"National University of Sciences & Technology"

"Military College of Signals"

- **Subject:**

  Applied Physics

- **Submitted by:**

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  - Class : 26
  - Section: B

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"Assignment # 4" "Applied Physics"

"Problem # 1"

⇒ **Statement:**

A horizontal wire carries current $I = 30\ A$, in the direction of positive x-axis. Magnetic field density = 1.5T is directed towards y-axis at an angle of 30° with X-axis. Find the magnitude and direction of magnetic force on 0.5 m section of the wire.

⇒ Solution:

-• Data Given:

Current $I = 30A$

Magnetic field $B = 1.5T$

Length $L = 0.5m$

Angle $\theta = 30°$

-• To find:

Magnitude and direction of magnetic force $F_B = ?$

-• Formula:

$$F_B = BIL\sin\theta$$

-• Put the values:

$$F_B = (1.5\ T)(30\ A)(0.5\ m)\sin 30°$$

$$F_B = 11.25\ N \quad \text{(Magnitude)}$$

-• Direction:

It is directed outwards (using Right Hand Rule.)

-• **Unit Justification:**

$(NA^{-1}m^{-1} \times A \times m) = N$ (unit justified)

"Problem # 2"

⇒ **Statement:**

What is a magnetic field line, compare and bring out major differences between magnetic and electric field lines.

⇒ Solution:

Magnetic Field lines:

- Magnetic field lines are the imaginary lines around the magnet. The magnitude of a field is indicated by it's line density. Near to South and North pole of a magnet, the magnetic field is stronger and will get weaker when moves away from the poles.

Features of Magnetic Field Lines:

- Number of Magnetic field lines per unit area held perpendicular to magnetic field gives magnetic field intensity.
- Generally curved lines, tangent to the line at a point gives the direction of Magnetic field.
- Magnetic field lines donot cross each other.
- It's a vector quantity.

Differences from Electric Field Lines:

- Electric force is parallel to the electric field lines, whereas, magnetic force acts perpendicular to the magnetic field lines.

- Magnetic field lines are directed from N to S poles and form closed loops, whereas electric field lines originate from positive
- charge and terminate at negative charge.

- Magnetic force is exerted only on moving charges in magnetic field, whereas electrical field force is experienced on a static as well as moving charge.

"Problem # 3"

⇒ **Statement:**

A strip of copper, thickness 450 μm is placed in a magnetic field having $B = 1.65\ T$ and perpendicular to the plane of strip, carrying current = 15 A, find Hall voltage if there was a single charge carrier per atom ($n = 8.49 \times 10^{28}\ m^{-3}$).

⇒ Solution:

-. **Data Given:**

Magnetic field $B = 1.65\ T$

Thicknes $t = 450 \times 10^{-6}\ m$

Current $I = 15\ A$

Concentration $n = 8.49 \times 10^{28}\ m^{-3}$

$e = 1.6 \times 10^{-19}\ C$

-. **To find:**

Hall Voltage $V_H = ?$

-. **Formula:**

$$V_H = IB / net$$

$$V_H = (15\ A)(1.65\ T) / (8.49 \times 10^{28}\ m^{-3})(1.6 \times 10^{-19}\ C)(450 \times 10^{-6}\ m)$$

$$= 4.04 \times 10^{6}\ V$$

-. **Justification of Units:**

$$(NA^{-1}m^{-1} \times A / m^{-3} \times m \times C) = Nm\,C^{-1} = JC^{-1} = V$$

"Problem # 4"

⇒ **Statement:**

State mass action law relating to electron and hole concentrations in case of intrinsic materials. An N-type bar of Si has dopant concentration = $4 \cdot 5 \times 10^{16}\ cm^{-3}$, find concentration of majority as well as minority carriers.

⇒ Solution:

Law of Mass Action:

Statement:

The law of mass action states that the product of number of electrons in the conduction band and the number of holes in the valence band is constant at a fixed temperature and is independent of amount of donor and acceptor impurity added.

Mathematical form:

$$n \times p = n_i^2 \quad (\text{at thermal equilibrium } p = n = n_i)$$

where,

n_i is the intrinsic carrier concentration.

n is the number of electrons in conduction band.

p is the number of holes in valence band.

