UNIT - 9

Electrostatics And Magnetostatics :

Electrostatics →

It is a branch of physics that studies electric charges at rest. And electric field $\vec{E}$ is said to be an electrostatic field if;

i) $\vec{E}$ is independent of time.
ii) ~~$\vec{\Delta} \times \vec{E} = 0$~~ (iii) $\vec{\nabla} \times \vec{E} = 0$
$\vec{\nabla}$ i.e. curl $\vec{E} = 0$

Electric charge →

A charge is a fundamental characteristic property of elementary particles of matter, which can explain certain forces of interaction, and some types of interaction energy.

* Electric charge is a scalar quantity.
* Like charges repel each other while opposite charges attract each other.

5 marks

Coulomb's Law →

It states that " The electrostatic force of attraction or repulsion between two charged bodies is directly proportional to the product of the charges and varries inversely as the square of the distance ~~between~~ in between the two bodies ".

* The force acts along the line joining the two charges.

Suppose two point charges q_1 and q_2 are situated at a distance r from each other in same medium. The magnitude of the electrostatic force (F) which one exerts on the other will be given by

$F \propto q_1 q_2$

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

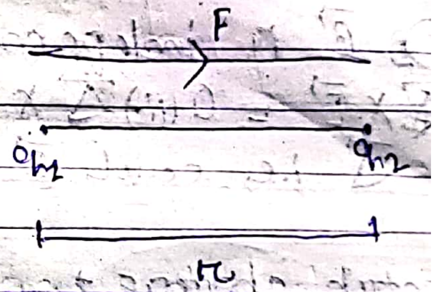


Figure. 1

Combining the above two we have;

$F \propto \frac{q_1 . q_2}{r^2}$

$$\Rightarrow \boxed{F = \beta \frac{q_1 q_2}{r^2}} \quad \text{(i)}$$

where β is a proportionality constant which depends on the nature of the medium in which the two charges are situated.

* Coulomb's Law is strictly truly for point charges only.

(i) In C.G.S (e.s.u) system,

$$B = \frac{1}{K}$$

where K = ~~directly~~ dielectric constant of the medium.

Hence $F = \frac{1}{K} \cdot \frac{q_1 q_2}{r^2}$ —— (ii) (for any medium)

In free space, $K = 1$

$\Rightarrow F = \frac{q_1 q_2}{r^2}$ —— (iii) (for free space)

(ii) In S.I Unit →

$$B = \frac{1}{4\pi\varepsilon} = \frac{1}{4\pi\varepsilon_0\varepsilon_r}$$

* while ε_0 or ε_r are the absolute permitivity and relative permitivity respectively.

Hence $F = \frac{1}{4\pi\varepsilon_0\varepsilon_r} \cdot \frac{q_1 q_2}{r^2}$ (iv) (for any medium)

for free space $\varepsilon_r = 1$

$F = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}$ —— (v) (for free space)

∴ The electrostatic force of attraction and repulsion of between two charged bodies is directly proportional to the product of their charges and varries inversely as the square of distance between the two bodies.

5 Marks

Unit charge :-

(i) In SI Unit the unit charge is called a coulomb (C).

The value of $\boxed{\frac{1}{4\pi\varepsilon_0} = 9\times10^9 \frac{Nm^2}{C^2}}$ —(vi)

We know that in free space

$$F = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}$$

Now if $q_1 = q_2 = q$, $r = 1$ metre and $F = 9\times10^9$ Newton

then $\rightarrow 9\times10^9 = 9\times10^9 \frac{q^2}{1^2}$

$\Rightarrow q^2 = 1 \Rightarrow q = \sqrt{1} = \pm 1$ coulomb

"One coulomb of charge is defined as that charge which when placed in air at a distance of one metre from an equal and similar charge repels it with a force of $F = 9\times10^9$ Newton."

(ii) C.G.S system the unit charge is called statcoulomb.

One statcoulomb is defined as that amount of charge which when placed in air at a distance of one c.m. from a similar charge repels it with a force of 1 dyne.

2 marks

Relation between Coulomb and stat coulomb :-

$$\boxed{1 \text{ coulomb} = 3 \times 10^9 \text{ stat coulomb}}$$

Permittivity (ε) →

It is a characteristic of a medium which determines the capability of a medium to convey the effect of a charge, from point to another in the same medium.

