CONTENTS

BASICS OF ELECTROMAGNETIC THEORY AND MAXWELL'S EQUATIONS

THEORY

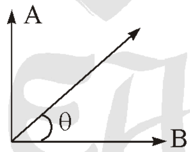
1.1 VECTOR ALGEBRA :

There are 3-types of product
(i) Dot Product
(ii) Cross Product
(iii) Triple Product

1.11 VECTOR PRODUCT :

(i) Dot Product :

The Dot Product of two Vectors $\overline{A}$ and $\overline{B}$ is given by,



$$\overline{A}\,\overline{B} = A \cdot B \cdot \cos\theta$$

Let, $$\overline{A} = A_x\hat{a}_x + A_y\hat{a}_y + A_z\hat{a}_z$$

$$\overline{B} = B_x\hat{a}_x + B_y\hat{a}_y + B_z\hat{a}_z$$

Thus, Dot product is given by :

$$\overline{A}\,\overline{B} = A_xB_x + A_yB_y + A_zB_z$$

Dot product is a Scalar quantity.

(ii) Cross Product

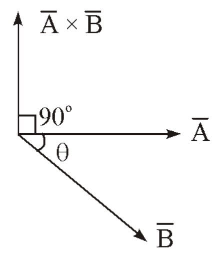
The Cross product of two Vectors $\overline{A}$ and $\overline{B}$ is given by :

$$\vec{A}\times\vec{B} = |\vec{A}|\bullet|\vec{B}|\sin\theta\,\hat{a}_n$$

where, $\hat{a}_n$ = Normal unit vector. (Normal unit vector to AB plane)

$$\overline{A}\times\overline{B} = \hat{a}_x\left(A_yB_z - A_z\bullet B_y\right) - \hat{a}_y\left(A_xB_z - A_zB_x\right) + \hat{a}_z\left(A_xB_y - B_xA_y\right)$$

It is represented in the determinant form as given below:



i.e.
$$\bar{A} \times \bar{B} = \begin{vmatrix} \hat{a}_x & \hat{a}_y & \hat{a}_z \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$$

Cross product is a Vector quantity.

(iii) Triple Product :

$$\vec{A} \times (\vec{B} \times \vec{C}) = \vec{B}(\vec{C}.\vec{A}) - \vec{C}(\vec{A}.\vec{B})$$

1.12 VECTOR OPERATORS :

1.12 Operators :

(1) Gradient Operator is ∇V of scaler v

(2) Divergence operator is $\nabla.\vec{V}$ of vector $\vec{V}$

(3) Curl $\nabla \times A$ of vector $\vec{A}$

(4) Laplacian $\nabla^2 V$ of scalar V

(1) Gradient, Divergence and Curl

Gradient ($\bar{\nabla}$ operator) : operator is given by ∇V

Here del operator
$$\bar{\nabla} = \frac{\partial}{\partial x}\hat{a}_x + \frac{\partial}{\partial y}\hat{a}_y + \frac{\partial}{\partial z}\hat{a}_z$$

Gradient is applicable for Scalar fields only.

It given the Rate of change of Scalar field along the different co-ordinate axes.

Example: Gradient of potential field V is given by-

$$\bar{\nabla} V = \frac{\partial V}{\partial x}\hat{a}_x + \frac{\partial V}{\partial y}\hat{a}_y + \frac{\partial V}{\partial z}\hat{a}_z$$

where, V is a Scalar field.

Note : *Gradient of a potential field gives the electric field.*

i.e. $\bar{E} = -\bar{\nabla} \cdot V$, where, E is the electric field intensity.

Note : *Gradient of a scalar field is a Vector quantity.*

(2) Divergence :

It is applicable for a Vector field. Divergence of a Vector field gives the flux coming out of a closed surface, when volume of the surface shrinks to zero.

Let, $\overline{D} = D_x\hat{a}_x + D_y\hat{a}_y + D_z\hat{a}_z$ = Electric flux density

$$\overline{\nabla}\cdot\overline{D} = \left(\frac{\partial}{\partial x}\hat{a}_x + \frac{\partial}{\partial y}\hat{a}_y + \frac{\partial}{\partial z}\hat{a}_z\right)\cdot\left(D_x\hat{a}_x + D_y\hat{a}_y + D_z\hat{a}_z\right)$$

$$\therefore \quad \overline{\nabla}\cdot\overline{D} = \frac{\partial}{\partial x}D_x + \frac{\partial}{\partial y}D_y + \frac{\partial}{\partial z}D_z$$

The above equation represent the divergence of a Vector quantity $(\overline{D})$.

Note : *Divergence of a Vector field is a Scalar field.*

Example : $\overline{\nabla}\cdot\overline{D} = \rho_v$ = Charge density

(3) Curl of a Vector field : The curl of a Vector field.

