $\varepsilon_{r1}=1.5$ and $\varepsilon_{r2}=3.5$ each occupy one half of the space between the plates of area 2 m^2 and $d=10^{-3}$ m.**

UNIT – III
MAGNETOSTATICS
PART- A

1. **Define magnetic flux and magnetic flux density.**

   Magnetic flux:

   Magnetic flux is defined as the flux passing through any area. Its unit is Weber .

   $\Phi = \int_a B.da$ Weber.

   Magnetic flux density.

   Magnetic flux density is defined as the magnetic flux density passing per unit area.

   Its unit is Weber / meter or Tesla. $B=\frac{\Phi}{A}$; $B=\mu H$

2. **Define magnetic Gauss's Law.**

   The total magnetic flux passing thorough any closed surface is equal to zero. $\oint_a B.da = 0$

3. **State Biot- Savart law.**

   It states that the magnetic flux density at any point due to current element is proportional to the current element and sine of the angle between the elemental length and the line joining and inversely proportional to the square of the distance between them.

   $$dB = \frac{\mu_o I dl \sin\theta}{4\pi r^2}$$

4. **State the Lorentz force equation.**

   The force on a moving particle due to combined electric and magnetic field is given by

   F = Q $\left[\vec{E} + \vec{V} \times \vec{B}\right]$.This force is called Lorentz force.

5. **State Ampere's circuital law.**

   Ampere's circuital law states that the line integral of magnetic field intensity H about any closed path is exactly equal to the direct current enclosed by the path.

   $$\oint H.dl = I$$

6. **Distinguish between diamagnetic, paramagnetic and ferromagnetic materials.**

   Diamagnetic: In diamagnetic materials magnetization is opposed to the applied field. It has magnetic field.

   Paramagnetic: In paramagnetic materials magnetization is in the same direction as the field. It has weak magnetic field.

   Ferromagnetic: In Ferromagnetic materials is in the same direction as the field. It has strong magnetic field.

7. **Compare scalar magnetic potential and vector magnetic potential.**

Scalar magnetic potential	Magnetic vector potential
It is defined as dead quantity whose negative gradient gives the magnitude intensity if there is no current source present. $H = -\nabla V_m$ where,Vm is the magnetic scalar potential. $V_m = -\int H.dl$	It is defined as that quantity whose curl gives the magnetic flux density. $B = \nabla$ x A; where A is the magnetic vector potential. $A = \frac{\mu}{4\pi}\iiint_V \frac{J}{r}dr$ Web / m

8. A solenoid with a radius of 2cm is wound with 20 turns per cm length and carries 10mA. Find H at the centre if the total length is10cm.

Given data,N=nl = 20 x 10 = 200 turns; l =10 X 10^{-2} m;I = 10 x 10^{-3}A;

$$H = \frac{NI}{l} = 20 \text{AT/m.}$$

9. Give four similarities between Electrostatic field and Magnetic field.

Electrostatic field	Magnetic field
1. Electric field intensity E (volts/m) **2.** Electric flux density D=εE c/m **3.** Energy stored is $1/2CV^2$ **4.** Charges are rest	1. Magnetic field intensity H (Amp/m) 2. Magnetic flux density B=μH (web / m2) 3. Energy stored is $1/2LI^2$ 4. Charges are in motion

10. Determine the force per unit length between two long parallel wires separated by 5 cm in air and carrying currents 40A in the same direction.

$$\text{Force / length} = \frac{\mu_o I_1 I_2}{2\pi D} = \frac{40\times 40}{2\pi \times 5\times 10^{-2}} x4\pi x 10^{-7} = 6.4 \text{ x } 10^{-3} \text{ N/m.}$$

11. Define magnetic susceptibility and their relation with relative permeability

Magnetic susceptibility is defined as the ratio of magnetization to the magnetic field intensity. It is dimensionless quantity. $\chi_m = \frac{M}{H}$