* Greater the value of permittivity, smaller will be the effect of charge at a given point. It's value varies from medium to medium.

Absolute Permittivity (ε_0) :-

It is the permittivity of free space, its value

$$\varepsilon_0 = 8.859 \times 10^{-12} \frac{C^2}{N-m^2}$$

Unit of $\varepsilon_0 = \frac{C^2}{N-m^2}$

Relative permittivity (ε_r) :-

It is the ratio between permittivity (ε) of a medium to the permittivity of (ε_0) free space.

$$\boxed{\varepsilon_r = \frac{\varepsilon}{\varepsilon_0} \quad \text{or} \quad \varepsilon = \varepsilon_0 \varepsilon_r} \quad \text{---(ix)}$$

* ϵ_r has no unit
* For air $\epsilon_r = 1$

Electric Potential →

"Potential at any point in an electric field is defined as the work done in moving a unit positive charge from infinity to that point against the electric field, along any path".

$$V(\vec{r}) = \frac{W}{q} \quad \text{——— (x)}$$

If $q = 1$, $V(\vec{r}) = W$

$$V(\vec{r}) = -\int_{\infty}^{r} \vec{E}(\vec{r}) \cdot d\vec{l} \quad \text{——— (xi)}$$

SI unit of V = volt

Electric Potential difference →

"Potential difference between two points in an electric field is defined as the work done in taking a unit positive charge from one point to the other, against the electric field.

$$V(\vec{r}_B) - V(\vec{r}_A) = \frac{W_{AB}}{q} \quad \text{(x.iii)}$$

$$V(\vec{r}_B) - V(\vec{r}_A) = -\int_{\vec{r}_A}^{\vec{r}_B} \vec{E} \cdot d\vec{l} \quad \text{——— (xiii)}$$

Scanned with CamScanner

* SI unit of electric potential difference is "volt"

$$1\text{ volt} = \frac{1\text{ joule}}{1\text{ coulomb}}$$

Electric field →

"When an electric charge is placed at a point the properties of the space around the charge get modified. The modified space around an electric charge is called electric field."

✓ Strength of electric field or Electric field Intensity ($\vec{E}$)

The strength of an electric field at any point is ~~measured~~ measured by noting the force expressed by a unit positive charge placed at that point.

Let $\vec{F}(\vec{r})$ be the force experienced by a test charge 'q' placed at a point is " P ". Then electric field intensity $\vec{E}(\vec{r})$ at that point is given by;

$$\vec{E}(\vec{r}) = \frac{\vec{F}(\vec{r})}{q}$$

Dimension of $\vec{E} = \vec{E} = \frac{F}{q} = \frac{[M^1 L^1 T^{-2}]}{[A^1 T^1]}$

$= [M^1 L^1 T^{-3} A^{-1}]$

Dimension of $q = [A^1 T^1]$ $\left[\because I = \frac{q}{t} \Rightarrow q = IT\right]$

Units of $\vec{E}$ →

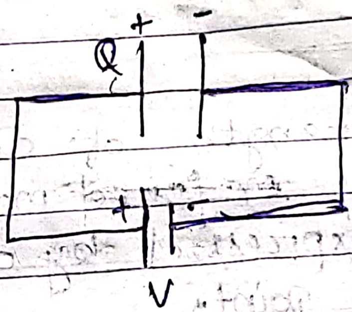
(i) SI unit → $\vec{E} = \frac{\vec{F}}{q} = \frac{\text{Newton}}{\text{Coulomb}}$

(ii) C.G.S Unit → $\vec{E} = \frac{\vec{F}}{q} = \frac{\text{dyne}}{\text{stat coulomb}}$

Capacitance →

Capacitance of a capacitor is defined as the ratio betwn the charge on the conductor to the potential difference between the plates

Capacitance $\boxed{C = \frac{Q}{V}}$ (xv)



Unit of capacitance →

(i) SI Unit → Farad (F)