$\overline{A} = A_x\hat{a}_x + A_y\hat{a}_y + A_z\hat{a}_z$ is given by-

$$\overline{\nabla}\times\overline{A} = \left(\frac{\partial}{\partial y}A_z - \frac{\partial}{\partial z}A_y\right)\hat{a}_x - \left(\frac{\partial}{\partial x}A_z - \frac{\partial}{\partial z}A_x\right)\hat{a}_y + \left(\frac{\partial}{\partial x}A_y - \frac{\partial}{\partial y}A_x\right)\hat{a}_z$$

For example, The curl of Magnetic field intensity $(\overline{H})$ represened as

$$\overline{H} = H_x\hat{a}_x + H_y\hat{a}_y + H_z\hat{a}_z$$

can be given by determinant form as shown below-

$$\overline{\nabla}\times\overline{H} = \begin{vmatrix} \hat{a}_x & \hat{a}_y & \hat{a}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ H_x & H_y & H_z \end{vmatrix} = \left(\frac{\partial}{\partial y}H_z - \frac{\partial}{\partial z}H_y\right)\hat{a}_x - \left(\frac{\partial}{\partial x}H_z - \frac{\partial}{\partial z}H_x\right)\hat{a}_y + \left(\frac{\partial}{\partial x}H_y - \frac{\partial}{\partial y}H_x\right)\hat{a}_z$$

Note : *Curl of a Vector field is a Vector quantity.*

Example : $\overline{\nabla}\times\overline{H} = J$ = Current density.

(4) Laplacian (∇^2) :

Laplacian of scalar V is divergence of gradient laplacian

$$\nabla^2 V = \nabla.\nabla V = \text{Divergence (Gradient V)}$$

For cartesion Cordinate :

Laplacian $\boxed{\nabla^2 V = \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2}}$

Note : *A vector* $\vec{A}$ *is said to be solenoidal of its divergence is zero*

$$\nabla.\vec{A} = 0$$

Example : Magnetic field is solenoidal

$$\nabla.\vec{B} = 0$$

- *A vector* $\vec{A}$ *is said to be urrotational if its curl is zero.*

$$\nabla \times \vec{A} = 0$$

Example : In static environment Electric field is urrotational or conservative

$$\nabla \times E = 0$$

- *A scalar field is said to be harmonic in given region if its laplacion is zero.*

$$\nabla^2 V = 0$$

- *Divergence of curl is always zero* $\nabla.(\nabla \times A) = 0$
- *Curl of gradient is always zero* $\nabla \times (\nabla.A) = 0$

1.13 Divergence Theorem

According the divergence theorem, "The surface integral of a vector field over a closed surface S is equal to the Volume integral of divergence of the Vector field".

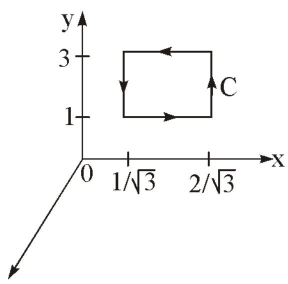
$$\oint_s \overline{D}\cdot\overline{ds} = \int_v \overline{\nabla}\cdot\overline{D}\,dv$$

1.14 Stokes Theorem

According to this theorem, "The Line integral of a Vector field over a closed path is equal to the Surface integral of curl of the Vector field".

$$\oint_\ell \overline{H}\cdot\overline{d\ell} = \int_s (\overline{\nabla}\times\overline{H})\cdot\overline{ds}$$

Example : Given vector field $\vec{A} = xy\hat{a}_x + x^2.\hat{a}_y$. Find $\oint_c A dl$ circulation by stoke's theorem over path given below.



Solution : Stoke's theorem

$$\oint_c A dl = \iint (\nabla \times A) ds$$

Curl $\nabla \times A = \begin{vmatrix} a_x & a_y & a_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ A_x & A_y & A_z \end{vmatrix} = \begin{vmatrix} a_x & a_y & a_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ xy & x^2 & 0 \end{vmatrix}$

$$= \left[\frac{\partial}{\partial y}(0) - \frac{\partial}{\partial z}(x^2)\right]a_x + \left[\frac{\partial}{\partial z}(xy) - 0\right]a_y + \left[\frac{\partial}{\partial x}(x^2) - \frac{\partial}{\partial y}(xy)\right]a_z$$

$$\nabla \times A = x.\hat{a}_z$$

area element $ds = dx \,.\, dy \,.\, \hat{a}_z$

using stokes' theorem

$$\oint A.dl = \iint (\nabla \times A).ds$$

$$\boxed{= \int_1^3 \int_{1/\sqrt{3}}^{2/\sqrt{3}} x.dx\,dy = 1}$$

Example : Given the vector field $A = y^2 a_x + (2xy + x^2 + z^2)\, a_y + (4x + 2yz)\, a_z$.

Find duvergence of vector field.

Solution : Divergence is given by $\nabla.\vec{A}$

$$= \frac{\partial}{\partial x}.A_x + \frac{\partial}{\partial y} + \frac{\partial}{\partial z}A_z$$

$$= \frac{\partial}{\partial x}[y^2] + \frac{\partial}{\partial y}[2xy + x^2 + z^2] + \frac{\partial}{\partial z}[4x + 2yz]$$

$$= 0 + 2x + 2y$$

$$= 2(x + y)$$

Example : A scalar field $g = (1 + 2k)x^2y + xyz$ will be harmonic at all point for which value of k.