Numerical Solution:

$n_n = 4 \cdot 5 \times 10^{16}\ cm^{-3}$, n_i for $S_i = 1 \cdot 5 \times 10^{10}\ cm^{-3}$

Formula: $P_n = n_i^2 / n_n$

$P_n = (1 \cdot 5 \times 10^{10}\ cm^{-3})^2 / (4 \cdot 5 \times 10^{16}\ cm^{-3})$

$P_n = 0 \cdot 5 \times 10^{4}\ cm^{-3} = 5 \times 10^{3}\ cm^{-3}$

where P_n is minority charge concentration

and n_n is majority charge concentration

"Problem # 5"

⇒ **Statement:**

Magnetic field of a point charge q, moving with velocity V, is $B = (qv \sin\theta)/r^2$, find magnetic field due to an element of current. How it can represent Biot-Savart Law.

⇒ Solution:

Magnetic Field due to Element of Current:

Let there be a small element of current carrying conductor having length dl, carrying current i, cross sectional area A, concentration of charges n, this element will have small quantity of charge:

$$dq = nAq\,dl$$

Magnetic field due to it $= k'\,dq\,V \sin\theta / r^2$

$$dB = k'\,nqvA\,dl \sin\theta / r^2$$

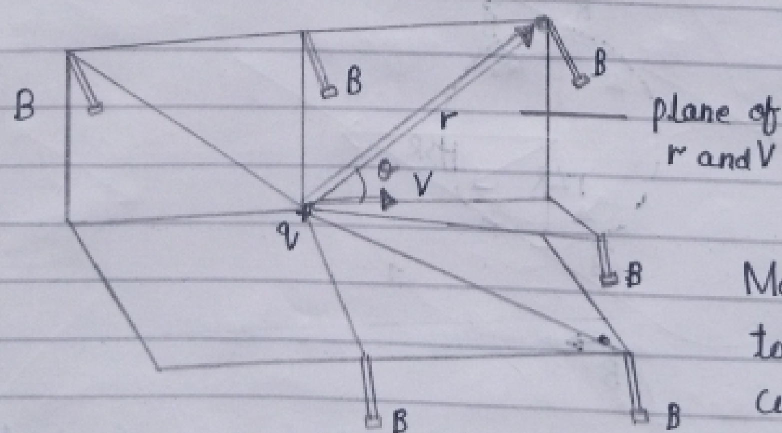
$$dB = k'\,JA\,dl \sin\theta$$

$$= k'\,I\,dl \sin\theta / r^2$$

$$B = k' \int I\,dl \sin\theta / r^2$$

This is Biot-Savart Law.

(That can be used to find the Magnetic field of any type of current carrying conductor).



Magnetic field due to an element of current.

Figure:

"Problem #-6"

⇒ **Statement:**

Using Ampere's Circuital law, find magnetic field due to a long conductor carrying current I.

⇒ Solution:

Magnetic Field of a Long Current Carrying Conductor:

A cylindrical conductor with radius R carries a current I. The current is uniformly distributed over the cross-sectional area of the conductor. Assume Amperian Loop having r equidistant from the conductor.

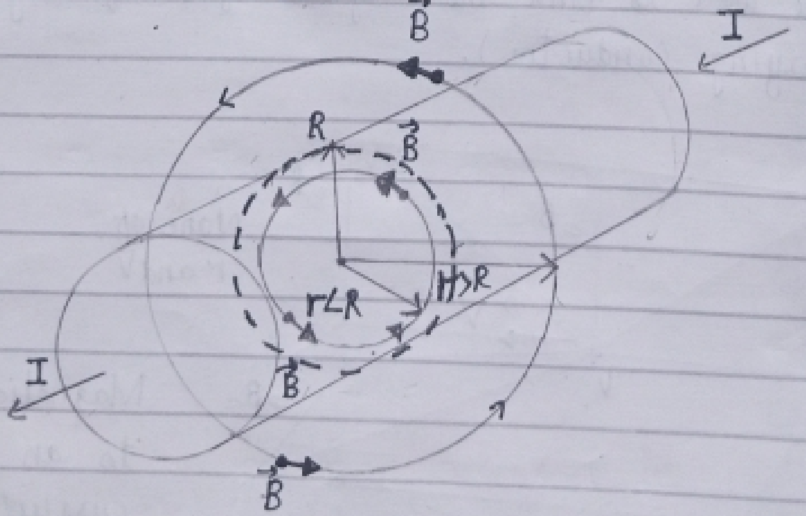
From Ampere's Law, we have:

$$\oint \vec{B} \cdot d\vec{l} = I_{encl}$$

B is constant at same distance r, taken out of integral, integral of dl is length of the circumference =

$$B \times 2\pi r = \mu_0 I$$

$$B = \frac{\mu_0 I}{2\pi r}$$



Demostrating M.Fd of a long Current Carrying Conductor.

