CONCEPT OF Electricity & Magnetism

CONTENT: Electricity Introduction, Charge, Resistance, Specific resistance, EMF and Potential difference, Ohm's Law, Kirchoff Laws, Wheatstone bridge, Metre bridge, Magnetism introduction, natural and artificial magnets, Coulomb's law, magnetic field intensity, permeability, para-dia-ferro magnets with examples, problems.

INTRODUCTION:

We know, the atom has positive charge(number of protons) in the nucleus and same amount of negative charge (number of electron) in various orbits. Hence the atom is said to be electrically neutral .

Atom becomes ion (+ve or –ve) when there is a transfer of electrons from one atom to another. This transformation of electrons occur easily by friction. This same phenomena occur in between two bodies. But in our daily life we can use flow of electrons that is known as current (A.C or D.C). Hence electricity is mainly two types.

Electricity ↓

Electrostatics (Static electricity)	Current Electricity
↓	↓
Forces between stationary electric charges (OR) Electricity generated by friction	Flow of charge in specified direction(OR) Study of various effect of electrical charges in motion
↓	↓
Ex:1)small piece of paper attracted by Silk or plastic paper when rubbing. 2)Lighting effects in clouds. 3)Rubbing of iron on road	Ex: bulb, fan, TV, wires, motor......

Electric Charge(Q): (unit is coulomb)

Electric charge is a basic property of the elementary particles such as electrons, protons. In metals charge is carried by electrons. In semi conductors charges carried by holes and electrons.

charge on a body $\boxed{Q = \pm ne}$ --------> units ---coulomb, dimensions-------> $M^0L^0T^1A^1$

Here n---->number of electrons , e----> charge of 1 electron $1\ e = 1.6 \times 10^{-19}$ coulombs

1 coulomb $= 6.25 \times 10^{18}$ electrons

Electric current:

It is the rate of flow of charge through any cross section of a conductor. Current flows from higher potential to lower potential. (or) transfer of electrical energy through flow of electrons.

Electric current $i = \frac{charge}{time} = \frac{q}{t} = \frac{ne}{t}$ -------> coulomb/sec------> Ampere, Dimensions----> $M^0L^0T^0A^1$

Electric current is a scalar quantity, since it does not obey the parallelogram (or) triangle law of vectors.

$$1 \text{ ampere} = \frac{n\ coulombs}{n\ \ seconds} = \frac{6.25\ X10^{18}\ \ \ electrons}{1\ sec}$$

In general it is measured in mA and µA . In our home --- 20Amp (1 phase) , 60Amp (3 phase)

Electric current can flow in low resistive path.

------→What is Electric Resistance and specific resistance ?

" It is the electrical property of opposition of free flow of electrons in a conductor".   It is denoted by R.

Every electrical component have resistance (fan,tv,bulb,heater....). Resistance is used to deliver other types of energy(bulb-light energy, heater-heat energy, tv-light and sound)

Resistance(physical property) of a resistor(conductor) is depends on nature of material, temperature, impurities, effect of magnetic field, effect of light.

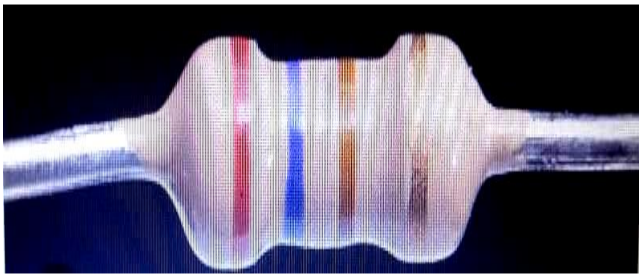
Resistance 'R' is directly proportional to length of a conductor, inversely proportional to area of cross section.

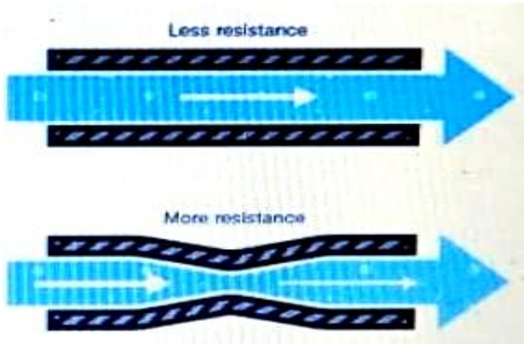
$\boxed{R = \rho \frac{l}{A}}$ R α $\frac{l}{A}$ -----> if L ↑ then R↑, and if L ↓ then R ↑

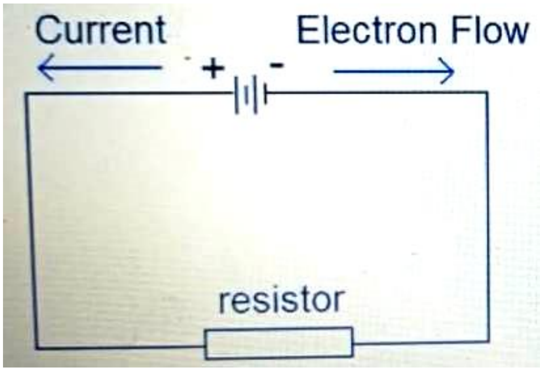
If A ↑ then R ↓, and if A ↓ then R ↓   but ρ is constant

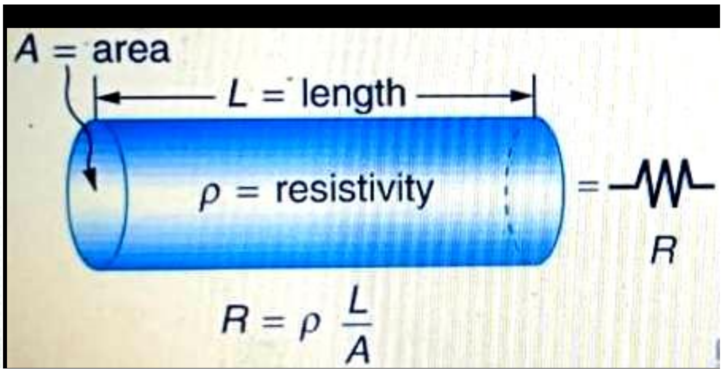
Units for resistance is ohm(Ω)

Here ρ ----> specific resistance or resistivity(electrical property) of the material ----> is constant irrespective of size, shape of body -----> it can change when material changes.









Specific resistance (or) Resistivity: [ρ]

It is the resistance of a conductor (specimen) of unit length and unit area of cross section.

$\rho = \frac{RA}{l}$ -------> units ----> ohm. metre ----->Ω. metre,

Material Name	Material Type	Resistivity (ρ) at 0°C
Carbon(graphite)	Conductor(metal)	35 X 10^{-6} Ωm ---------------high
Nichrome	Conductor(metal)	1 X 10^{-6} Ωm
Mercury	Conductor(metal)	0.98 X 10^{-6} Ωm
Iron	Conductor(metal)	0.1 X 10^{-6} Ωm
Tungsten	Conductor(metal)	0.056 X 10^{-6} Ωm
Aluminium	Conductor(metal)	0.027 X 10^{-6} Ωm
Copper	Conductor(metal)	0.017 X 10^{-6} Ωm
Silver	Conductor(metal)	0.016 X 10^{-6} Ωm------------low
Silicon, Germanium	Semi conductors	2300 , 0.46
Pure water	Insulator	180000 Ωm
Hard Rubber	Insulator	10^{13} to 10^{16}
Glass	Insulator	10^{10} to 10^{14}

From above metals like Silver, Copper, and Aluminium have very low values of resistivity and are used in the manufacture of electric cables, connecting wires ....

Note: 1)Resistivity is the specific property of a material while resistance is a bulk property of a conductor.
2)The resistance and resistivity of the conductor are depends on temperature. If ρ_1 is the resistivity of a material at temperature t_1 and ρ_2 is the resistivity of the same material at temperature t_2,then

$\boldsymbol{\rho_2 = \rho_1 + \alpha\, \rho_1}(t_2 - t_1)$ here $\alpha = \frac{d\rho/\rho}{dt} = \frac{(\rho 2-\rho 1)/\rho 1}{t2-t1}$ ---->temperature coefficient of resistivity

3)similarly resistance $R_2 = R_1 + \alpha\, R_1(t_2 - t_1)$ ----> if t↑ then R↑

........>What is Potential , potential difference and EMF ?