Solution : Condition for harmonic field $\nabla^2 g = 0$

$$\nabla^2 g = \frac{\partial^2 g}{\partial x^2} + \frac{\partial^2 g}{\partial y^2} + \frac{\partial^2 g}{\partial z^2} = 0$$

$$= \frac{\partial}{\partial x}[2x(1+2k)y + yz] + \frac{\partial}{\partial y}[(1+2k)x^2 + xz] + \frac{\partial}{\partial z}[xy]$$

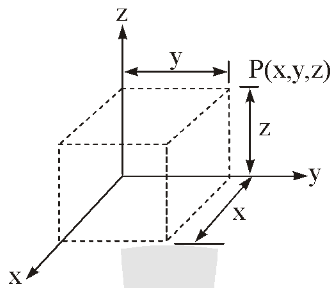
$$= 2(1+2k) + 0 + 0 = 0$$

Therefore $\boxed{k = -\frac{1}{2}}$

1.2 *CO-ORDINATE SYSTEMS :*

1.21 CARTESIAN CO-ORDINATE SYSTEM

The co-ordinates of a point P in the cartesian co-ordinate system is x, y & z along th x, y & z axes. It can be represented as P (x, y, z) as shown below-



- Differential length in cartesian coordinate is

$$\overline{dl} = dx\hat{a}_x + dy\hat{a}_y + dz\hat{a}_z$$

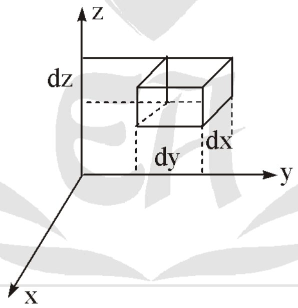
- Differential area in cartesian co-ordinates

$$\overline{ds_1} = dy\,dz \cdot \hat{a}_x$$

$$\overline{ds_2} = dx\,dz \cdot \hat{a}_y$$

$$\overline{ds_3} = dx\,dy \cdot \hat{a}_z$$

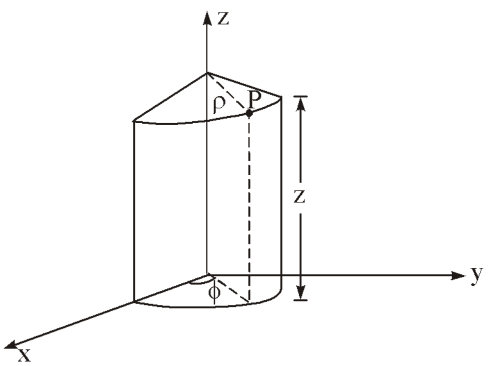
- Differential volume in cartesian co-ordinates is



$$dv = dx\ dy\ dz$$

1.22 CYLINDRICAL CO-ORDINATE SYSTEM

The cylindrical co-ordinates of a point is represented in terms of ρ, ϕ & z along the cylinder as given below



Here, ρ = Radius of cylinder.

ϕ = Angle between x-axis and perpendicular on x-axis of the point.

- *Differential volume in cylindrical co-ordinates is given by*

$$dv = \rho d\rho . d\phi . dz$$

- *Differential Length in cylindrical co-ordinates is given by*

$$d\ell = d\rho \hat{a}_\rho + \rho d\phi \hat{a}_\phi + dz \hat{a}_z$$

- *Differential Area in cylindrical co-ordinates is given by*

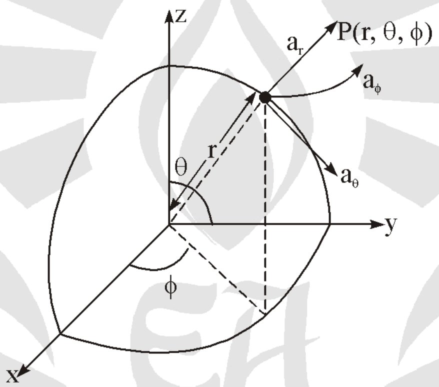
$$\overline{ds_\rho} = \rho d\phi dz \cdot \hat{a}_\rho$$

$$\overline{ds_\phi} = d\rho \cdot dz \cdot \hat{a}_\phi$$

$$\overline{ds_z} = (d\rho)(\rho d\phi) \cdot \hat{a}_z$$

1.23 SPHERICAL CO-ORDINATE SYSTEM

The spherical co-ordinates of a point is represented interms of r, θ & ϕ along the spherical surface as shown below :



Differential length

$$dl = dr\ \hat{a}_r + rd\theta\ \hat{a}_\theta + r\sin\theta . d\phi\ \hat{a}_\phi$$

Differential area

$$ds = \begin{cases} r^2 \sin\theta\ d\theta\ d\phi\ \hat{a}_r \\ r\sin\theta\ dr d\phi\ \hat{a}_\theta \\ r\ dr\ d\theta\ \hat{a}_\phi \end{cases}$$