$\mu_r = 1 + \chi_m$ Where μ_r is relative permeability; χ_m is susceptibility

12. What will be effective inductance, if two inductors are connected in (a) series (b) parallel?

(a) For series L = $L_1 + L_2 \pm 2M$

(b)For Parallel L = $\frac{L_1 L_2 - M^2}{L_1 + L_2 \pm 2M}$

Where, (+)sign for aiding , (-) sign for opposition

13. Distinguish between solenoid and toroid.

Solenoid	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 thereby closed on itself, it becomes toroid
Inductance of solenoid is given by $L = \frac{\mu_o N^2 A}{l}$	Inductance of solenoid is given by $L = \frac{\mu_o N^2 A}{2\pi R} = \frac{\mu_o N^2 r^2}{2R}$;

.

14. Define magnetostatic energy density.

It is defined as the ratio of magnetic energy per unit volume.

15. State the law of conservation of magnetic flux.

An isolated magnetic charge does not exist. Thus the total flux through a closed surface is zero.

$\iint B.ds = 0$ .This is called as law of conservation of magnetic flux.

16. Write down the magnetic boundary conditions.

1. The tangential component of magnetic field intensity is continuous across the boundary. $H_{t1} = H_{t2}$.
2. The normal component of magnetic flux density is continuous across the boundary. $B_{n1} = B_{n2}$

17. State Ohm's law for magnetic circuits.

Sum of Magnetic motive force (mmf) in a closed path is zero.

18. State Lorentz Law of force.

When a current carrying conductor is placed in a magnetic field, it experiences a force given by, dF = I x B dl = BI dl sinθ Newton.

19. Write the expression for the inductance per unit length of a long solenoid of N turns and having a length 'L' meter carrying a current of I amperes.

$$H=\frac{NI}{2l}[\text{Cos}\theta_2 - \text{Cos}\theta_1]$$

20. Determine the value of magnetic field intensity at the centre of a circular loop carrying a current of 10A. The radius of the loop is 2m.

$$H=\frac{I}{2a}=\frac{10}{2x2}=2.5\text{A/m}$$

21. What is the mutual inductance of two inductively tightly coupled coils with self inductance of 25mH and 100mH.

L_1 = 25mH, L_2 = 100mH, M=K $\sqrt{L_1 L_2}$ $=\sqrt{25 X 100}$ = 50mH

22. Find the force of interaction between two charges $4*10^{-3}$ and $6*10^{-3}$ spaced 10cm apart n kerosene ($\varepsilon_r = 2$).

Force of repulsion = $\frac{Q_1 Q_2}{4\pi\varepsilon_0 R^2} a_r$ = 1.07908 N

PART-B

1. **Derive an expression for the magnetic field intensity and magnetic flux density at a point P in a medium of permeability 'µ' due to (i) an infinitely long current carrying conductor at a distance 'r' meters from the point.(ii) a finite length conductor.**
2. **Obtain an expression for inductance and torque on a long solenoid coil.**
3. **What is magnetization? Explain the classification of magnetic materials with examples and draw a typical magnetization (B_H) curve.**
4. **Derive the magnetostatic boundary conditions.**
5. **Derive Biot-Savart's Law and Ampere's Law from concept of magnetic vector potential.**
6. **Derive an expression for torque in a rectangular loop which is carrying a current of 'I' amperes and is situated in a uniform magnetic field 'B' Wb/m^2.**
7. **Deveop an expression for the magnetic field intensity at any point on the line through the centre at a distance 'h' m from the centre and perpendicular to the plane of a circular loop (in XY plane) of radius 'a' m and carrying a current I Ampere in the anti-clockwise direction. Find the magnetic field intensity at point P (1.5, 2, 3) caused by a current filament of 24 Ampere in the az direction on the z axis and extending from z=0 to z=6.**