Potential: Potential is the average energy per unit charge(electron) when it is moving in same material.

$$V_A = V_B = \frac{W}{q} \quad \text{(OR)} \quad V = I\,R \quad \text{units --- joule/coulomb ------ volt}$$

Potential Difference (or) Voltage drop: If a charge(electron) moving through one material to another material then it's energy will change(drop) , due to this work will done by the resistance(machine).

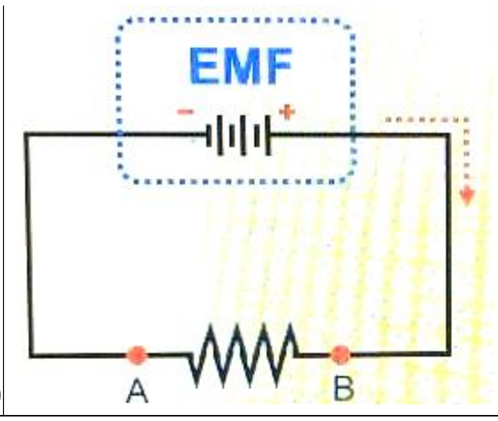
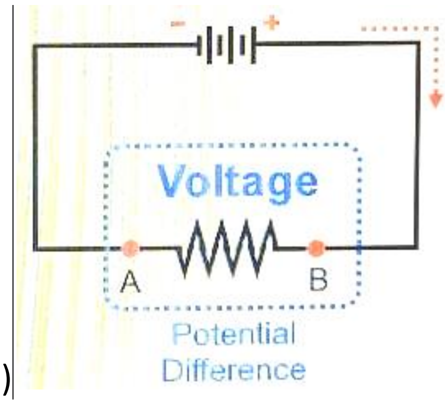
(or) It is the difference in potentials between any two points of a conductor.

$$V = V_A - V_B = \frac{dW}{dq} \quad \text{units ---- volt}$$

EMF : Work done on unit charge to move in the circuit.

Ex: Battery--emf = 5 volt ---- $\frac{5\ joules}{1\ coulomb}$--- $\frac{5\ joules}{6.25\ x\ 10^{18}\ electrons}$ = 5 x 1.6 x 10^{-19} joule/electron = 8 x 10^{-19} j/e.

----→Write the differences between EMF and voltage(or) potential difference ?

EMF	Voltage (or) Potential difference
1)It is the source (battery) that gives energy to electric charge(electrons) to move in the circuit.	1)It is the energy drop across a resistor (Load – bulb, tv, fan ....)
2)It is the work done (energy) by the source on unit charge.	2)It is the energy used to one end of a resistor to another end.
3) E = V = W/q ---- volt	3) V = IR ------ volt
4)EMf exists in open circuit and closed circuit also.	4)Voltage drop exist in closed circuit only.
5)It is the cause of electric current in the circuit.	5)It is the effect due to electric current.
6) 	6) 

-----→ Define ohm's Law ?

At constant temperature, the electric current (I) flowing in a conductor is directly proportional to the applied potential difference (V) across the ends.

I α V -----> I = **G**V =($\frac{1}{R}$)V -----> $I = \frac{V}{R}$ **G**--->conductance(constant), **R**-->Resistance (constant)

(OR)

At constant temperature, voltage developed across the ends of a given conductor is directly proportional to current flowing through the conductor.

V α I -------> V = **R** I -------> V = I **R** **R**---->Resistance (proportionality constant)

(OR)

At constant temperature, voltage drops across the ends of a given conductors is directly proportional to Resistance of the conductors.----->**Series** combination

V α R -------> V = **I** R **I** ---->Electric current passing (proportionality constant)

(OR)

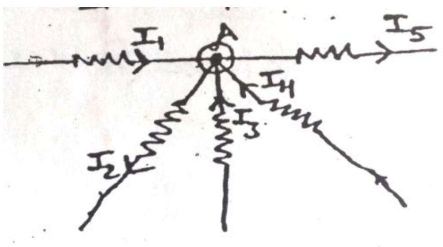
At constant temperature, the Electric currents passing through the conductors is inversely proportional to Resistance of the conductors.----->**Parallel** combination

I α $\frac{1}{R}$ ------> I = **V** ($\frac{1}{R}$) ------> $I = \frac{\mathbf{V}}{R}$ **V** --->applied voltage(proportionality constant)

Properties of ohm's law:

1)ohm's law is not a universal law.
2)ohm's law obey only for metallic conductors like in resistors, capacitors, inductors.....
3)ohm's law does not obey in semiconductors like in diodes, transistors, amplifiers, transformers....

------->State and explain Kirchhoff laws?



Kirchhoff first law(or)Kirchhoff current law: [KCL]

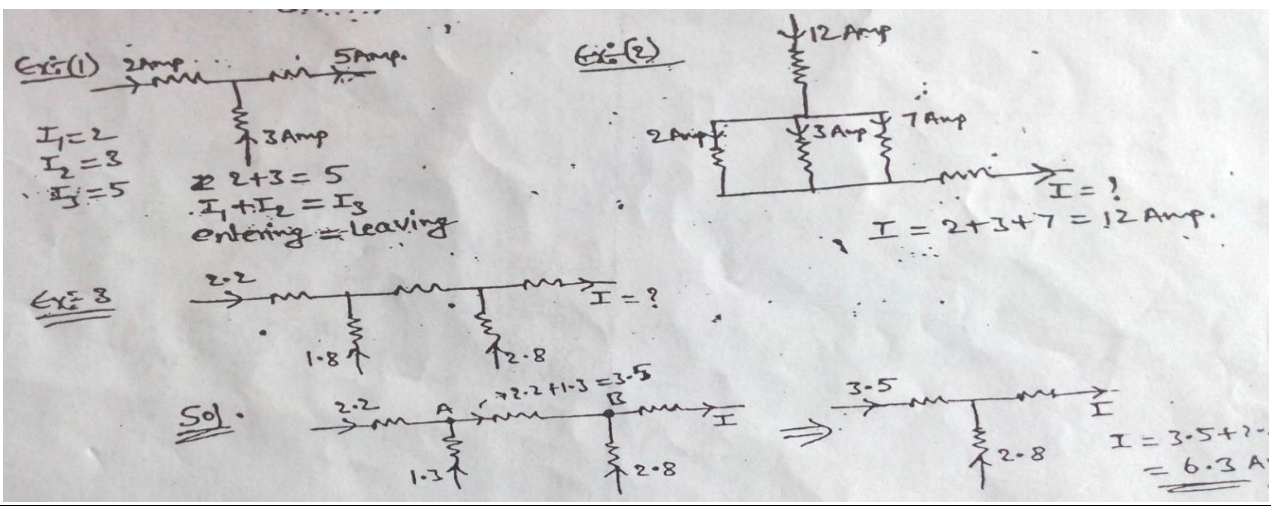
The algebraic sum of currents flowing towards the junction point (node) is Zero.

(OR) The sum of input currents flowing towards a junction is equal to sum of currents flowing away from the junction.

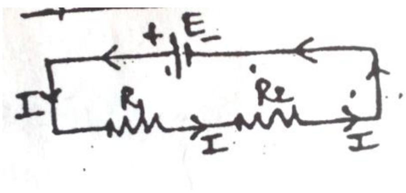
Explanation : Figure shows Node A and five electric currents. Here currents i1,i2,i4 are flowing towards the junction a, and currents i2, i5 are flowing away from the junction A. Let entering currents are taken as +Ve, leaving currents are taken as –Ve.

Then from Kirchhoff first law, we can write $+i_1 - i_2 + i_3 + i_4 - i_5 = 0$ ----> $i_1 + i_3 + i_4 = i_3 + i_5$

So it is also known as conservation of energy (current).



Kirchhoff Second Law (or) Kirchhoff Voltage Law: [KVL]



The algebraic sum of electrical potential differences in various branches(loops) of a closed circuit is Zero.

(OR) In a closed circuit, the algebraic sum of the products of the current and resistance of each part of the circuit is equal to the resultant emf(battery voltage) in the circuit.

Explanation: Figure shows simple series combination of two resistors. Current starts from +ve terminal and ends at –ve terminal through R_1 and R_2 resistors.Take +E when current passing from + to – terminals. Take –E when current passing from – to + terminals.

By KVL, we can write $+E - iR_1 - iR_2 = 0$ ----> $E = iR_1 + iR_2$ -----> $E = V_1 + V_2$ That is applied emf = Sum of individual potential drops(voltages)------> that emf can be used in two ways.