Defferential volume $dv = (dr)\ (rd\theta)\ (r\ \sin\ \theta\ d\phi)$

1.24 GENERAL CO-ORDINATE SYSTEM : (U, V, W)

	U	V	W	h_1	h_2	h_3
Rectangular	x	y	z	1	1	1
Cylindrical	ρ	ϕ	z	1	ρ	1
Spherical	r	θ	ϕ	1	r	$r\sin\theta$

Mathematical Expressions of Operators :

(i) Gradiant $\nabla V = \frac{1}{h_1}\frac{\partial v}{\partial u}\hat{a}_u + \frac{1}{h_2}\frac{\partial v}{\partial v} + \frac{1}{h_3}\frac{\partial v}{\partial w}$

(ii) Divergence of Vector $\vec{A} = A_u\hat{a}_u + A_v\hat{a}_v + A_w\hat{a}_w$

$$\nabla.\vec{A} = \frac{1}{h_1h_2h_3}\left[\frac{\partial}{\partial u}[h_2h_3A_u] + \frac{\partial}{\partial v}(h_3h_1A_v) + \frac{\partial}{\partial w}(h_1h_2A_w)\right]$$

(iii) Laplacian $\nabla^2 V = \frac{1}{h_1h_2h_3}\left[\frac{\partial}{\partial u}\left(\frac{h_2h_3}{h_1}\frac{\partial v}{\partial u}\right) + \frac{\partial}{\partial v}\left(\frac{h_3h_1}{h_2}\frac{\partial v}{\partial u}\right) + \frac{\partial}{\partial w}\left(\frac{h_1h_2}{h_3}\frac{\partial v}{\partial w}\right)\right]$

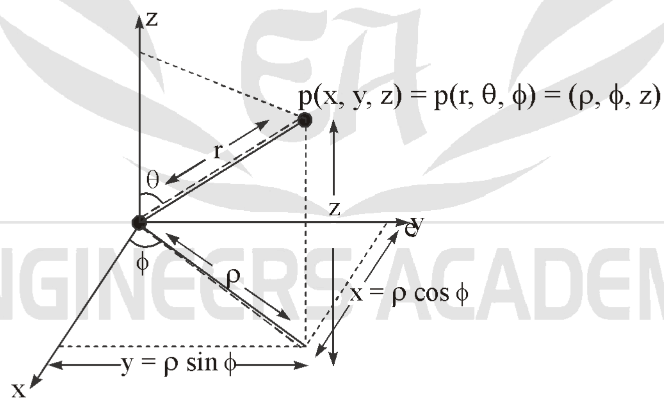
(iv) Curl $\nabla \times \vec{A} = \frac{1}{h_1h_2h_3}\begin{vmatrix} h_1\hat{a}_u & h_2\hat{a}_v & h_3\hat{a}_w \\ \frac{\partial}{\partial u} & \frac{\partial}{\partial v} & \frac{\partial}{\partial w} \\ h_1A_u & h_2A_v & h_3A_w \end{vmatrix}$

(v) Area $ds = \begin{cases} h_2h_3 & \partial v\partial w & \hat{a}_u \\ h_1h_3 & \partial u\partial w & \hat{a}_v \\ h_1h_2 & \partial v\partial w & \hat{a}_w \end{cases}$

(vi) Volume $dv = h_1 h_2 h_3 \partial u\ \partial v\ \partial w$

(vii) Length $dl = h_1du\ \hat{a}_u + h_2dv\ \hat{a}_v + h_3dw\ \hat{a}_w$

1.25 CO-ORDINATE TRANSFEORMATION :



Relation between Cylindrical and cartesian co-ordenates

Cylindrical	*Cartesian*
$\rho = \sqrt{x^2 + y^2}$	$x = \rho \cos \phi$
$\phi = \tan^{-1}\left[\frac{y}{x}\right]$	$y = \rho \sin \phi$
$z = z$	

Relation between spherical and other co-ordinates

Spherical	***Other Co-ordinates***
$r = \sqrt{x^2 + y^2 + z^2}$	$\rho = r \sin\theta$
$\theta = \tan^{-1}\left(\frac{\rho}{z}\right) = \tan^{-1}\left(\frac{\sqrt{x^2+y^2}}{z}\right]$	$x = r \sin\theta . \cos\phi$
$\phi = \tan^{-1}\left(\frac{y}{x}\right)$	$y = r \sin\theta \sin\phi$

Example : Determine divergence of vector fields

(a) $\vec{A} = \rho \sin\phi\ \hat{a}_e + e^2 z\ \hat{a}_\phi + z\cos\phi\ \hat{a}_z$

(b) $\vec{B} = \frac{1}{r^2}\cos\theta\ \hat{a}_r + r\sin\theta\cos\phi\ \hat{a}_\theta + \cos\theta\,\hat{a}_\phi$