8. **Deduce the point form of Ampere's circuital law. Determine the torque on a rectangular loop (a m X b m) carrying current I and placed in a uniform magnetic field.**
9. **Derive the expression for magnetic field intensity due to infinitely long straight conductor carrying a current of I amps along Z-axis.**
10. **Determine H for a solid cylindrical conductor of radius a, where the current I is uniformly distributed over the cross section. Calculate the inductance of a ring shaped coil of mean diameter 20 cm, wound on a wooden core of 2 cm diameter containing 200 turns.**

UNIT – IV
ELECTRO DYNAMIC FIELDS
PART- A

1. **State Faraday's law of electromagnetic induction.**

   Faraday's law states that electromagnetic force induced in a circuit is equal to the rate of change of magnetic flux linking the circuit. Emf= $\frac{d\Phi}{dt}$

2. **Define mmf and reluctance**

   Magnetic motive force (mmf) is given bymmf = flux x reluctance

   mmf = $\Phi \Re$ Amp.turns.

   Reluctance is the ratio of mmf of magnetic circuit to the flux through it.

   $\Re = \frac{mmf}{flux(\Phi)}$. It is also written as $\Re = \frac{l}{\mu A}$;Where$l$is the length, A is the area of cross- section, μ is permeability.

3. **What is the expression for energy stored and energy density in magnetic field?**

   Energy W = $\frac{1}{2}LI^2$;WhereL is the inductance , I is the current.

   $$\text{Energy density (w)} = \frac{1}{2}BH = \frac{1}{2}\mu H^2$$

4. **State Lenz's law.**

   Lenz's law states that the induced emf in a circuit produces a current which oppose the change in magnetic flux producing it.emf = $-\frac{d\Phi}{dt}$

5. **State Ampere's circuital law. Must the path of integration be circular? Explain.**

   The integral of the tangential component of the magnetic field strength around a closed path is equal to the current enclosed by the path. $\oint H.dl = I$.The path of integration must be enclosed one. It must be any shape and it need not be circular alone.

6. **What is meant by Displacement current?**

   Displacement current is nothing but the current flows through the Capacitor.

   I_c=C dV/dt.

7. **Mention four similarities between electric circuit and magnetic circuit.**

Electric circuit	Magnetic circuit
1.emf (volts)	1. mmf (Amp-turns)
2.current $= \frac{emf}{resistance}$	2.magnetic flux $= \frac{mmf}{reluctance}$
3.resistance R $= \frac{\rho l}{A}$	3. Reluctance $\Re = \frac{1}{\mu A}$
4.Conductance G $= \frac{1}{R}$	4. Permeance P $= \frac{1}{\Re}$

8. Write down the Maxwell's equation in integral form.

From Ampere's Law

$$\oint H.dl = \iint_S \left(J + \frac{\partial D}{\partial t} \right) ds$$

From Faraday's Law

$$\oint E.dl = -\iint_S \frac{\partial B}{\partial t} ds$$

From Electric Gauss's Law

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

From Magnetic Gauss's Law

$$\oiint_s B.ds = 0$$

9. Write down the Maxwell's equation in point form.

From Ampere's Law

$$\nabla X H = J + \frac{\partial D}{\partial t}$$

From Faraday's Law

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

From Electric Gauss's Law, $\nabla . D = \rho$,

From Magnetic Gauss's Law, $\nabla . B = 0$

10. Write the fundamental postulate for electromagnetic induction and explain how its leads to Faraday's Law.

A changing magnetic flux (Φ) through a closed loop, produces an emf or voltage at the terminals as given by $v = -\frac{d\Phi}{dt}$ where the voltage is the integral of the electric field E around the loop.For uniform magnetic field Φ = B.A where B is the magnetic flux density and A is the area of the loop. $v = \oint E.dl = -\iint \frac{\partial B}{\partial t} ds$ .This is Faraday's law. It states that the line integral of the electric field around a stationary loop equals the surface integral of the time rate of change of the magnetic flux density B integrated over the loop area.