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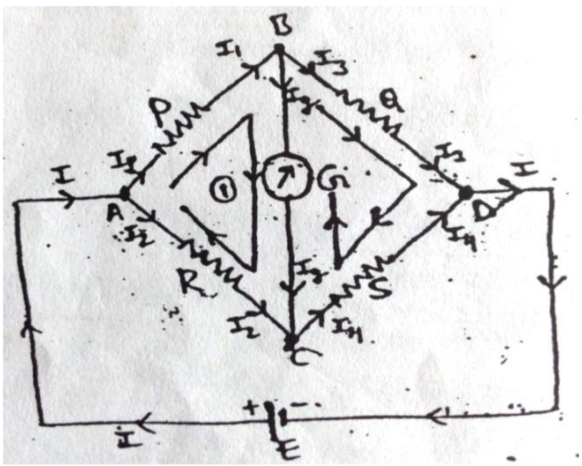
----->Explain the application of Kirchhoff laws- WHEATSTONE BRIDGE ?
(or) Explain the balancing condition for Wheatstone bridge?

Description:

Four resistors P,Q,R,S are connected in the form of quadrilateral is known as Wheatstone bridge.

Applications (uses):



1)Using this we calculate the unknown Resistance when the remaining three resistances are known.
2)Using this we can compare the two unknown resistances.

Below circuit shows quadrilateral form of four resistors P,Q,R,S. Four junctions A,B,C,D are formed.

Galvanometer of resistance G is connected in between Nodes B and C. Battery of emf 'E' is connected in between Nodes A and D.

At Node A, current i divides into i_1 and i_2
At Node B, current i_1 divides into i_g and i_3
At Node C, current i_2 and i_g combines to form i_4
At Node D, current i_3 and i_4 combines to form i

By applying KCL at Node B, we have $i_1 = i_g + i_3$ -------> (1)
By applying KCL at Node C, we have $i_2 + i_g = i_4$ -------> (2)
By applying KVL to loop(1) that is ABCA, we have $+i_1\mathbf{P} + i_g\mathbf{G} - i_2\mathbf{R} = 0$ -------> $i_1\mathbf{P} + i_g\mathbf{G} = i_2\mathbf{R}$ ------>(3)

By applying KVL to loop(2) that is BDCB, we have $+i_3\mathbf{Q} - i_4\mathbf{S} - i_g\mathbf{G} = 0$ -------> $i_3\mathbf{Q} = i_4\mathbf{S} + i_g\mathbf{G}$ ----->(4)

Galvanometer always shows deflection when there is a flow of current in any direction.

" if current flows through the galvanometer is Zero, then it shows Zero deflection. Then the wheatstone bridge is said to be balanced." So in bridge balanced case $i_g = 0$

So from (1),(2) equations, we have $i_1 = i_3$(come in series), $i_2 = i_4$ (come in series),

From (3),(4) equations we have $i_1\mathbf{P} = i_2\mathbf{R}$ -----> $i_3\mathbf{P} = i_4\mathbf{R}$ ------> (a)

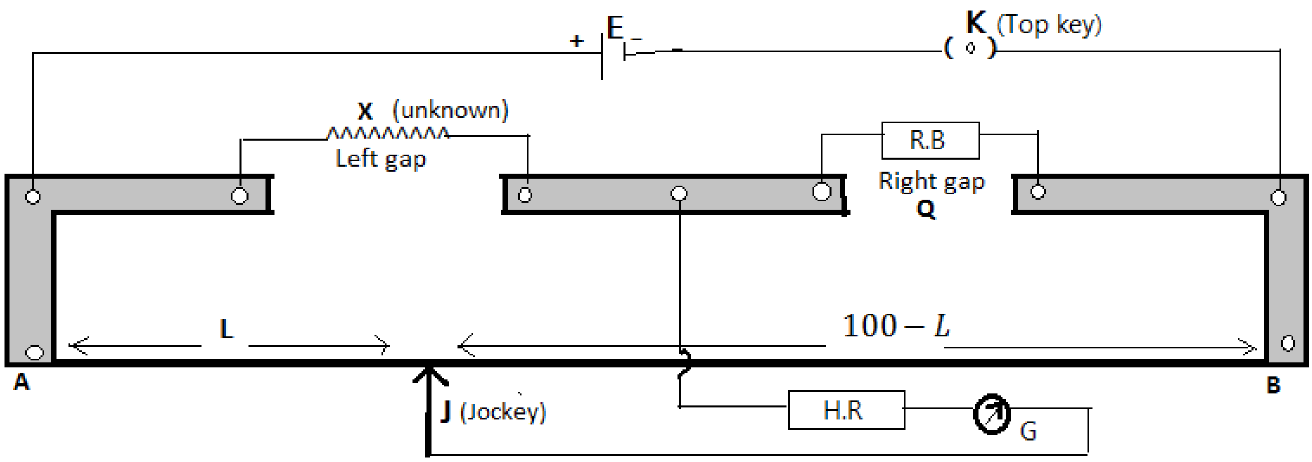
and $i_3\mathbf{Q} = i_4\mathbf{S}$ -----> $i_3\mathbf{Q} = i_4\mathbf{S}$ ------> (b)

from $\frac{(a)}{(b)}$, we get $\frac{i_{3\,P}}{i_{3\,Q}} = \frac{i_{4\,R}}{i_{4\,S}}$ ------> $\boxed{\frac{\mathbf{P}}{\mathbf{Q}} = \frac{\mathbf{R}}{\mathbf{S}}}$

This is called the balancing condition for Wheatstone bridge and also the Wheatstone bridge principle.

---->Describe Meter Bridge with legible sketch and Write the formula in Meter Bridge to determine specific resistance ?

Description of Meter bridge:



It consists of two L shaped strips and one rectangular shaped strip made up of brass (or) copper. A manganin wire of uniform cross section of length 1metre (100cm) is fixed between A,B. A galvanometer ,High resistance and Jokey are connected in series from the middle of the rectangular strip.

The unknown resistance 'X' and Resistance box are connected in left gap and right gap. If the jockey is placed anywhere on AB wire, it divides the wire into two R and S namely L and 100–L. These resistance along with X and Q form a wheat stone's bridge.

Formula:

From the principle of Wheatstone bridge, when bridge is balanced i_g =0, we can write

$$\frac{P}{Q} = \frac{R}{S} \text{ -----> } \frac{X}{Q} = \frac{L}{100-L}$$

There fore unknown resistance $\boxed{X = \frac{QL}{100-L}}$

and specific resistance or resistivity of the given wire is $\boxed{\rho = \frac{X\pi r^2}{\mathcal{L}}}$ here $\mathcal{L}$ = length of the wire

Magnetism

Introduction:

1) Magnetite (Fe304) attract magnetic substances like iron, steel, cobalt etc. Magnets available in the form of Bar magnets, Horse shoe shaped etc.
2) Our earth having a weak magnetic field of 0.5 guass. (0.25 to 0.65 guass-----25 to 65 μT)
3) Every electron in an atom creates own magnetic field around it.
4) This field is due to orbital and spin motion of electron results a magnetic moment.
5) This property of attraction is due to Net magnetic moment of all electrons in a material.

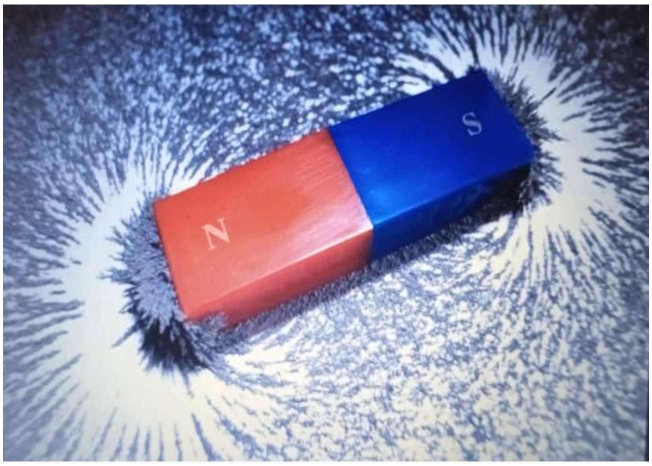
PROPERTIES:

1)When a bar magnet is suspend freely, it will align in North and South directions of earth.
2)When a magnet is broken into two (or) more pieces, each piece behaves like a magnet, So magnet with single pole is not exist.
3)Law of magnetic poles says like poles repel each other and unlike poles attract each other.
4)Poles exist inside the surface of a magnet.
5)The Attraction or repulsion is due to magnetic lines.

----→ What are the types of magnets?

