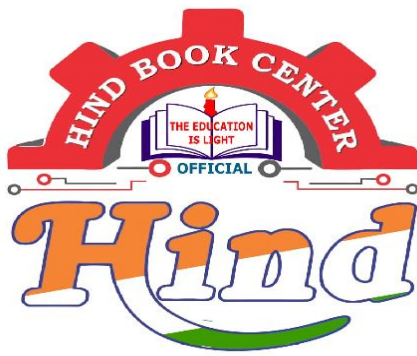




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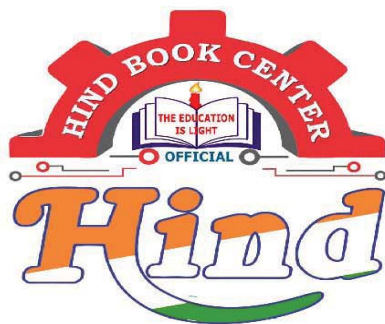
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V. KUMAR SIR

ELECTRO MAGNETIC THEORY

- ① Basics → 1-20
- ② Static electric field → 20-53
- ③ Static magnetic field → 54-76
- ④ Time Varying fields and
maxwell equations } → 77-85
- ⑤ 2020 EMT work book solution → 1-60

①

- Books: Principles of Electromagnetics by Matthew N. O. Sadiku

i) x, y, z are 3 distance variables, which represents 3-Dimensions (3-D)

- $$\left. \begin{array}{l} x = 1 \\ y = 4 \\ z = 7 \end{array} \right\} \begin{array}{l} 3 \text{ constants} \\ \text{or} \\ \text{No variables} \end{array}$$

iii) Line: Ex: $y=0 \quad y=1$ } 2 constants (x, z)
or
1 variable (y) }

For above example $\vec{\lambda} = 1\hat{a}_y$

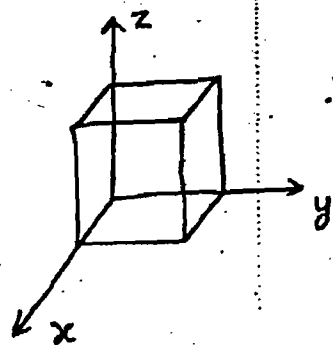
- iv) Surface: Ex:  $x=0$
 $x=\text{constant}$ } 1 constant (x)
or
2 variables (y, z)

→ Surface vector is defined as

where, $\hat{a}_N \rightarrow$ Normal unit vector to the surface in outward direction

For above example $d\vec{S} = dydz \hat{a}_x$
↓
 differential surface vector

V) Volume: Ex:



No constants

or

3 variables (x, y, z)

②

by definition volume is a scalar.

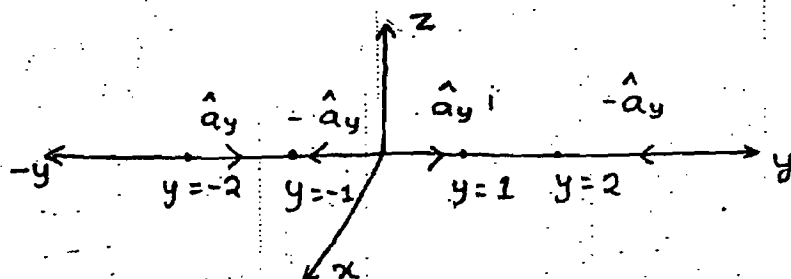
vi) Unit vector:

$$\hat{a}_y \rightarrow |\hat{a}_y| = 1$$

$\hat{a}_y$ is in the direction of increasing y value

$$-\hat{a}_y \rightarrow |-\hat{a}_y| = 1$$

$-\hat{a}_y$ is in the direction of decreasing y value



$\hat{a}_x, \hat{u}_x, \hat{x}, \hat{i} \rightarrow$ unit vector in x direction

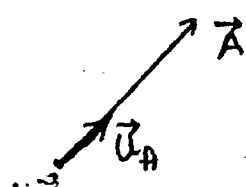
$\hat{a}_y, \hat{u}_y, \hat{y}, \hat{j} \rightarrow$ unit vector in y direction

$\hat{a}_z, \hat{u}_z, \hat{z}, \hat{k} \rightarrow$ unit vector in z direction

NOTE If $\vec{A} = A_x \hat{a}_x + A_y \hat{a}_y + A_z \hat{a}_z$ is any vector then unit vector in $\vec{A}$ direction is

$$\vec{U}_A = \frac{\vec{A}}{|\vec{A}|} = \frac{A_x \hat{a}_x + A_y \hat{a}_y + A_z \hat{a}_z}{\sqrt{A_x^2 + A_y^2 + A_z^2}}$$

$\vec{U}_A$ is unit vector in $\vec{A}$ direction (or) direction of $\vec{A}$

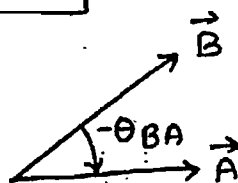
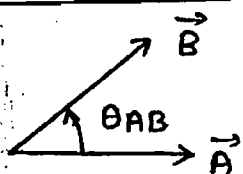