11. Write down the Maxwell's equations in point phasor forms.

$$\nabla x H = J + j\omega D = (\sigma + j\omega\varepsilon)E$$

$$\nabla x E = -j\omega B = -j\omega\mu H$$

$$\nabla . D = \rho$$

$$\nabla . B = 0$$

12. Write the expression for total current density?

$J=J_C + J_D$

J_C is conduction current density, $J_D$is displacement current density.

13. Explain why $\nabla .B = 0$ and $\nabla xE = 0$.

$\nabla .B = 0$ States that there is no magnetic charges. The net magnetic flux emerging through any closed surface is zero.

In a region in which there is no time changing magnetic flux, the voltage around the loop would be zero. By Maxwell's equation, $\nabla XE = -\frac{\partial B}{\partial t}$ =0 (irrotational).

14. Explain why $\nabla .D = 0$?

In a free space there is no charge enclosed by the medium. The volume charge density is zero. By Maxwell's equation $\nabla .D = \rho_v = 0$.

15.Compare the relation between Circuit theory and Field theory.

Circuit Theory	Field Theory
This analysis originated by its own.	Evolved from Transmission theory.
Applicable only for portion of RF range.	Beyond RF range (Microwave)
The dependent and independent parameters I, V are directly obtained for the given circuit.	Not directly , through E and H.
Parameters of medium are not involved.	Parameter of medium (permittivity and permeability) are involved in the analysis.
Laplace Transform is employed.	Maxwell's equation is employed
Z, Y, and H parameters are used .	S parameter is used.
Low power is involved.	Relatively high power is involved.
Simple to understand.	Needs visualization ability
Two dimensional analysis	Three – dimensional analysis
Frequency is used as reference.	Wave length is used as reference
Lumped components are involved	Distributed components are involved.

16. Distinguish between conduction and displacement current.

Conduction current.	Displacement current
Conduction current is nothing but the current flows through the conductor.	Displacement current is nothing but the current flows through the Capacitor.
$I_c = \sigma E$.	$I_d = \int_S \frac{\partial D}{\partial t} .ds$

17. A conductor of 1m length is moved with a velocity of 100m/sec. perpendicular to a field of 1 tesla. What is the value of emf induced?

$E_{induced}=vlB$, where v=100m/sec, l=1m, B=1 tesla, Therefore $E_{induced}$=100x1x1 =100V

18. A loop is rotating about the Y axis in a magnetic field B= B_0sinwt i web/m^2. What is the type the voltage induced in the loop?

Motional or Generator emf is induced in the conductor as the conductor position varies with respect to time.

19. What is the significance of displacement current?

The displacement current I_D through a specified surface is obtained by integration of the normal component of J_D over the surface.

$$I_d = \int_S J_D . ds = \int_S \frac{\partial D}{\partial t} . ds$$

$$I_d = \varepsilon \frac{\partial E}{\partial t} ds$$

This is a current which directly passes through the capacitor.

20. Calculate the characteristics impedance of free space and of the medium whose relative permeability is 1 and relative permittivity is 3?

$$\eta = \frac{E}{H} = \sqrt{\frac{\mu}{\varepsilon}}$$

$$= \sqrt{\frac{4\pi \times 10^{-7} \times 1}{8.854 \times 10^{-12} \times 3}} = 217.4$$

21. Define mutual inductance and self-inductance.

Mutual inductance.

The mutual inductance between two coils is defined as the ratio of induced magnetic flux linkage in one coil to the current through in other coil(M) = $\frac{N_2 \Phi_{12}}{i_1}$;Where N_2 is number of turns in coil 2; Φ_{12} is magnetic flux links in coil 2 and i_1 is the current through coil 1.

Self inductance.

The self induction of a coil is defined as the ratio of total magnetic flux linkage in the circuit to the current through the coil (L) = $\frac{N\Phi}{i}$ Where Φ is magnetic flux; N is number of turns of coil; i is the current.