Natural Magnets	Artificial Magnets
1)These are naturally found in nature. 2)Having no regular shapes. (stones) 3)It has permanent magnetic field. 4)These are weak powerful magnets. 5)ex: Lodestone or Magnetite. 6)having few applications in daily life.	1)These are man made magnets. 2)It can be made in different regular shapes. 3)It has permanent and temporary magnetic fields. 4)These are very powerful magnets. 5)ex : bar magnet, ring , horse shoe, disc magnets. 6)having very vast usage in daily life.

<u>Bar Magnet:</u> A bar magnet having poles N & S. The poles exist inside the edge of a magnet. The physical parameters are pole strength(m), magnetic movement(M), magnetic length(2L), magnetic field intensity(B).



<u>Pole:</u> Pole is the region of a magnet towards which the lines of magnetic induction converge(S) and which the lines of induction diverge(N).

<u>Pole Strength(m):</u>

It is the measure of the force exerted by one face of a magnet on a face of another magnet when both magnets are represented by equal and opposite poles.

(OR) It is the strength of a magnetic pole to attract other magnetic materials towards itself.

It is denoted by 'm'. It is a scalar quantity. Units---->Ampere. metre,

<u>Magnetic length (2L) :</u>

The poles (N,S) of a magnet exist inside of the magnet. " The distance between two poles of a magnet is known as length of the magnet." It is denoted by 2L.

S-------0-------N

<------2L------>

Units-----> meter (or) cm

<u>Magnetic Moment(M): (Dipole moment)</u>

It is the property of a magnet that interacts with an applied magnetic field to give a mechanical moment.

(OR) The product of pole strength(m) and length of a magnet (2L) is defined as Magnetic Moment (M) of a magnet. it is a vector quantity, which directs from South to North.

Units ----> Amp.m^2 ,

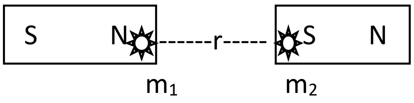
$$\boxed{\mathbf{M = m \times 2L = 2mL}}$$

NOTE: Imagine ---- current 'i' flowing through a wire of cross sectional area 'A' ---- then it will rotates --- it means it acquire magnetic moment ...... M = current x area = i x A ------ ampere. Metre^2

Hence Pole strength(m) is the magnetic moment per unit length ----- m = $\frac{M}{2L}$ ---- units – ampere . metre

.....> State Coulomb's inverse square law of force in Magnetism?

" The force of attraction (or) repulsion between two magnetic poles is directly proportional to the product of the strength of the poles and inversely proportional to the square of the distance between them."



Mathematically $F_o \alpha \frac{m_1 m_2}{r^2}$ ------> $\boxed{F_o = \frac{\mu_0}{4\pi}\frac{m_1 m_2}{r^2}}$

here μ_0 ------> Absolute permeability of free space (or) Air (or)vacuum

$\mu_0 = 4\pi \times 10^{-7}$ Newton/amp^2 (or) Henry/m

For any other medium in between the poles then $F = \frac{\mu}{4\pi}\frac{m_1 m_2}{r^2}$, μ--->permeability of medium

----→ What is Magnetic field lines (or) Magnetic force lines and write it's properties?

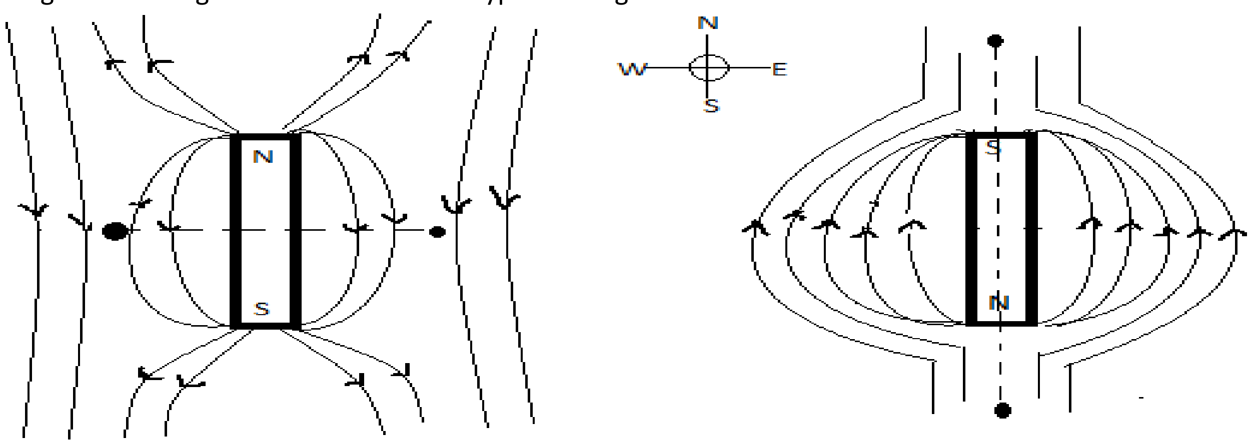
Magnetic field:

The space (or) field occupied by a given magnet is known as magnetic fields. (OR) It is the space around a bar magnet which influence other magnetic materials. It is a vector quantity. A bar magnet has non uniform field, where as field produced between two magnets results a uniform field.

Magnetic lines of force: These are the cause for attraction of other materials.

" The path followed by a unit North Pole in a magnetic field is known as magnetic force line"

This path is either straight line (or) curve. Lines of force of a given magnet are traced by a compass. For a given bar magnet we can arrive two types of magnetic fields.



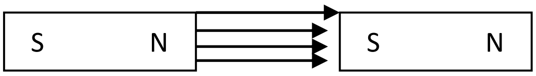
Properties (or) characteristics of a magnetic lines of force:

1)Magnetic lines can not interact with each other.
2)The directions of magnetic lines are North to South pole in Outside of the magnet.
3)The directions of magnetic lines are South to North pole in inside of the magnet.
4)Magnetic lines repel each other.
5)These are repel each other.
6)These are 3 dimensional lines.
7)At the poles, the ,magnetic lines are very high . This results force is high at poles.

----→ What is Uniform and non uniform magnetic fields ?

Uniform magnetic field: If the force on any magnetic material is **same** in a magnetic field the then field is known as uniform magnetic field.

Ex: field exerted between two non similar poles of two magnets.



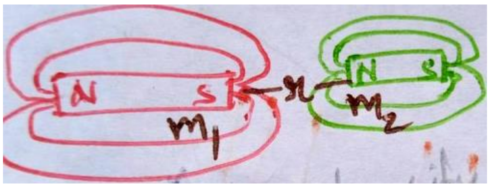
Non uniform magnetic field: If the force on any magnetic material is **varies** in a magnetic field the then field is known as uniform magnetic field.

Ex: field around a Bar magnet, field around earth .

---→ What is Magnetic field Intensity of a Bar magnet [B]

Let us take a small magnet of pole strength m_2 is placed at a distance 'r' in a magnetic field(non uniform) of large magnet with pole strength m_1, then force between two magnets is

$F \; \alpha \; m_2$ ---- $F = B_1 m_2$ ----- $B_1 = \frac{F}{m_2}$ -----> $B = \frac{\mu_0}{4\pi}\frac{m_1}{r^2}$



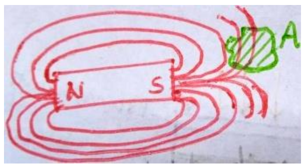
Similarly $F \; \alpha \; m_1$ ---- $F = B_2 m_1$ ----- $B_2 = \frac{F}{m_1}$ -----> $B = \frac{\mu_0}{4\pi}\frac{m_2}{r^2}$

It is the average force experienced by a unit north pole(m_2) at a point in a magnetic field(m_1), is defined as magnetic field intensity at that point in the field. (OR) It is the average force given by first magnet on second magnet. It is denoted by 'B'. It is a vector quantity.

$$B = \frac{F}{m} \text{ -----> } B = \frac{\mu_0}{4\pi}\frac{m}{r^2}$$

units-----> Newton/Amp. metre (or) Tesla

----→What is Magnetic induction (OR) flux density of a material ?

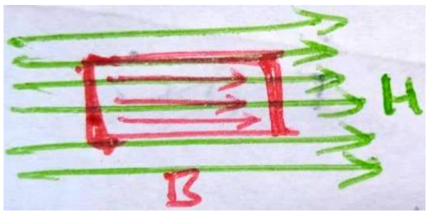


Let a metal piece of iron with area 'A' placed in a non uniform magnetic field of a bar magnet. The magnetic force lines can attract the iron piece with few lines, those are known flux lines.