$1 \text{ Farad (F)} = \frac{1 \text{ coulomb}}{1 \text{ Volt}}$

(ii) e.s.u unit → stat farad

$1 \text{ statfarad} = \frac{1 \text{ stat coulomb}}{1 \text{ stat Volt}}$

$\boxed{1 \text{ Farad} = 9 \times 10^{11} \text{ statfarad}}$

(iii) E.M.U unit → abfarad

$$1 \text{ abfarad} = \frac{1 \text{ abcoulomb}}{1 \text{ abvolt}}$$

$$\boxed{1 \text{ farad} = \frac{1}{10^9} \text{ abfarad}}$$

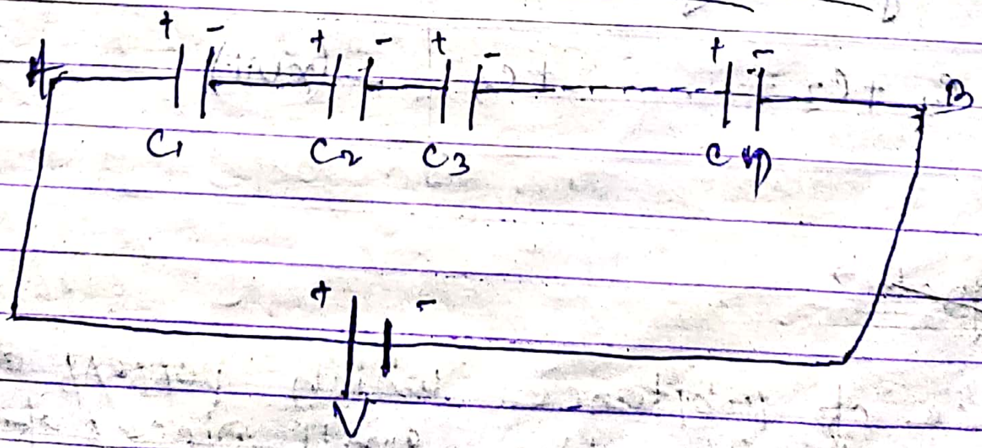
$$\left[\because 1 \text{ coulomb} = \frac{1}{10} \text{ abcoulomb},\quad \because 1 \text{ volt} = 10^8 \text{ abvolt}\right]$$

Dimension of capacitance :-

$$\text{Capacitance} = \frac{\text{Coulomb}}{\text{Volt}} = \frac{\text{Coulomb}}{\text{Joule/coulomb}}$$

$$\Rightarrow \frac{(\text{Coulomb})^2}{\text{Joule}} = \frac{[A^2T^2]}{[M^1L^2T^{-2}]} = [M^{-1}L^{-2}T^4A^2]$$

Series combination of Capacitors →



Suppose 'n' capacitor of capacitance $c_1, c_2, c_3 \ldots c_n$ are connected in a series as shown in the above figure, the effective capacitance of the total capacitance "c" is given by :-

$$\frac{1}{c} = \frac{1}{c_1} + \frac{1}{c_2} + \ldots + \frac{1}{c_n} \quad \text{—(xvi)}$$

Parallel combination of Capacitors :

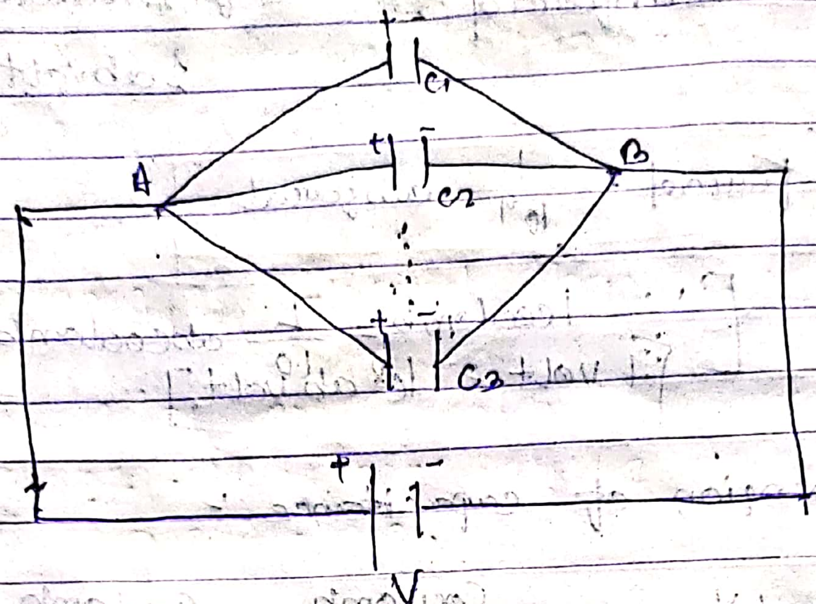


figure 3. Capacitors in parallel

Suppose n capacitor of capacitance $C_1, C_2, ... C_n$ are connected in paralel as shown in the effective capacitance of the total capacitance will be given by