Solution : (a) $\nabla.\vec{A} = \frac{1}{\rho}\frac{\partial}{\partial\rho}(\rho A_\rho) + \frac{1}{\rho}\frac{\partial}{r_\phi}(A_\phi) + \frac{\partial}{\partial z}A_z$

$$= \frac{1}{\rho}\frac{1}{\partial\rho}(\rho^2\sin\phi) + \frac{1}{\rho}\frac{\partial}{\partial\phi}(\rho^2 z) + \frac{\partial}{\partial z}[z\cos\phi]$$

$$= 2\sin\phi + \cos\phi$$

(b) $\nabla.\vec{B} = \frac{1}{r^2}\frac{\partial}{\partial r}(r^2 B_r) + \frac{1}{r\sin\theta}\frac{\partial}{\partial\theta}(B_\theta\sin\theta) + \frac{1}{r\sin\theta}\frac{\partial}{\partial\phi}(B_\phi)$

$$= \frac{1}{r^2}\frac{\partial}{\partial^r}(\cos\theta) + \frac{1}{r\sin\theta}\frac{\partial}{\partial\theta}(r\sin^2\theta\cos\phi) + \frac{1}{r\sin\theta}\frac{\partial}{\partial\phi}(\cos\theta)$$

$$= 0 + 2\cos\theta\cos\phi + 0$$

$$= 2\cos\theta\cos\phi$$

Example : For above vector field $\vec{A}$ find curl $\nabla \times \vec{A}$

Solution : $\nabla \times A = \frac{1}{\rho}\begin{vmatrix} a_\rho & \rho a_\phi & a_z \\ \frac{\partial}{\partial\rho} & \frac{\partial}{\partial\phi} & \frac{\partial}{\partial z} \\ A_\rho & \rho A_\phi & A_z \end{vmatrix}$

$$= \frac{1}{\rho}\begin{vmatrix} a_\rho & \rho a_\phi & a_z \\ \frac{\partial}{\partial\rho} & \frac{\partial}{\partial\phi} & \frac{\partial}{\partial z} \\ \rho\sin\phi & \rho^2 z & z\cos\phi \end{vmatrix}$$

$$= \left[\frac{z}{\rho}\sin\phi - \rho^2\right]\hat{a}_\rho + 0 + \frac{1}{\rho}[3\rho^2 z - \rho\cos\phi]\hat{a}_z$$

$$= -\frac{1}{\rho}(z\sin\phi + \rho^3).\hat{a}_\rho + (3\rho z - \cos\phi)a_z$$

1.3 *ELECTROSTATICS:*

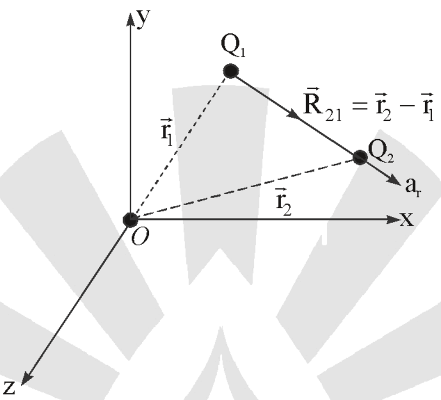
Stationary charge produces electric field $\vec{E}$.

A charge may be point charge, line charge, surface charge or volume charge distributed.

There are two laws in electrostatics **coulomb's law and gauss law.**

1.31 COULOMB'S LAW :

Statement : The force between two point charge Q_1 and Q_2 is inversely propotional to square of distance between two charges and directed along the vector connecting two charges.



force $$F = \frac{kQ_1Q_2}{|\vec{R}_{21}|}.\hat{a}_r$$

$$F_{21} = \frac{Q_1Q_2.(\vec{r}_2 - \vec{r}_1)}{4\pi \in_0 |\vec{r}_2 - \vec{r}_1|^3}$$

Electric field $\vec{E}$ untensity is defined as force per unit charge

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

- Electric field due to point change

$$\vec{E} = \frac{Q}{4\pi \in_0 r^2}.\hat{a}_r$$

- Electric field due to line charge

$$\vec{E} = \frac{\int e_L dl}{4\pi \in_0 r^2}.\hat{a}_r$$

- Electric field due to surface charge

$$\vec{E} = \frac{\iint e_s ds}{4\pi \in_0 r^2}.\hat{a}_r$$

- Electric field due to volume charge

$$\vec{E} = \frac{\iiint e_v dv}{4\pi \in_0 r^2}.\hat{a}_r$$

Electrostatic potential is defined as work done per unit charge and it is scalar potential due to point charge.

$$\boxed{V = \frac{Q}{4\pi \in_0 r}}$$

Gradient of potential is electric field.