Flux $\Phi \; \alpha \; A$ ----- $\Phi = B A\cos\theta$ ------ $B = \frac{\Phi}{A\cos\theta}$ ----- weber/m^2 ------ Tesla

Hence, the magnetic flux per unit area is also known as magnetic induction.

----→What is magnetic field strength(B) of a material?



Let a metal piece is placed in an external uniform magnetic field 'H' , then few magnetic field induced with in the magnetic material.

$B \; \alpha \; H$ ------- $B = \mu H$, here μ is permeability , B ---Tesla

------→What is magnetic permeability (μ) ?

It is the ability of a magnetic material to allow magnetic field lines to pass through it when it is placed in magnetic field.

This passing of lines through it occurs only when it has unpaired electrons in an atoms. It can changes to material to material.

Magnetic lines can also pass through Air (or) free space (or) vacuum with Absolute permeability $\mu_0 = 4\pi \times 10^{-7}$ Newton/Amp^2 = 1.256 x 10-6 N/Amp^2 (or) Henry/metre.

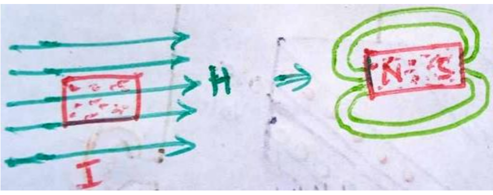
Hence, permeability of any material medium is calculated by using μ_0.

That is $\mu \propto \mu_0$ ------ $\mu = \mu_r \mu_0$ ------ constant $\mu_r = \frac{\mu}{\mu_0}$ ----- μ_r =relative permeability

Ex: for nickel μ_r = 600, iron μ_r=200000, cobalt μ_r=250, Air μ_r = 1 ---- $\mu = \mu_0$

---→What is Magnetic susceptibility (χ) ?

It is the ability of a magnetic material to with stand (hold) the magnetism with in it **after removing** external magnetic field.



$I \propto H$ ----- $I = \chi H$ ---------- $\chi = \frac{I}{H}$ --- Amp/metre

It is also defined as magnetic moment developed per unit volume. ----- $\chi = \frac{M}{V} = \frac{m \times 2L}{A \times 2L} = \frac{m}{A}$

Hence, it is also defined as pole strength per unit area.

So final induction $B = \mu_0 H + \mu_0 I$

-----→Explain Dia, para, ferro magnetic materials?

Dia magnetic materials:

1)These are very slightly magnetic in the opposite direction of applied field.

2)These are repelled by magnetic fields.

3)They do not retain the magnetic properties when the external field is removed.

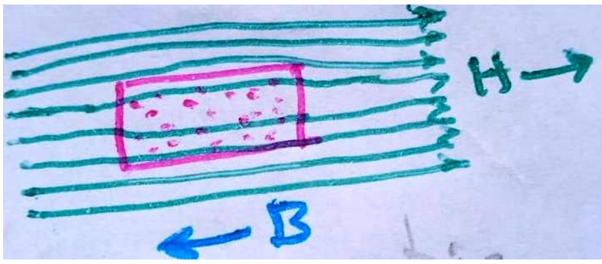
4)These materials have paired electrons, hence it has no net magnetic moment(M=0).

5)Hence the relative permeability $\mu_r < 1$ ---- B < H

6)ex : Bismuth, Zinc, Copper, Silver, Gold, salt, water, mercury, hydrogen, wood.

7)These are used in MRI scan, magnetic levitation.

8)It's susceptibility is very small and negative(-)



Para magnetic materials:

1)These are slightly magnetic with in the direction of applied field.

2)These are weekly attracted by magnetic fields.

3)They retain partly the magnetic properties when the external field is removed.

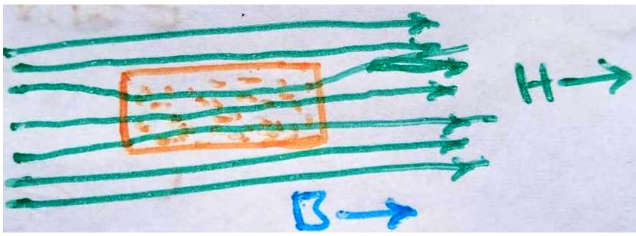
4)These materials have few unpaired electrons, hence it has some magnetic moment.

5)Here the relative permeability $\mu_r > 1$ ---- B > H

6)ex : Aluminium, platinum, manganese, oxygen..

7)These are used in refrigerator, spectroscopy.

8)It 's susceptibility is small and positive(+).



Ferro magnetic materials:

1)These are strongly magnetise with in the direction of applied field.

2)These are strongly attracted by the magnetic fields.

3)They retain almost all magnetic properties when the external field is removed.

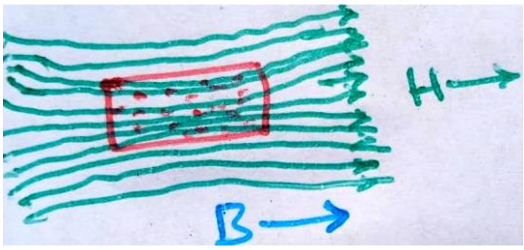
4)These materials have more unpaired electrons, hence it has more magnetic moment.

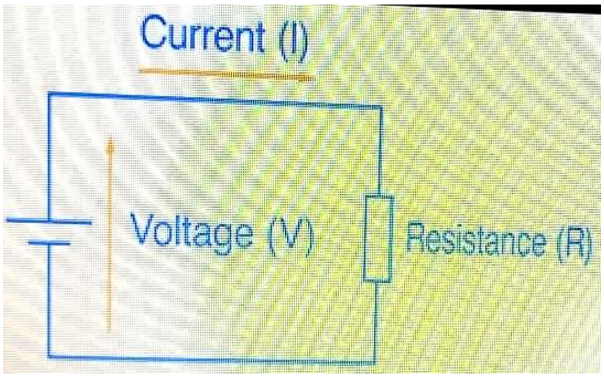
5)Here the relative permeability $\mu_r >> 1$ ---- B >> H

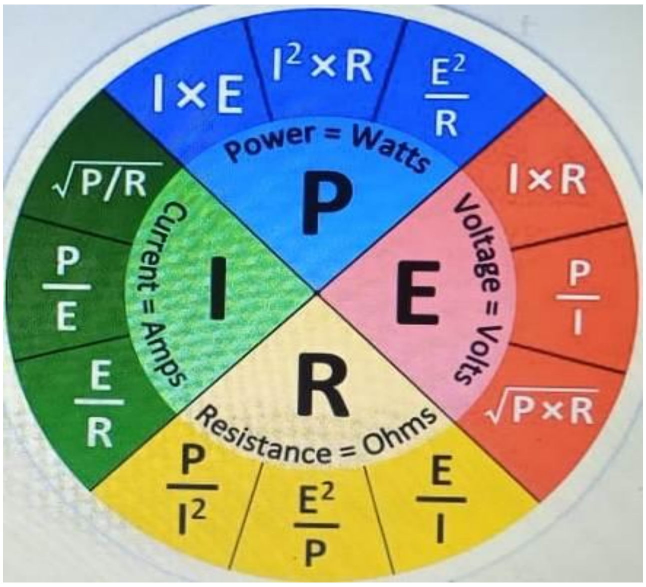
6)ex: iron, nickel, cobalt, magnetite,

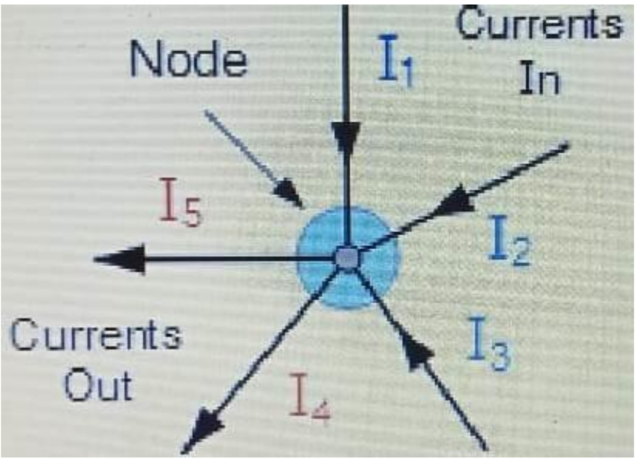
7)These are used in Audio speakers, data storages, transformers...