$$\boxed{C = C_1 + C_2 + ... + C_n} \quad \text{(xvii)}$$

Magnet :

A piece of substance which posses of the property of attracting small pieces of iron towards it, is called a magnet.

Properties of a Magnet :-

→ A magnet possess the following properties

(i) Two poles of a magnet :-

A magnet has two poles one is north pole (N) while second is south pole (S)

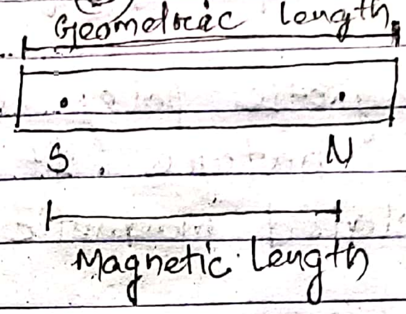


fig. 4 Magnetic pole (N) (S)

Phase to phase length of a magnet is called geometric length while pole to pole length is called the magnetic length of the magnet.

$$\boxed{\text{Magnetic length} = \frac{7}{8} \times \text{geometric length}}$$

(ii) Attracting property of a Magnet :-

A magnet is capable of attracting small pieces of iron towards it. These pieces are attracted towards both north as well as south pole. This attraction is greatest at the poles and decreases as we moved towards the centre of the magnet.

(iii) Directional Property of a Magnet →

When freely suspended the north pole of a magnet points towards geografic north while south pole points towards geografic south.

(iv) No existance of Isolated Magnetic poles →

The magnetic poles exist only in pairs of opposite nature. It is not possible to obtain an isolated magnetic pole.

(v) Nature of force between two Poles →

The nature of force between similar poles is ripels it, while opposite poles is attrac ~~i.e. that is like poles ripels~~ each ~~o~~ other this is called basic law of magnetostatic.

Coulomb's Law of Magnetostatic →

It states that the magnitude of force between two magnetic poles varries directly as ~~their~~ the product of their poles strength and inversly as the square of the distance between them.

Consider 2 magnetic ~~of~~ poles of similar nature of strength M_1, M_2 separated by a distance r by each other the force of ripplision between them is

$$F \propto m_1 m_2$$

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

$$\Rightarrow F \propto \frac{m_1 m_2}{r^2}$$

$$\Rightarrow \boxed{F = k \frac{m_1 m_2}{r^2}}$$

where k is a properpnality constant.

In SI system, $k = \frac{\mu_0}{4\pi}$

$$\Rightarrow \boxed{F = \frac{\mu_0}{4\pi} \cdot \frac{m_1 m_2}{r^2}}$$

where $\mu_0 = 4\pi \times 10^{-7}$ wb A^{-1} m^{-1}.

μ_0 is called the absolute magnetic ~~permit~~ permeability of free space.

In C.G.S system $k = 1$

$$F = \frac{m_1 m_2}{r^2} \quad \text{---} (xx)$$

Above two eqns represents the mathematical forms of coulomb's Law of magnetostatics in S.I. and C.G.S system respectivity.

Unit Pole

We know that $F = \frac{\mu_0}{4\pi} \frac{m_1 m_2}{r^2}$

If $m_1 = m_2 = m$, $r = 1$ meter and $F = 10^{-7}$ N, then

$$10^{-7} = \frac{4\pi \times 10^{-7}}{4\pi} \times \frac{m^2}{(1)^2}$$

$$\Rightarrow m^2 = 1$$

$$\Rightarrow m = \sqrt{1} = \pm 1$$

"A unit pole is that pole which when placed in vacuum at a distance of 1 m. from a similar pole repels it with a force of 10^{-7} Newton."