22. Distinguish between transformer emf and motional emf.

The emf induced in a stationary conductor due to the change in flux linked with it, is called transformer emf or static induced emf. emf = - $\iint \frac{\partial B}{\partial t} . ds$ eg. Transformer.

The emf induced due to the movement of conductor in a magnetic field is called motional emf or dynamic induced emf. emf =- $\oint_c v \times B . dl$ eg. Generator

PART – B

1. **Derive the maxwell's equations in both point and integral forms from ampere's law and faraday's law of electromagnetic induction for general case and in free space. State the boundary conditions of time varying fields at the interface between two dielectric media, between a dielectric medium and a perfect metal.**
2. **Briefly explain the relation between electric circuit and magnetic circuit.**
3. **State and derive the time –harmonic Maxwell's equations in point and integral form. Why are Maxwell's equations not completely symmetrical?**
4. **Obtain the expression for energy stored in the magnetic field and also derive the expression for magnetic energy density.**
5. **A parallel plate capacitor with plate area of $5cm^2$ and plate separation of 3mm has a voltage $50\sin 10^3 t$ V applied to its plates. Calculate the displacement current assuming $\varepsilon = 2\varepsilon_0$**
6. **A circular loop of wire is placed in a uniform magnetic field of flux density $0.5 wb/m^2$. the wire has 200 turns and frequency of rotation of 100 revolutions/minute. If the radius of the coil is 0.2m,determine (1) the induced emf ,when the plane of the coil is 60 degree to the flux lines and (2) the induced emf, when the plane of the coil is perpendicular to the field.**
7. **By means of simple RLC series circuit , explain the relationship between the field theory and circuit theory. Also explain the limitations of the circuit theory. (b) Compare and explain in detail conduction and displacement currents.**
8. **Explain the concept of emf induction in static and time varying magnetic field. (b) In a material for which σ =5.0 S/m and ε_r=1 with $E=250 \sin 10^{10} t$ (V/m). Find J_c and J_D and also the frequency at which they equal magnitudes.**

UNIT – V
ELECTROMAGNETIC WAVES
PART- A

1. Write down the wave equations for E and H in a non-dissipative (free space) and conducting medium.

In Free space.

$$\nabla^2 E - \mu_0\varepsilon_0 \frac{\partial^2 E}{\partial t^2} = 0 \,; \quad \nabla^2 H - \mu_0\varepsilon_0 \frac{\partial^2 E}{\partial t^2} = 0$$

In conducting medium.

$$\nabla^2 E - \mu\varepsilon \frac{\partial^2 E}{\partial t^2} - \mu\sigma \frac{\partial E}{\partial t} = 0 \,; \quad \nabla^2 H - \mu\varepsilon \frac{\partial^2 H}{\partial t^2} - \mu\sigma \frac{\partial H}{\partial t} = 0$$

1. Define uniform plane wave.

If the phase of a wave is the same for all points on a plane surface it is called plane wave. If the amplitude is also constant in a plane wave, it is called uniform plane wave.

2. Define intrinsic impedance or characteristic impedance

It is the ratio of electric field to magnetic field. Or It is the ratio of square root of permeability to permittivity of the medium. $\eta = \frac{E}{H} = \sqrt{\frac{\mu}{\varepsilon}}$ Ohms

3. Calculate intrinsic impedance or characteristic impedance of free space.

$$\eta = \frac{E}{H} = \sqrt{\frac{\mu_o}{\varepsilon_o}} = \sqrt{\frac{4\pi\times10^{-7}}{8.854\times10^{-12}}} = 120\pi = 377 \text{ ohms}$$

4. Define polarization.

Polarization is defined as the polarization of a uniform plane wave refers to the time varying nature of the electric field vector at some fixed point in space.

5. Define Surface impedance.

Surface impedance is defined as the ratio of tangential component of electric field at the surface of a conductor to the linear current density.