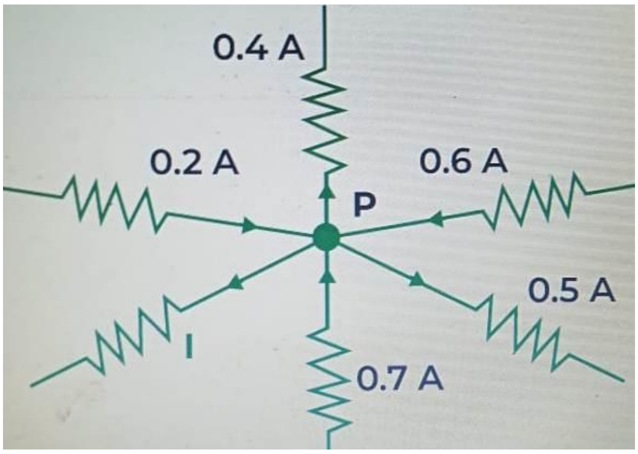
8)It's susceptibility is high and positive(+).

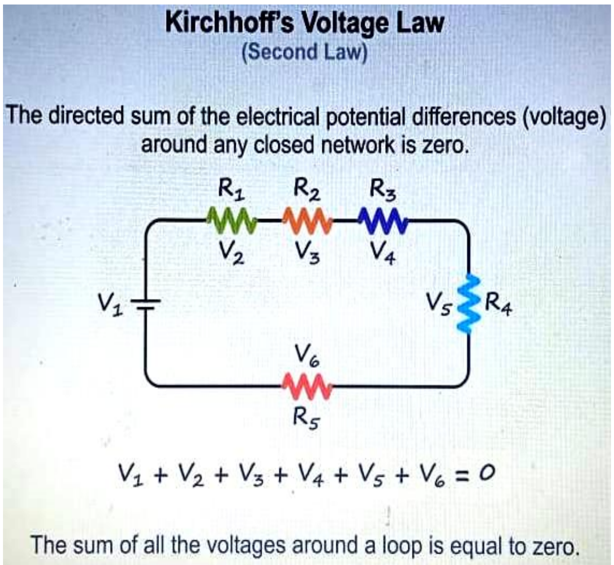


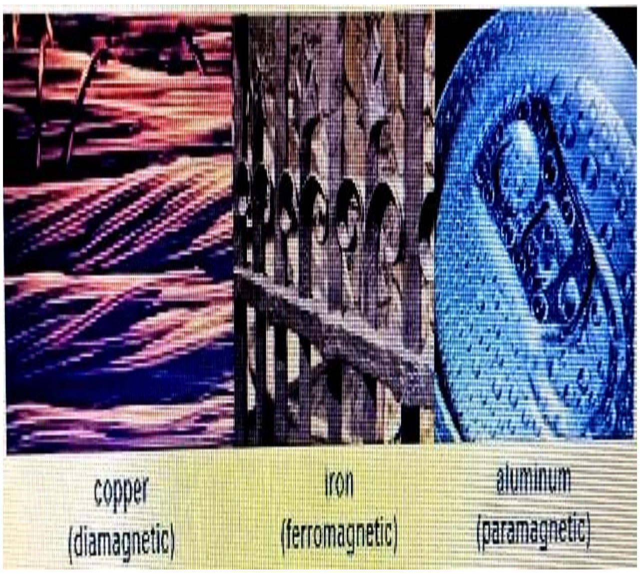


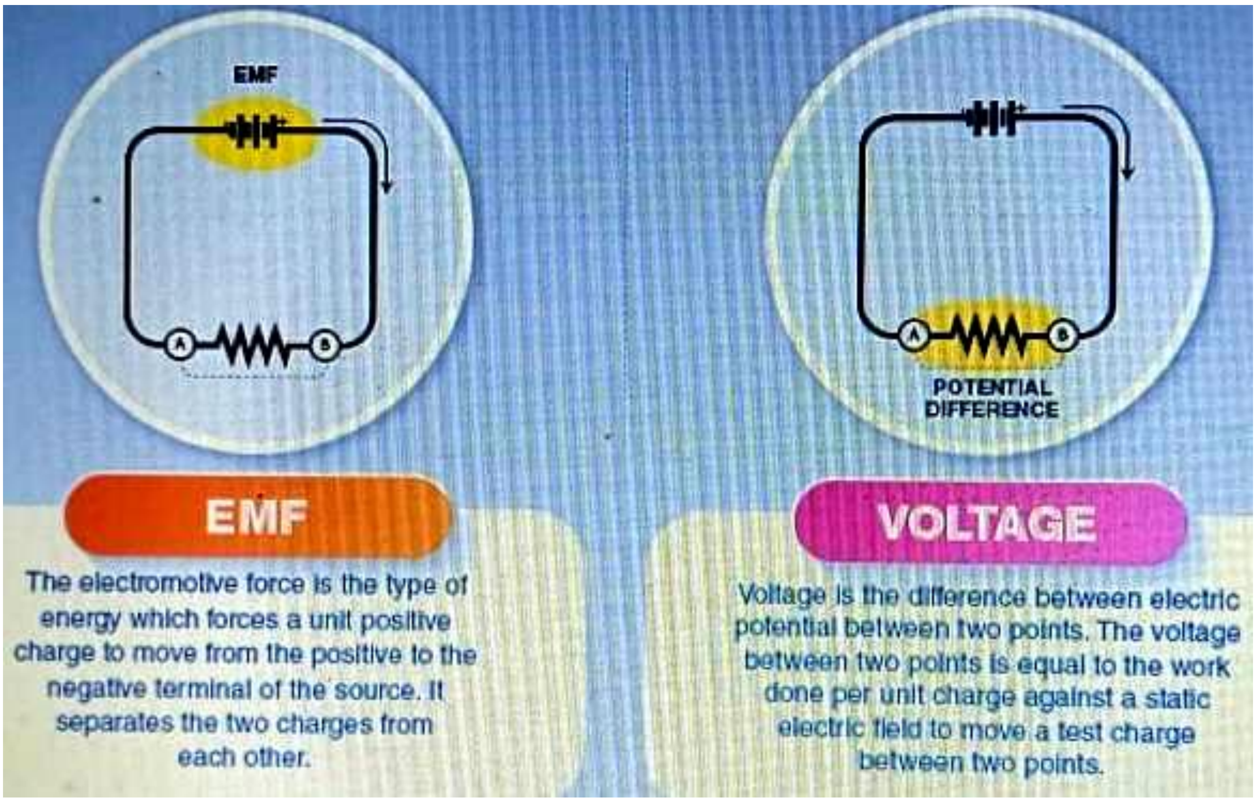


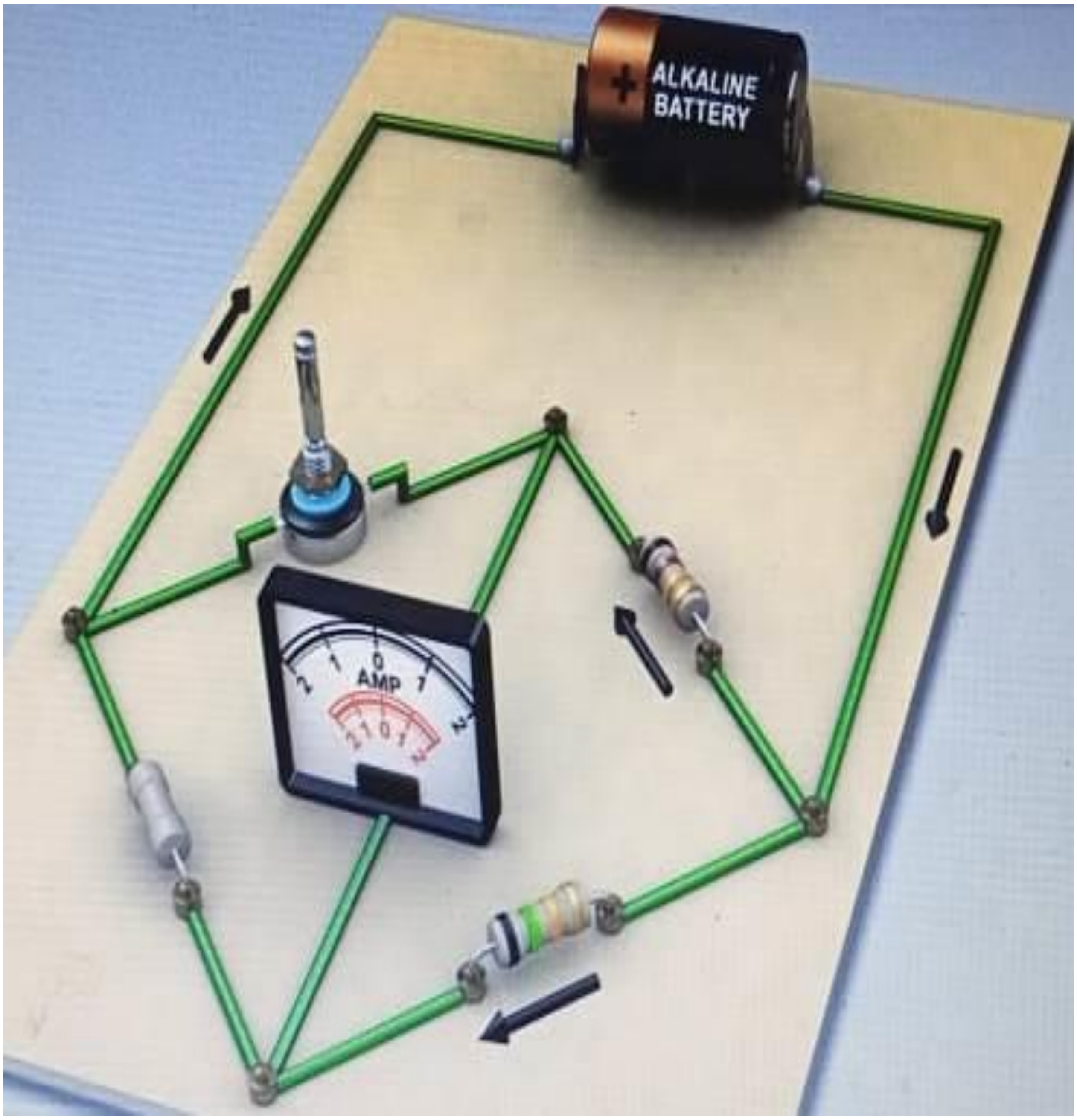

Node
I_1
Currents In
I_5
I_2
Currents Out
I_4
I_3


0.4 A
0.2 A
0.6 A
P
0.5 A
I
0.7 A


Kirchhoff's Voltage Law
(Second Law)
The directed sum of the electrical potential differences (voltage) around any closed network is zero.
R_1 R_2 R_3
V_2 V_3 V_4
V_1
V_5 R_4
V_6
R_5
$V_1 + V_2 + V_3 + V_4 + V_5 + V_6 = 0$
The sum of all the voltages around a loop is equal to zero.


copper
(diamagnetic)
iron
(ferromagnetic)
aluminum
(paramagnetic)


EMF
POTENTIAL DIFFERENCE
EMF
The electromotive force is the type of energy which forces a unit positive charge to move from the positive to the negative terminal of the source. It separates the two charges from each other.
VOLTAGE
Voltage is the difference between electric potential between two points. The voltage between two points is equal to the work done per unit charge against a static electric field to move a test charge between two points.



Coulomb's inverse square law of force: [F] in Electricity:

The force of attraction (or) repulsion between two stationary charges Q1 and Q2 is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance between them.

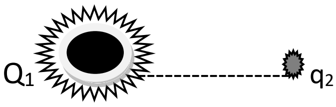
☼ -------- r -------- ☼ $\quad$ F α $\frac{Q_1\,Q_2}{r^2}$ ---------> F = $\frac{1}{4\pi\varepsilon_0}\frac{Q_1\,Q_2}{r^2}$ ---->Newton

Q_1 $\quad$ Q_2

Here ε_o ----->permittivity of free space = 8.85×10^{-12} coulomb^2/N.m^2

proportionality constant $\frac{1}{4\pi\,\varepsilon_0}$ = **9 x 10^9** N.m^2/coulomb^2 $\quad$ $\boldsymbol{\varepsilon_o}$ ---->dimensions--->$M^{-1}L^{-3}T^4A^2$

Electric field intensity: [E]



"It is force experienced by a unit positive chare denoted by E."

$E = \frac{F}{q_2}$ ------> $E = \frac{\mathbf{1}}{\mathbf{4\pi\,\varepsilon_0}}\frac{Q_1}{r^2}$ ------> Newton /coulomb -------> $M^1L^1T^{-3}A^1$

$E = \frac{\mathbf{1}}{\mathbf{4\pi\varepsilon_0\,k}}\frac{Q_1}{r^2}$ k----->dielectric constant k=1 for air, k=2 for paraphin

Electric Potential: [V]

The force 'F' is used to move the charged body to a distance 'r' . Hence this force doing work . this work done is proportional to charge.