Electric Potential

The work per unit of charge required to move a charge from reference point to a specified point is known as "electric Potential".

The work per unit of charge required to move a charge from reference point to a specified point is known as electric potential.

Unit charge →

The value of $\boxed{= \frac{1}{4\pi\varepsilon_0} = 9\times10^9 \frac{Nm^2}{C^2}}$

We know that in free space,

$$F = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}$$

If $q_1 = q_2 = q$ and $r = 1$ metre and $F = 9\times10^9 N$

$$\Rightarrow 9\times10^9 = 9\times10^9 \frac{q^2}{1^2}$$

$$\Rightarrow q^2 = (1)^2 \Rightarrow q^2 = 1$$

$$\Rightarrow q = \sqrt{1} = \pm 1 \text{ coulomb}$$

Electric field

When ~~and~~ an electric charge is placed at a point the properties of ~~charge~~ space get modified. The modified space is known as electric field.

Magnetic Field :-

Magnetic field of any magnetic pole is the space around it in which it's magnetic influence can be realised.

Magnetic Lines of Force :-

Lines of Force is the path along which a unit north pole would move in it were ~~so to act~~ free to do so.

Properties of Magnetic Lines of Force :-

(i.) Lines of force are directed away from a north pole and at direct towards a south pole

(ii.) Tangent at any point to the magnetic Lines of force, gives the direction of Magnetic Intensity at that point.

(iii.) Two Lines of force never cross each other

(iv.) 4π Lines of force start from a unit magnetic poles.

(v.) The more concentration of Lines represents stronger magnetic field.

Magnetic Flux (Φ)

It is the number of magnetic field lines passing through a surface.

$$\Phi = \int_S \vec{B} \cdot d\vec{s} \quad \text{——— (xxi)}$$

S.I. Unit of Φ is weber (wb) and C.G.S unit of Φ is maxwell.

Strength of Magnetic Field → ($\vec{B}$)

"Strength of magnetic field at any point is defined as the number of flux lines passing through a unit area placed normally to the flux lines at that point".

$$B = \frac{\text{Magnetic Flux}}{\text{Area}} = \frac{\Phi}{A} \quad \text{(xxii)}$$

* S.I. unit of B is Tesla or wb/m^2 and it's C.G.S unit is maxwell/cm^2.

Strength of magnetic field at any point is defined as the force experienced by a unit north pole placed at that point.

Magnetic Field Intensity ($\vec{H}$) →

Magnetic field intensity 'H' is given by;

$$\boxed{\vec{B} = \mu \vec{H}} \quad \text{——— (xxiii)}$$

In free space $\vec{B} = \mu_0 \vec{H}$

$$\Rightarrow \vec{H} = \frac{\vec{B}}{\mu_0}$$

SI unit of magnetic field intensity (H) is

$\frac{\text{Ampere}}{\text{Meter}}$ (A/m)

UNIT - 10

:- Current Electricity :-

Electric Current (i) →

Current strength in a conductor is defined as the rate of flow of charge accross any crossection of the conductor.

If a charge "q" flows accross any crossection in "t" seconds, then current "i" is given by;

$$\boxed{i = \frac{q}{t}} \quad -(i)$$

* Electric current is considered to be a scalar quantity.

* SI unit of current is Ampere / coulomb/sec

It states that: "at constant temperature the current flowing through a conductor of uniform ~~area~~ of crossection is directly proportional to the difference of potential across the two ends of the conductor."

Let V = potential difference across the two ends of the conductor. I = current flowing through the conductor.

According to Ohm's law

$i \propto V$

$\Rightarrow i = \frac{1}{R} V$

$\Rightarrow \boxed{V = iR}$ —— (ii)

Where R is known as the resistance of the conductor.

* SI unit of resistance ohm.

$(\Omega)\ 1\text{ohm} = \frac{1\text{volt}}{1\text{ampere}}$

Applications of Ohm's law

(i) Ohm's law helps us in determining either voltage, current or resistance of a linear electric circuit when the other two quantities are known to us.