$Zs = \frac{E_{\tan}}{J_s} = \frac{\gamma}{\sigma}$; Where γ is propagation constant σ is conductivity medium.

6. Define Poynting vector.

The pointing vector is defined as rate of floe of energy of a wave as it propagates. It is the vector product of electric field and magnetic field. P = E x H

7. State Slepian vector.

Slepian vector is a vector which defined at every point,such that its flux coming out of any volume is zero. $(\nabla.S) = 0$. Slepian vector is given by $S = \nabla \times (\nabla H)$

Where, V is electric potential, H is magnetic field intensity.

8. State Poynting theorem.

The vector product of electric field intensity at any point is a measure of the rate of energy flow per unit area at that point. P = E x H.

9. Fine the skin depth at a frequency of 2MHz is Aluminum where σ = 38.2M s/m and $\mu_{r=1}$.

Solution:

Given data:σ = 38.2M s/m = 38.2 x 10^6 s/m; $\mu_{r=1}$; $\omega = 2\pi f = 2\pi x 2x10^6$

For Good conductor, Skin depth $\delta = \frac{1}{\alpha} = \sqrt{\frac{2}{\omega\mu\sigma}} = \sqrt{\frac{2}{2\pi\times2\times10^6\times1\times4\pi\times10^{-7}\times38.2\times10^6}}$

=5.758 x 10^{-5} m.

10. State Snell's law.

When a wave is travelling from one medium to another medium, the angle of incidence is related to angle of reflection as follows. $\frac{\sin\theta_i}{\sin\theta_t} = \sqrt{\frac{\eta_1}{\eta_2}} = \sqrt{\frac{\varepsilon_2}{\varepsilon_1}}$ ($\mu_1 = \mu_2 = \mu_0$)

Where θ_i is angle of incidence; θ_t is angle of refraction; ε_1 is dielectric constant of medium 1 ε_2 is dielectric constant of medium 2 .

11. Write Helmholtz's equation.

$\nabla^2 E - \gamma^2 E = 0$; where $\gamma = \sqrt{j\omega\mu(\sigma + j\omega\varepsilon)}$

12. What is Brewster angle?

Brewster angle is an incident angle at which there is no reflect wave for parallel polarized wave. $\theta = \tan^{-1}\sqrt{\frac{\varepsilon_2}{\varepsilon_1}}$ Where, ε_1 is dielectric constant of medium 1, ε_2 is dielectric constant of medium

13.What do you meant by total internal reflection?

When a wave is incident from the denser medium to rarer medium at an angle equal to or greater than the critical angle, the wave will be totally internally reflected back. This phenomenon is called Total internal reflection.

14.Write the expression for pointing theorem in integral form and in point form?

Integral form

$$-\oint_S P.ds = \int_V \sigma E^2 + \frac{\partial}{\partial t}\int_V \frac{1}{2}\frac{\partial}{\partial t}[\mu H^2 + \varepsilon E^2]$$

Point form:

$$-\nabla.\overline{P} = \sigma E^2 + \frac{1}{2}\frac{\partial}{\partial t}[\mu H^2 + \varepsilon E^2]$$

15. What is practical significance of skin depth.

Skin depth or depth of penetration (δ) is defined as that of depth in which the wave has been attenuated to 1 / e or approximately 37% of its original value.

$\delta = \frac{1}{\alpha} = \sqrt{\frac{2}{\omega\mu\sigma}}$ for good conductor. $\delta = \sqrt{\frac{1}{\pi f\mu\sigma}}$; $\delta \propto \frac{1}{f}$

For low frequency, the skin depth δ is large. For High or microwave frequency range, the skin depth δ is small.

16. Define normal incidence and oblique incidence.

Normal incidence: When a uniform plane wave incidences normally to the boundary between the media, then it is known as normal incidence.