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

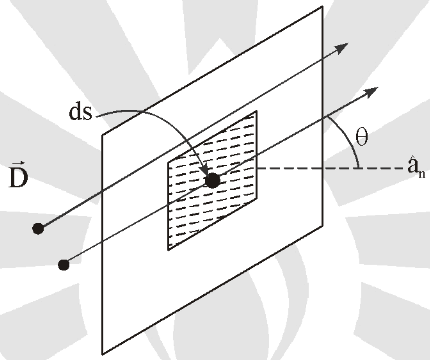
For close loop 'C' work done is zero

$$V = -\oint_C E.dl = 0$$

by stokes theorem for static field.

$$\boxed{\nabla \times \vec{E} = 0}$$

Electric flux passing through any surface areas



Electric flux

$$\boxed{\Psi = \iint D.ds}$$

where, D = Electric field density c/m^2.

1.32 GAUSS'S LAW :

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

i.e., $$\boxed{\Psi = \oint_S D.ds = Q_{enclosed}}$$

Integral form $$\oint_S D.ds = \int_v e_v dv \qquad (e \neq \rho_v)$$

e_v = Volume charge density

Differential form $\boxed{\nabla.D = e_v}$

Example : Charge density inside a hollow spherical shell of radius r = 4 cm. centered at origion definad as

$$e_v = \begin{cases} 0 & \text{for} \quad r \le 2 \\ \frac{4}{r^2} c/m^3 & \text{for} \quad 2 < r \le 4 \end{cases}$$

Find Electric field intensity at r = 3

Solution: From Gauss law

$$\oint E.ds = \frac{Q_{enc}}{\epsilon_0} = \frac{1}{\epsilon_0}\int e_v dv$$

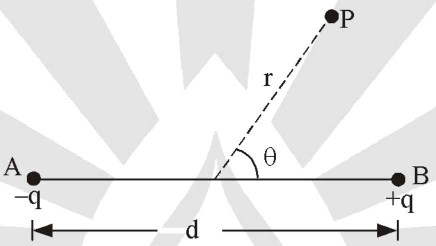
$$= \frac{1}{\epsilon_0}\int (0)dv + \frac{1}{\epsilon_0}\int \frac{4}{r^2}dv \qquad [0 < r \le 3]$$

$$E(4\pi R^2) = \frac{1}{\epsilon_0}\int_{r=2}^{3}\int_0^{\pi}\int_0^{2\pi}\frac{4}{r^2}\,[r^2 \sin\theta\ dr\ d\theta\ .d\phi]$$

$$E\ (4\pi \times 3^2) = \frac{4\pi \times 4}{\epsilon_0}(3-2)$$

$$\boxed{E = \frac{4}{9\epsilon_0}a_r}$$

1.33 Electric Dipole :



- Electric dipole consist of two point charge, separated by small destance d having opposite polarity.
- Dipole moment $p = qd$
- Electric potential the to depole is given by

$$\boxed{V = \frac{P\cos\theta}{4\pi\epsilon_c .r^2}}$$

Note : *Potential is maximum along depole and it is inversaly propotional to square of distance.*

- Electric field due to depole is given by

$$\boxed{\vec{E} = \frac{P}{4\pi\epsilon_0 r^3}[2\cos\theta\ a_r + \sin\theta\ a_\theta]}$$

Note: *For monopele* $\vec{E}\alpha\frac{1}{r^2}$

For Dipole $\vec{E}\alpha\frac{1}{r^3}$

1.34 ELECTROSTATIC ENERGY :

- Energy stored in the system with electric field E and electric flox density $\vec{D}$ is given by

$$W_e = \frac{1}{2}\int_v \vec{D}.\ \vec{E}.dv$$

$$= \frac{1}{2}\int_v \epsilon_0 E^2 dv$$

PRACTICE SHEET

OBJECTIVE QUESTIONS

1. The open circuit impedance of a certain length of loss-less line is 100Ω. The short circuit impedance of the same line is also 100Ω. The characteristic impedance of the line is
(a) $100\sqrt{2}\,\Omega$ (b) 50Ω
(c) $100/\sqrt{2}\,\Omega$ (d) 100Ω

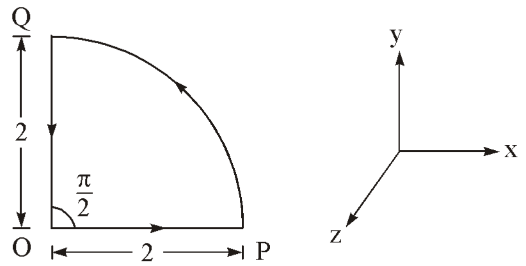
2. ***Assertion (A):*** The relationship between Magnetic Vector potential $\bar{A}$ and the current density J in free space is
$\nabla\times\left(\nabla\times\bar{A}\right)=\mu_0\bar{J}$
For magnetic field in free space due to a dc or slowly varying current is $\nabla^2 A=-\mu_0\bar{J}$.
Reason (R): For magnetic field due to dc or slowly varying current $\nabla\cdot\bar{A}=0$.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

3. Given that $\nabla\times\bar{H}=\bar{J}+\frac{\partial\bar{D}}{\partial t}$
Assertion (A): In the equation, the additional term $\frac{\partial\bar{D}}{\partial t}$ is necessary.
Reason (R): The equation will be consistent with the principle of conservation of charge.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4. ***Assertion (A):*** When there is no charge in the interior of a conductor the electric field intensity is infinite.
Reason (R): As per Gauss's law the total outward electric flux through any closed surface constituted inside the conductor must vanish.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