"Problem # 7"

⇒ **Statement:**

Define potential and potential energy, find potential at a distance of 12cm from a charged cylinder, charge density is 4m μC per cm, radius of the cylinder is 4cm.

⇒ Solution:

-· **Potential:**

The potential is the amount of work or energy needed to move a unit of electric charge from a reference point to the specific point in an electric field.

-· **Potential Energy:**

Electric potential energy is the energy that is needed to move a charge against the electric field.

-· **Numerical Solution:**

Data Given:

$r = d = 12\ cm = 12 \times 10^{-2} m$ (Distance)

$\sigma = 4 m\mu C\ cm^{-1} = 4 \times 10^{-6} C / 10^{-2} m$ (Charge density)

$R = 4\ cm = 4 \times 10^{-2} m$ (Radius of cylinder)

-· **Formula:**

$$V = \frac{\lambda}{2\pi \varepsilon_0} \ln \frac{R}{r}$$

Putting the values:

$$V = \frac{(4 \times 10^{-6} C) / 10^{-2} m}{2\pi (8.85 \times 10^{-12} C^2 N^{-1} m^{-2})} \ln \left(\frac{4 \times 10^{-2} m}{12 \times 10^{-2} m} \right)$$

$$V = -7.9 \times 10^{6} V$$

$$V = -7.9\ MV$$

"Problem # 8"

⇒ **Statement:**

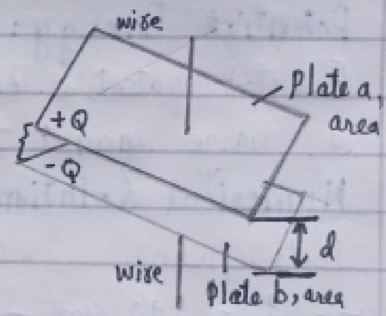
Find capacitance of a parallel plate capacitor having rectangular and spherical plates, comment C depends on the geometrical features of the capacitor.

⇒ Solution:

- Capacitance of a parallel plate capacitor having rectangular plates:

Consider to parallel conducting plates, separated by vacuum, each carries a charge Q

Let the conducting plate A have area 'A' and separated by distance 'd'.



By Gauss's law, magnitude of electric field between the two parallel plates is given by: $E = \sigma / \varepsilon_0 = Q / \varepsilon_0 A$

E field being uniform for a parallel plate capacitor

$$E = V_{ab} / d \Rightarrow V_{ab} = Ed = Qd / \varepsilon_0 A$$

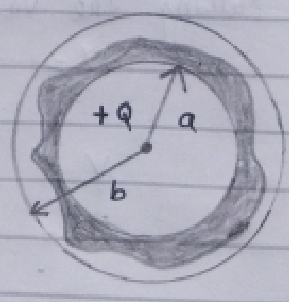
Putting this all together;

$$C = \frac{Q}{V_{ab}} = \varepsilon_0 \frac{A}{d}$$

- Capacitance of a spherical pate capacitor:

Using line integral the potential difference is,

$$V_{ab} = \Delta V = \int_a^b E \cdot dr \quad , \quad E = kQ/r^2$$



$$\Delta V = kQ \int_a^b r^{-2} dr$$

$$\Delta V = kQ \left| \frac{1}{a} - \frac{1}{b} \right|$$

The capacitance will be

$$C = Q / \Delta V = (ab) / k (b-a)$$

$C = 4\pi \varepsilon_0 (ab) / b-a$, where, $b-a$ is separation b/t plates.

- The capacitance depends on the geometry of the capacitor and on the material b/t the plates

$$\Rightarrow \quad C = \varepsilon_0 \frac{A}{d}$$

We can notice from this equation that capacitance is a function only of the geometry and what materials fill the space between the plates of capacitor.
From $Q = CV$, there exists a general feature that adding charges will also increase the potential difference but always in such a way that the ratio of Q/V remains constant and is determined by geometry of the system.

$\Rightarrow$ Increasing area of plates will increase C and increasing separation b/t the plates will decrease capacitance.