(ii.) Ohm's law makes power calculation simpler

If the current I ampere flows through a resistance and V is the voltage across the resistance then power is given by;

$$P = VI \quad \text{—— (iii)}$$

Using Ohm's law we can write;

$$\left.\begin{aligned} P &= IR \times I = I^2R \\ P &= V \times \frac{V}{R} = \frac{V^2}{R} \end{aligned}\right\} \text{—— (iv.)}$$

(iii.) In voltage devider circuit ohm's law is used to devide the source voltage across the output resistance.

(iv.) Conventional domestic fan regulator is one very common device, where the current through the fan gets regulated by controling the resistance of the regulator circuit.

- Serise combination of resistors:

$R_1 + R_2 + R_3$

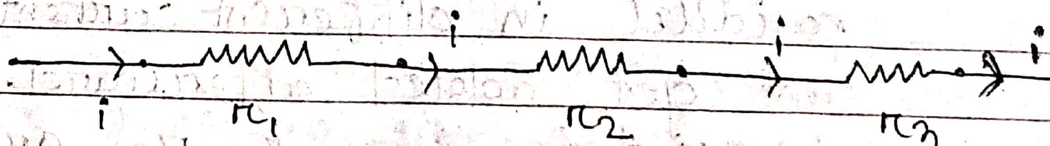


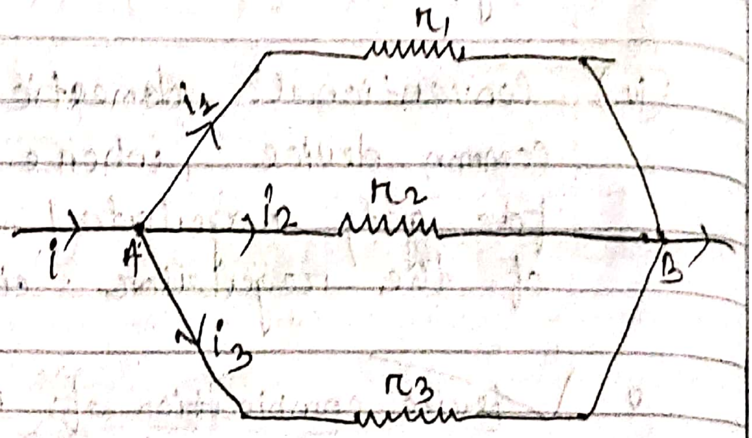
fig. 1 Resistances in

The resistance are said to be in series if same current flows through all of them. Consider resistors r_1, r_2, r_3 are connected in series each other as shown in the above figure. The effective resistance and total resistance is given by

$$\boxed{R = r_1 + r_2 + r_3} \quad \text{—— (v)}$$

Thus if a number of resistances are connected with series each other the net resistance is equal to the sum of their individual resistance.

Parallel combination of resistance :-



Resistance are said to be in connected to be parallel in different current flow through them, and get added afterward. Consider a number of resistance r_1, r_2, r_3 are connected to parallel to each other. The effective resistance of the total resistance R of the above combination is given by →

$$\boxed{\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}} \quad \text{—— (vi)}$$

Scanned with CamScanner

Theis if a number of resistances are connected in parallel the reciprocal of the resistance of the combination is equall to the sum of the reciprocals of their individual resistances.

Kirchoff's Laws →

~~First~~ Law :- (KCL)

Its states that the algebric sum of currents meeting at a point is "0". This law maybe called as kirchoff's current Law.(KCL)

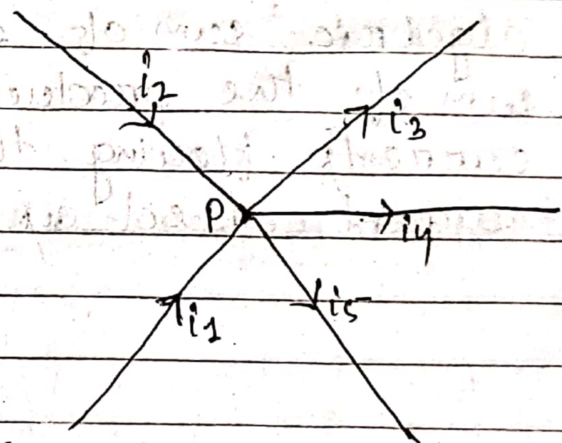


fig. 3. Currents meeting at a Point

To explain this Law consider a number of wires connected at a point "p". The currents i_1, i_2, i_3, i_4, i_5 flow through these wires in the direction as shown in the above figure.