Dot product (or) Scalar product:- of A, B

(3)

vectors is defined as

$$\vec{A} \cdot \vec{B} = |\vec{A}| |\vec{B}| \cos(\theta_{AB})$$



$$\theta_{AB} = -\theta_{BA} \text{ or } \theta_{BA} = -\theta_{AB}$$

$$\vec{B} \cdot \vec{A} = |\vec{B}| |\vec{A}| \cos(\theta_{BA})$$

$$= |\vec{A}| |\vec{B}| \cos(-\theta_{AB}) = |\vec{A}| |\vec{B}| \cos(\theta_{AB}) = \vec{A} \cdot \vec{B}$$

$$\vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A} \rightarrow \text{commutative Law}$$

$$\theta_{AB} = \cos^{-1} \left(\frac{\vec{A} \cdot \vec{B}}{|\vec{A}| |\vec{B}|} \right)$$

$$\text{Ex: } \hat{a}_x \cdot \hat{a}_x = |\hat{a}_x| |\hat{a}_x| \cos 0 = 1 \cdot 1 \cdot 1 = 1$$

$$\hat{a}_x \cdot \hat{a}_x = \hat{a}_y \cdot \hat{a}_y = \hat{a}_z \cdot \hat{a}_z = 1$$

$$\hat{a}_\rho \cdot \hat{a}_\rho = \hat{a}_\phi \cdot \hat{a}_\phi = \hat{a}_z \cdot \hat{a}_z = 1$$

$$\hat{a}_r \cdot \hat{a}_r = \hat{a}_\theta \cdot \hat{a}_\theta = \hat{a}_\phi \cdot \hat{a}_\phi = 1$$

$$\text{Ex: } \hat{a}_x \cdot \hat{a}_y = |\hat{a}_x| |\hat{a}_y| \cos(90^\circ) = 0$$

$$\hat{a}_x \perp \hat{a}_y \perp \hat{a}_z$$

$$\hat{a}_\rho \perp \hat{a}_\phi \perp \hat{a}_z$$

$$\hat{a}_r \perp \hat{a}_\theta \perp \hat{a}_\phi$$

$$\hat{a}_x \perp \hat{a}_y \perp \hat{a}_z \Rightarrow \hat{a}_x \cdot \hat{a}_y = \hat{a}_y \cdot \hat{a}_z = \hat{a}_x \cdot \hat{a}_z = 0$$

orthogonal (perpendicular) property

• A phasor

→ may be scalar or vector

[Voltage phasor is a scalar & Electric field Phasor is a vector]

→ is a time or space dependent quantity.

→ is complex with Amplitude and phase variation.

Cross product (or) Vector product : of $\vec{A}, \vec{B}$

vectors is defined as

$$\vec{A} \times \vec{B} = |\vec{A}| |\vec{B}| \sin(\theta_{AB}) \hat{a}_N$$

$\hat{a}_N$ is normal unit vector to the surface in outward direction

$$\begin{aligned} \vec{B} \times \vec{A} &= |\vec{B}| |\vec{A}| \sin(\theta_{BA}) \hat{a}_N = |\vec{B}| |\vec{A}| \sin(-\theta_{AB}) \hat{a}_N \\ &= -|\vec{A}| |\vec{B}| \sin(\theta_{AB}) \hat{a}_N \\ &= -\vec{A} \times \vec{B} \end{aligned}$$

$$\boxed{\vec{A} \times \vec{B} = -\vec{B} \times \vec{A}} \rightarrow \text{Anti commutative law}$$

$$|\vec{A} \times \vec{B}| = |\vec{A}| |\vec{B}| \sin(\theta_{AB}) |\hat{a}_N|$$

$$\theta_{AB} = \sin^{-1} \left(\frac{|\vec{A} \times \vec{B}|}{|\vec{A}| |\vec{B}|} \right)$$

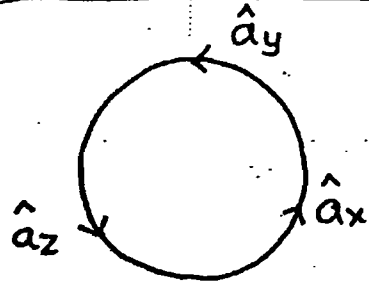
Ex: $\hat{a}_x \times \hat{a}_x = |\hat{a}_x| |\hat{a}_x| \sin(0) \hat{a}_N = 0$

Cross product of same unit vectors is zero

Ex: $\hat{a}_x \times \hat{a}_y = |\hat{a}_x| |\hat{a}_y| \sin 90^\circ \hat{a}_z = \hat{a}_z$

$\hat{a}_y \times \hat{a}_x = |\hat{a}_y| |\hat{a}_x| \sin(-90^\circ) \hat{a}_z = -\hat{a}_z$