Oblique incidence: When a uniform plane wave incidences obliquely to the boundary between the two media, then it is known as oblique incidence.

17. Define voltage reflection coefficient at the load end of the transmission line.

It is defined as the ratio of the magnitude of the reflected wave to that of the incident wave.

18. What is 'standing wave ratio'?

It is defined as the ratio of maximum to minimum amplitudes of voltage.

$$S = \frac{E_{1s\,\max}}{E_{1s\,\min}} = \frac{1+|\Gamma|}{1-|\Gamma|}$$

19. The capacitance and inductance of an overhead transmission line are 0.0075μF/km and 0.8mH/km respectively. Determine the characteristic impedance of the line.

The characteristic impedance of a transmission line is equal to the square root of the ratio of the line's inductance per unit length divided by the line's capacitance per unit length $Z_0 = \sqrt{\frac{L}{C}}$

=326.5Ω

20. Compare the equi-potential plots of uniform and non-uniform fields.

Uniform field	Non-uniform field
The equipotential surface are perpendicular to $\vec{E}$ and are equidistant for fixed increment of voltages	The equipotential surface are perpendicular to $\vec{E}$ and are no equidistant for fixed increment of voltages

21. What is the wavelength and frequency of a wave propagation in free space when β=2?

$\beta = \sqrt{\omega\mu} = \omega\sqrt{\mu_0\omega_0}$; $2 = 2\pi f\sqrt{\mu_0\omega_0}$; f = 0.955 *10^8 Hz; wavelength = 3.14m

22. If a plane wave is incident normally from medium 1 to medium2, write the reflection and transmission co-efficients.

Reflection Co-efficients $Er_0 = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} Ei_0$

Transmission Co-efficients $Et_0 = = \frac{2\eta_2}{\eta_2 + \eta_1} Ei_0$

23. Mention the properties of uniform plane wave.

The properties of uniform plane wave are as follows:

a. At every point in space , the electric field E and Magnetic field H are perpendicular to each other and to the direction of the travel.

b. The fields vary harmonically with the time and at the same frequency, everywhere in space.

c. Each field has the same direction, magnitude and phase at every point in any plane perpendicular to the direction of wave travel.

PART – B

1. **Obtain the electromagnetic wave equation for free space in terms of electric field.**
2. **Obtain the electromagnetic wave equation in general and for free space in terms of magnetic field.**
3. **A distortion less line has Z_0=60 ohms=20mNp/m, u=0.6c, where c is the speed of the light in a vacuum. Find R, L, G, C and λ at 100 MHZ.(b) A Certain transmission line operating at ω = 10^6 rad/s has α = 8 dB/m, β=1 rad/m and Z_0=60+j40 ohms and is 2 m long. If the line is connected to a source of 10∟0^o, Z_g =40 ohms and terminated by a load of 20+ j50 ohms.**
4. **Define Brewster angle and derive its expression.**
5. **Describe the concept of electromagnetic wave propagation in a linear, isotropic, homogeneous, lossy dielectric medium.**
6. **State Pyonting theorem and thus obtain an expression for instantaneous power density vector associated with electromagnetic field. A uniform plane wave propagating in a medium has E = $2e^{-ax}\sin(10^8t-\beta z)a_y\ v/m$**
7. **If the medium is characterized by $\in_r = 1, \mu_r = 20\ and\ \sigma$ =3S/m, find α, β and H.**
8. **Deduce the wave equations for conducting medium.Discuss group velocity, phase velocity and propagation constant of electromagnetic waves.**
9. **Deduce the expression for fields of a plane electromagnetic waves which are incident normally on the surfaces of a perfect dielectric medium.**
10. **(b) Write short note on standing waves.**
11. **A 6580 MHz uniform plane wave is propagating in a material medium of Ɛr=2.25. If the amplitude of the electric field intensity of lossless medium is 500 V/m. calculate the phase constant, propagation constant, velocity, wavelength and intrinsic impedance.**