$W \propto q$ ------ $W = V \times q$ ------ $V = \frac{W}{q}$ (oR) Potential energy per unit charge (1 coulomb).

$V = \frac{W}{q_2} = \frac{\mathbf{1}}{\mathbf{4\pi\varepsilon_0}}\frac{Q_1}{r}$ ------> Joule/coulomb ------> volt, and Dimensions------->$M^1L^2T^{-3}A^1$

Ex: 15 volt battery ----- 15 joules/ 1 coulomb ---- battery gives energy of 15 joules for 1 coulomb electrons ----- battery doing work of 15 joules on 1 coulomb electrons in the circuit .

potential of earth is '0' volt----means we can leave excess electrons to earth (or) we can take electrons from earth.

------>Derive the expression for Magnetic field strength(B) at a point on the Axial line of a bar magnet?

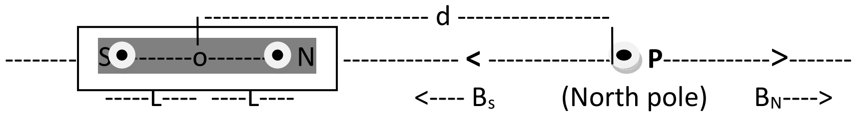
Axial line:

"It is the line passing through the midpoint and two poles of a bar magnet." ------------ S------N ---------

Derivation of field strength(B):

Consider a bar magnet of length '2L' and pole strength 'm' and Magnetic Moment M=2mL.

Let a point 'p' on axial line at a distance 'd' from the midpoint of a magnet.



Consider a unit North pole at a point 'P'. Then Magnetic strength at 'P' due to North pole 'N' of the magnet is

$$B_{NP} = \overrightarrow{B_N} = \frac{+\mu_0}{4\pi}\frac{m}{(d-L)^2}, \quad \text{+ for Repulsion force.}$$

And magnetic strength at 'P' due to south pole 'S' of the magnet is

$$B_{PS} = \overrightarrow{B_S} = \frac{-\mu_0}{4\pi}\frac{m}{(d+L)^2}, \quad \text{– for Attraction force.}$$

Therefore the total (or) resultant magnetic field strength at a point 'P' due to a bar magnet is $\vec{B} = \overrightarrow{B_N} + \overrightarrow{B_S}$

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{m}{(d-L)^2} + \frac{-\mu_0}{4\pi}\frac{m}{(d+L)^2}$$

$$\vec{B} = \frac{\mu_0 m}{4\pi}\left[\frac{1}{(d-L)^2} - \frac{1}{(d+L)^2}\right]$$

$$\vec{B} = \frac{\mu_0 m}{4\pi}\left[\frac{(d+L)^2-(d-L)^2}{(d-L)^2(d+L)^2}\right]$$

$$\vec{B} = \frac{\mu_0 m}{4\pi}\left[\frac{4dL}{(d^2-L^2)^2}\right] = \frac{\mu_0}{4\pi}\left[\frac{2(2mL)d}{(d^2-L^2)^2}\right]$$

$$\boxed{\vec{B} = \frac{\mu_0}{4\pi}\left[\frac{2Md}{(d^2-L^2)^2}\right]}$$

Since $B_N > B_S$, resultant $\vec{B}$ can have a direction from N to P.

If d >> L then $\boxed{\vec{B} = \frac{\mu_0}{4\pi}\left[\frac{2M}{d^3}\right]}$ from N to P.

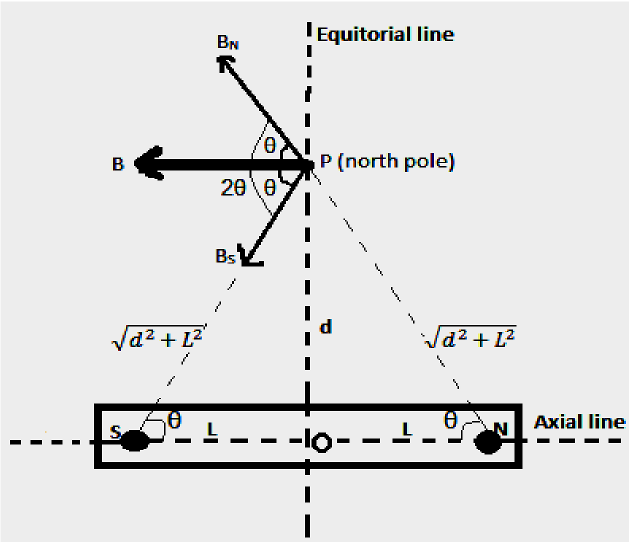
------>Derive the expression for Magnetic field strength(B) at a point on the Equatorial line of a bar magnet?