To determine the algebric sum of electric current we follow the following sign conventions.

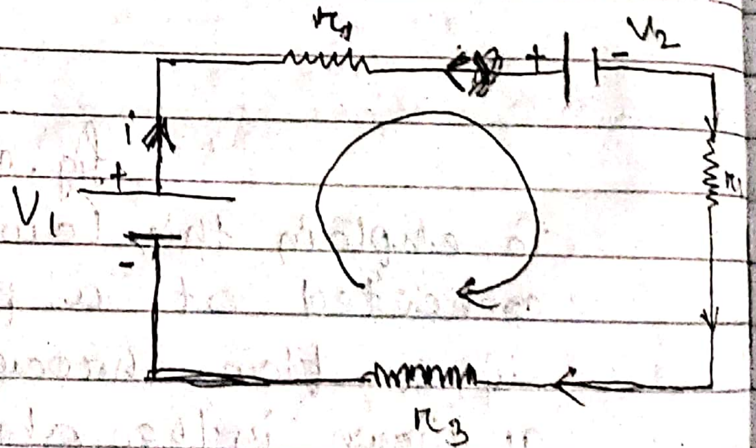
(i) The currents approaching a given point are taken as positive.
(ii) The current living the given point are taken as negative.

Then according to kirchoff's first law

$$\boxed{i_1 + i_2 - i_3 - i_4 - i_5 = 0} \quad \text{(vii)}$$

Kirchoff's voltage law:- (K.V.L)

It states that in a close electric circuit the algebric sum of (e.m.f) is equall to the algebric sum of the product of the registances and the currents flowing through them. This law may be called as kirchoff's voltage law.

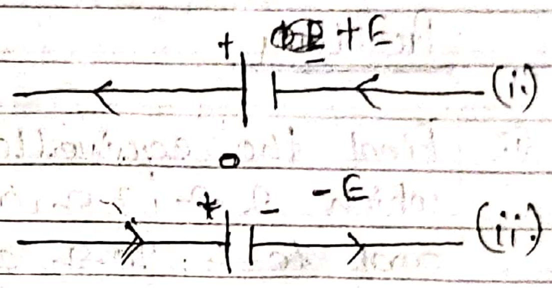


$$V_1 + ir_1 - V_2 + ir_2 + ir_3 = 0 \quad \text{(viii)}$$

In order to uses Kirchoff's voltage law, we shall follow the following sign convention.

(i) If the electric current flows through the cell from negative to positive terminal the emf of the cell is taken as (+E)

(ii) If the electric current flows through the cell from positive to negative terminal the emf of the cell is taken as (−E)



UNIT - 11

Electromagnetism And Electromagnetic Induction

Electromagnetism →

Electromagnetism is a branch of physics involving the study of electromagnetic force, a type of physical interaction, that occurs between electrically charged particles. The electromagnetic force is carried by electromagnetic fields composed of electric fields and magnetic fields.

* Electromagnetic force is responsible for electromagnetic radiation such as light and one of the four fundamentals interactions in nature.

$F_e = qE$ (Force on a charged particle in electric field)

$\vec{F_m} = q(\vec{v} \times \vec{B})$ (Force on a charged particle in magnetic field.)

$\vec{F_{em}} = q(\vec{E} + \vec{v} \times \vec{B})$ (Force on a charged particle in electromagnetic field)

Problems

(1) Find the equivallent resistance of 5 resisters of which 2Ω, 3Ω, and 5Ω are connected in serise and 10Ω, 20Ω are connected to parallel to them

(2) Find the total capacity when three capacitors of capacity 2 microfarad, 3, and 5 microfarad are connected into serise.

(3) Calculate the equivallent resistance of 5 register of 5Ω is connected in parallel.

(4) Calculate the equivallent capacitance between 3 capacitors of capacity 5, 10 microfarad and 0.3 milli farad connected in parallel.

(5) Find the equivallent resistance when three resisters of resistances 2Ω, 5Ω, and 10Ω are connected in parallel.

(6) Find the equivallent resistance between 5 register of 5Ω is connected in serise.

Scanned with CamScanner