5. ***Assertion (A):*** The solution to the wave equation at the critical diffracting condition in a crystal yields standing waves.
Reason (R) : Standing waves have periodic variation both in amplitude as well as in the electron probability density in the crystal.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

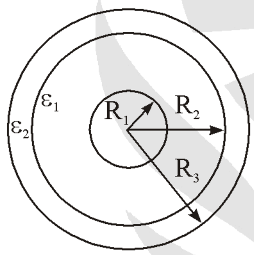
6. If $A = \hat{a}_r + \hat{a}_\phi + \hat{a}_z$, the value of $\oint \bar{A}.\overline{dl}$ around the closed circular quadrant shown in the given figure is



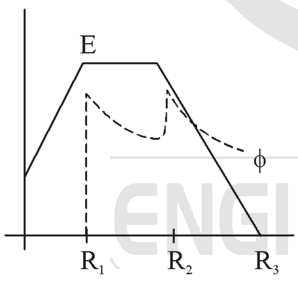
(a) π (b) $\frac{\pi}{2}+4$

(c) $\pi + 4$ (d) $\frac{\pi}{2}+2$

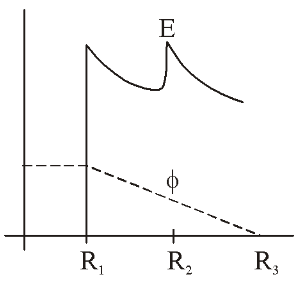
7. A coaxial cable has two concentric dielectrics separated by a sheath as shown in the given figure. The distribution of electric field 'E' and potential 'ϕ' in the coaxial cable exist as



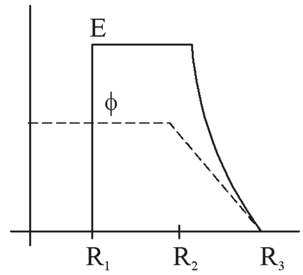
(a)



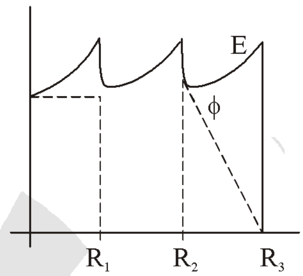
(b)



(c)



(d)



8. A point charge +Q is brought near a corner of two right angle conducting planes which are at zero potential as shown in the given figure 1. Which one of the following configurations describes the total effect of the charges of calculating the actual field in the first quadrant?

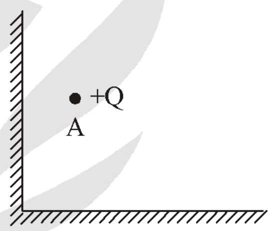
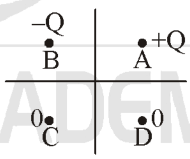
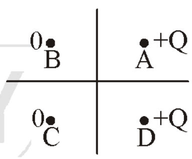


Figure 1

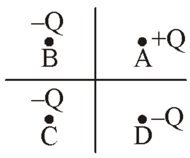
(a)



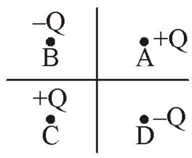
(b)



(c)



(d)



9. Plane defined by $z = 0$ carry surface current density $2\hat{a}_x$ A/m. The magnetic intensity 'H_y' in the two regions $-\alpha < z < 0$ and $0 < z < \alpha$ are respectively.

(a) $\hat{a}_y$ and $-\hat{a}_y$ (b) $-\hat{a}_y$ and $\hat{a}_y$

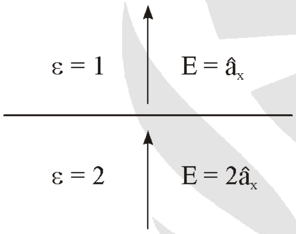
(c) $\hat{a}_x$ and $-\hat{a}_x$ (d) $-\hat{a}_x$ and $\hat{a}_x$

10. A solid cylindrical conductor of radius 'R' carrying a current 'I' has a uniform current density. The magnetic field intensity 'H' inside the conductor at the radial distance 'r' (r < R) is

(a) Zero (b) $I/2\pi r$

(c) $Ir/2\pi R^2$ (d) $IR^2/2\pi R^3$

11. The electric field across a dielectric-air interface is shown in the given figure. The surface charge density on the interface is



(a) $-4\epsilon_0$ (b) $-3\epsilon_0$

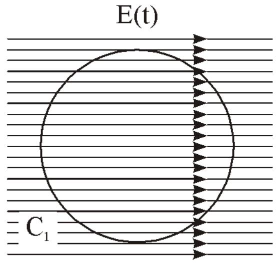
(c) $-2\epsilon_0$ (d) $-\epsilon_0$

12. When air pocket is trapped inside a dielectric of relative permittivity '5', for a given applied voltage across the dielectric, the ratio of stress in the air pocket to that in the dielectric is equal to