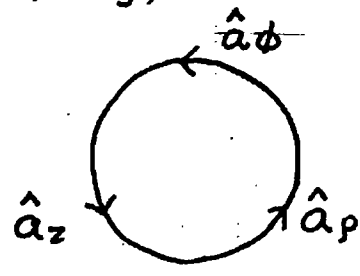
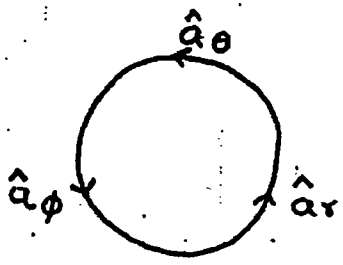
$\hat{a}_x \times \hat{a}_y = \hat{a}_z \rightarrow \text{ortho normal property}$



$\Rightarrow$

$\hat{a}_x \times \hat{a}_y = \hat{a}_z$	$\hat{a}_y \times \hat{a}_x = -\hat{a}_z$
$\hat{a}_y \times \hat{a}_z = \hat{a}_x$	$\hat{a}_z \times \hat{a}_y = -\hat{a}_x$
$\hat{a}_z \times \hat{a}_x = \hat{a}_y$	$\hat{a}_x \times \hat{a}_z = -\hat{a}_y$

Similarly,

Scalar: is a quantity having magnitude and sign ($\pm$)

Ex: $Q \rightarrow$ charge (Coulomb)

$t \rightarrow$ time (second)

$I \rightarrow$ current (Ampere)

$V \rightarrow$ Voltage (Volt)

$\Psi \rightarrow$ Electric flux (Coulomb)

$\phi \rightarrow$ Magnetic flux (Weber)

Vector: is a quantity having magnitude and direction

Ex: $\vec{J} \rightarrow$ current density (A/m^2)

$\vec{B} \rightarrow$ magnetic flux density (Wb/m^2)

$\vec{D} \rightarrow$ Electric flux density ($Coulomb/m^2$)

$\vec{E} \rightarrow$ Electric Field Intensity ($Volt/m$)

$\vec{H} \rightarrow$ Magnetic Field Intensity (Amp/m)

observation

i) given $\vec{J} = 10 \hat{a}_x$ then $\vec{J}$ is uniform and static

ii) given $\vec{J} = 10x \hat{a}_x$ then $\vec{J}$ is non-uniform and static

iii) given $\vec{J} = 10 \cos \omega t \hat{a}_x$ then $\vec{J}$ is uniform and time varying

iv) given $\vec{J} = 10x^2 \cos \omega t \hat{a}_x$ then $\vec{J}$ is non uniform and time varying

NOTE

1) To multiply with meter, take $\int d\vec{l}$

Ex: given $\vec{H}$ (A/m) then current I is

$$I = \int \vec{H} \cdot d\vec{l}$$

(A) (A/m) (m)

↑
Scalar

If $\vec{H}$ is non uniform

$$I = \vec{H} \cdot \int d\vec{l} = \vec{H} \cdot \vec{l}$$

⏟
If $\vec{H}$ is uniform

⑥

2) To multiply with meter² (m²) take $\iint d\vec{S}$

Ex: given $\vec{J}$ then I is

Scalar

$$I = \iint_{(A)} \vec{J} \cdot d\vec{S} \quad \begin{matrix} (A/m^2) (m^2) \end{matrix}$$

If $\vec{J}$ is non uniform

$$I = \vec{J} \cdot \iint d\vec{S} = \vec{J} \cdot \vec{S}$$

If $\vec{J}$ is uniform

3) To multiply with meter³ (m³) take $\iiint dV$

Ex: given volume charge density ρ_v (C/m³) then Q is

$$Q = \iiint_C \rho_v dV \quad \begin{matrix} (C/m^3) (m^3) \end{matrix}$$

If ρ_v is non uniform

$$Q = \rho_v \iiint dV = \rho_v (\text{Volume})$$

If ρ_v is uniform

Pythagoras Theorem:

a, b, r scalars & same units

By definition

$$\sin \theta = \frac{\text{opp}}{\text{hyp}} = \frac{b}{r}$$

$$b = r \sin \theta \rightarrow \textcircled{1}$$

$$\boxed{(\text{opp}) = (\text{hyp}) \sin(\text{angle})}$$

$$\cos \theta = \frac{\text{adj}}{\text{hyp}} = \frac{a}{r} \Rightarrow a = r \cos \theta \rightarrow \textcircled{2}$$

$$\boxed{(\text{adj}) = (\text{hyp}) \cos(\text{angle})}$$

$$\textcircled{1}^2 + \textcircled{2}^2 = a^2 + b^2 = r^2 (\cos^2 \theta + \sin^2 \theta)$$

$$r = \sqrt{a^2 + b^2}$$

$$\boxed{\text{hyp} = \sqrt{(\text{adj})^2 + (\text{opp})^2}}$$

NOTE: Any vector $\vec{A}$ is sum of its tangential vector ($\vec{A}_t$) and its Normal vector ($\vec{A}_N$)

$$\vec{A} = \vec{A}_t + \vec{A}_N$$