Equatorial line:

"A line passing through the midpoint of a bar magnet and perpendicular to its axial line is known as equatorial line."

Derivation:

Consider a bar magnet of length '2L' and pole strength 'm' and magnetic moment M=2mL.



Let a point 'P' on equatorial line at a distance 'd' from the mid point at a point 'P'.

Now magnetic field strength at 'P' due to North pole of the magnet on equatorial line is

$$\overrightarrow{B_{NP}} = \overrightarrow{B_N} = \frac{\mu_0}{4\pi}\frac{m}{(\sqrt{d^2+L^2})^2} = \frac{\mu_0}{4\pi}\frac{m}{d^2+L^2}$$

(repulsion)

Magnetic field strength at 'P' due to South pole of the magnet on equatorial line is

$$\overrightarrow{B_{PS}} = \overrightarrow{B_S} = \frac{-\mu_0}{4\pi}\frac{m}{(\sqrt{d^2+L^2})^2} = \frac{-\mu_0}{4\pi}\frac{m}{d^2+L^2}$$

(attraction)

From above , $|\overrightarrow{B_N}| = |\overrightarrow{B_S}|$ that is magnitudes are same

Then the resultant field strength **B** due to these two strengths is obtain by using parallelogram law of vectors.

Resultant field strength $\vec{B} = \overrightarrow{B_S} + \overrightarrow{B_N}$ vector notation

In magnitude $|\vec{B}| = B = \sqrt{B_N^2 + B_S^2 + 2B_N B_S cos2\theta}$, 2θ -----> angle between B_N and B_S

$$B = \sqrt{B_S^2 + B_S^2 + 2B_S B_S cos2\theta} = \sqrt{2B_S^2 + 2B_S^2 cos2\theta}$$

$$B = \sqrt{2B_S^2\,(1 + cos2\theta)} = \sqrt{2B_S^2\,(2\,COS^2\,\theta)}$$

$$B = \sqrt{4B_S^2\,COS^2\,\theta} = 2\,B_S\,\mathrm{COS}\theta$$

$$B = 2 \,.\left(\frac{\mu_0}{4\pi}\frac{m}{d^2+L^2}\right).\frac{L}{\sqrt{d^2+L^2}} = \frac{\mu_0}{4\pi}\frac{2mL}{(d^2+L^2)^{3/2}}$$

$$\boxed{B = \frac{\mu_0}{4\pi}\frac{M}{(d^2+L^2)^{3/2}}}$$

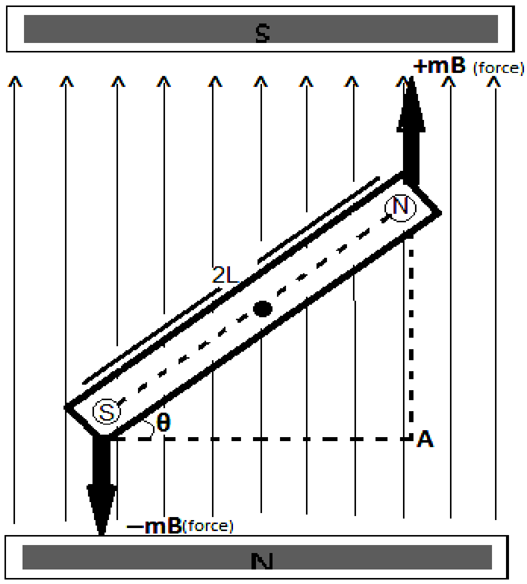
If d >> L then, $B = \frac{\mu_0}{4\pi}\frac{M}{(d^2)^{3/2}} = \boxed{B = \frac{\mu_0}{4\pi}\frac{M}{d^3}}$

----->Expression for Moment of COUPLE on a bar magnet placed in a uniform magnetic field:

Consider a magnet of pole strength ‘m’, length ‘2L’ placed in a uniform magnetic field of strength B, making angle ‘θ’ with the direction of field ‘B’.

Then North pole experiences a force +mB and south pole experiences a force –mB.

These two forces are equal in magnitude, opposite in direction and parallel to each other. These two forces form a couple. This couple of forces tends to rotate the magnet in the direction of ‘B’.



The Moment of couple on the magnet (C) = one of force X perpendicular distance between two forces.

$C = F \times SA = (mB)x(2L\sin\theta)$

$C = (2mL)\,B\sin\theta$

$\boxed{C = \mathbf{MB}\sin\theta}$, M=2mL=Magnetic moment

In vector form $\vec{C} = \vec{M} \times \vec{B}$

if a magnet is placed uniform magnetic field of magnetic induction 1 Tesla with an angle 90° then the couple on the magnet is same as magnetic moment of a bar magnet.

That is B =1,θ= 90° ------> C = M(1) sin90° -----> Couple C = M

Electricity & Magnetism Links

When two Magnets comes close together there happened a Moment in a Smaller Magnet

Dipole Moment (or)
Magnetic Moment $M = m \times 2l$

→ Pole strength $m = \frac{M}{2l}$ → Moment per unit length.

when a current 'I' flow in circular coil, then it turns about an axis.
→ it aquire magnetic Moment (Motion)

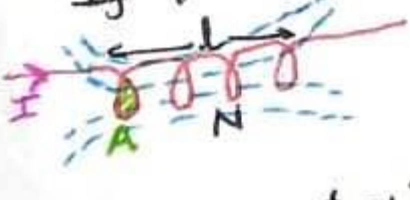
$M = \text{current} \times \text{Area}$

$M = IA$ → Units → $\text{Amp} \times \text{metre}^2$

∴ pole strength $m = \frac{M}{2l} \rightarrow \frac{\text{Amp} \times \text{metre}^2}{\text{metre}}$

m UNITS → Amp × metre.

If we take no. of turns (N) to form a coil.



no. of Magnetic lines (flux) is proportional to current pass it. (Continous)

$\phi \propto i \rightarrow \phi = Li \rightarrow$ Weber = Henry × Amp

L → Henry → Weber/Amp
(inductance) → 10^8 lines/Amp

Henry → 10^8 Maxwell/1Amp

inductance of the coil depends on no. of ~~coi~~ turns (N^2), Area of the coil (A), length of the coil (l).

$L \propto \frac{N^2A}{l} \rightarrow L = \mu_0 \frac{N^2A}{l} \rightarrow \mu_0 \rightarrow$ permeability

UNITS → $\mu_0 \rightarrow \frac{Ll}{N^2A}$ → Henry/metre

If there is discontinous current flows in a coil, then emf will be developed in it.

$$emf \propto \frac{dI}{dt} \Rightarrow emf = L\frac{di}{dt}$$

$$\text{UNITS} \rightarrow L \longrightarrow \frac{emf}{dI/dt} \rightarrow \frac{\text{volt} \times \text{sec}}{\text{Amp}}$$

$$\downarrow$$

$$\text{Henry} \rightarrow \frac{\text{volt} \times \text{sec}}{\text{Amp}} \rightarrow \frac{\text{weber}}{\text{Amp}}$$

$$\therefore \underset{(\phi)}{\text{flux}} \rightarrow \text{weber} \longrightarrow \text{volt} \times \text{sec}$$

When Material of Area 'A' is placed in a uniform magnetic field of strength 'B' then a few lines can pass through it.

flux lines $\phi = \overline{B} \cdot \overline{A}$

$$\phi = B\,A\cos\theta$$

$$B \rightarrow \frac{\phi}{A\cos\theta} \rightarrow \text{weber}/m^2 \rightarrow \text{Tesla}\ (SI)$$

$$SI \rightarrow 1\ \text{Tesla} \rightarrow 10^8\ \text{maxwell}/m^2$$

$$CGS \rightarrow 1\ \text{Gauss} \rightarrow 1\ \text{line}/cm^2 \rightarrow 1\ \frac{\text{Maxwell}}{cm^2}$$

$$\therefore \text{Tesla} = \frac{10^8\ \text{lines}}{(100\,cm)^2} \rightarrow 10^4\ \text{lines}/cm^2$$

$$1\ \text{Tesla} = 10^4\ \text{gauss}.$$