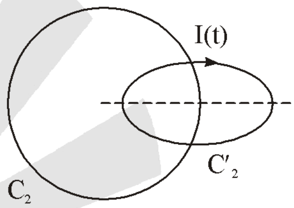
(a) 1/5 (b) 5

(c) 1 + 5 (d) 5 – 1

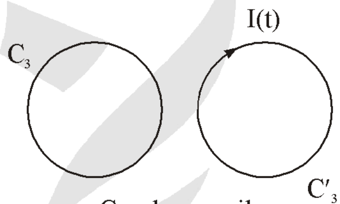
13. Consider coils C_1, C_2, C_3 and C_4 (Shown in the given figures) which are placed in the time-varying electric field $\bar{E}(t)$ and electric field produced by the coils C'_2, C'_3 and C'_4 carrying time varying current I(t) respectively :

1.


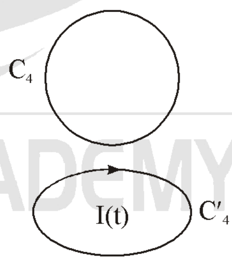
Time varying electric field $\bar{E}(t)$ parallel to the plane of coil C_1

2.


Coil planes are orthogonal

3.


Co-planer coils

4.


Co-planes are orthogonal

The electric field will induce an emf in the coils

(a) C_1 and C_2 (b) C_2 and C_3

(c) C_1 and C_3 (d) C_2 and C_4

14. A circular loop is rotating about the y-axis as a diameter in a magnetic field $\bar{B} = B_0 \sin\omega t\ \hat{a}_x \text{Wb/m}^2$. The induced emf in the loop is

(a) due to transformer emf only
(b) due to motional emf only
(c) due to a combination of transformer and motional emf
(d) zero

15. Match List-I (Law/quantity) with List-II (Mathematical expression) and select the correct answer:

	List-I		**List-II**
A.	Gauss's law	**1.**	$\nabla \bar{D} = \rho$
B.	Ampere's law	**2.**	$\nabla \times \bar{E} = -\frac{\partial \bar{B}}{\partial t}$
C.	Faraday's law	**3.**	$S = \bar{E} \times \bar{H}$
D.	Poynting vector	**4.**	$\bar{F} = q(\bar{E} + \bar{v} \times \bar{B})$
		5.	$\nabla \times \bar{H} = \bar{J}_c + \frac{\partial \bar{D}}{\partial t}$

Codes :

	A	B	C	D
(a)	1	2	4	3
(b)	3	5	2	1
(c)	1	5	2	3
(d)	3	2	4	1

16. In the relation $S = \frac{1+|\Gamma|}{1-|\Gamma|}$; the values of S and Γ (where S stands for wave ratio and Γ is reflection coefficient), respectively, vary as

(a) 0 to 1 and −1 to 0
(b) 1 to ∞ and −1 to + 1
(c) −1 to + 1 and 1 to ∞
(d) −1 to 0 and 0 to 1

17. In the source free wave equation

$$\nabla^2 \bar{E} - \mu_0\ \varepsilon_0 \mu \in \frac{\partial^2 \bar{E}}{\partial t^2} - \mu_0 \mu \sigma \frac{\partial \bar{E}}{\partial t} = 0$$

The term responsible for the attenuation of the wave is

(a) $\mu_0 \mu \sigma \frac{\partial \bar{E}}{\partial t}$

(b) $\mu_0 \in_0 \mu \in \frac{\partial^2 \bar{E}}{\partial t^2}$

(c) $\nabla^2 \bar{E}$

(d) $\mu_0 \mu \sigma \frac{\partial \bar{E}}{\partial t}$ and $\mu_0 \in_0 \mu_0 \in \frac{\partial^2 \bar{E}}{\partial t^2}$

18. Three media are characterized by

1. $\in_r = 8$, $\mu_r = 2$, $\sigma = 0$
2. $\in_r = 1$, $\mu_r = 9$, $\sigma = 0$
3. $\in_r = 4$, $\mu_r = 4$, $\sigma = 0$

$\in_r$ is relative permittivity, μ_r is relative permeability and σ is conductivity.

The value of the intrinsic impedances of the media 1, 2 and 3 respectively are

(a) 188 Ω, 377 Ω and 1131 Ω
(b) 377 Ω, 1131 Ω and 188 Ω
(c) 188 Ω, 1131 Ω and 377 Ω
(d) 1131 Ω, 188 Ω and 377 Ω

19. A plane EM wave $(\bar{E}_i, \bar{H}_i)$ travelling in a perfect dielectric medium of surge impedance 'Z'; strike normally on an infinite perfect dielectric medium of surge impedance 2Z. If the refracted EM wave is $(\bar{E}_i, \bar{H}_i)$, the ratios of E_i/E_r and H_i/H_r are respectively.

(a) 3 and −3 (b) 3/2 and 1/3
(c) 3/4 and 3/2 (d) 3/4 and 2/3