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Chapter-19 Electric Charge

Electrostatics:-

Branch of physics that deals with the study of charge particale and its behaviour when it is at rest is called electrostatics.

Current: Alignment of electrons.

Types of Charge:

i) Positive charge: The kind of charge in which atoms lose electron is known as positive charge.

example: glass rod, fur, etc.

ii) Negative charge: The kind of charge in which atoms gain extra electron is known as negative charge.

$$Me = 9.3 \times 10^{-31} \text{ kg}$$

$$Mp \simeq Mn = 1.67 \times 10^{-27} \text{ kg}$$

Properties of electric charge

(i) Same charges repel each other and opposite charge attract each other. Therefore, the concept of repulsive and attractive force is originated.

(ii) Quantization of charge:

The charge of atom is always available in discrete form if atom has n number of electron with electronic charge e then total amount of charge of atom is $Q = ne$.

(iii) Charge always follows principle of conservation of charge.

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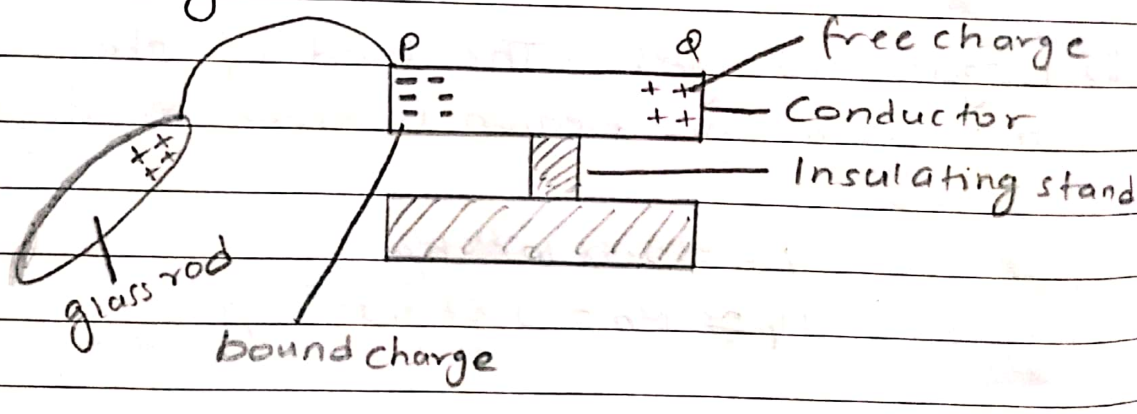
(iv) Magnitude of charge is not affected by speed of the body.

(v) Charge is scalar quantity. It is because it doesn't obey vector algebra.

Electrostatic's Induction

The temporary electrification of electric conductor when it comes ~~cho~~ close to any charge particle is known as electrostatic Induction. For eg: when silk is kept near to glass ~~and~~ rod then there is electric charge setup in rod and becomes chargeless when we remove silk.

Induced Charge



The amount of charge setup in conductor due to process of electrostatic induction is known as Induced charge.

In given experiment, the charge developed in close end (1^{st} end) of condultor is said to be bound charge & the same charge is developed at far end (2^{nd} end) is called free charge.

Charging by negatively Induction

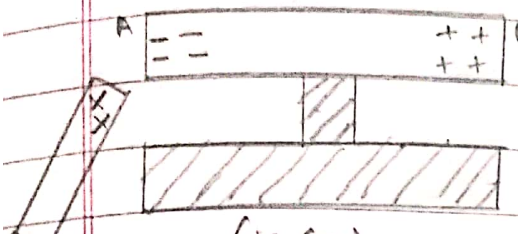


fig (a)

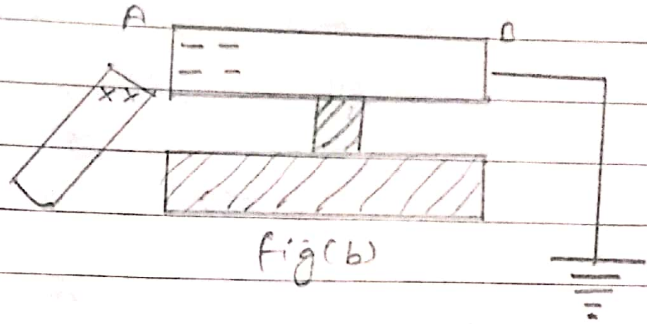


fig (b)

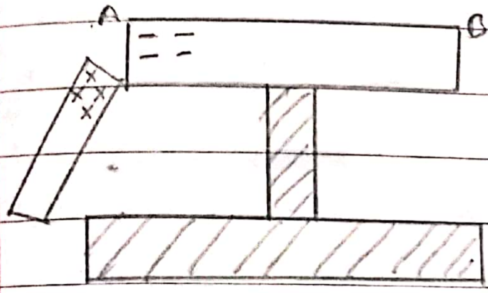


fig (c)

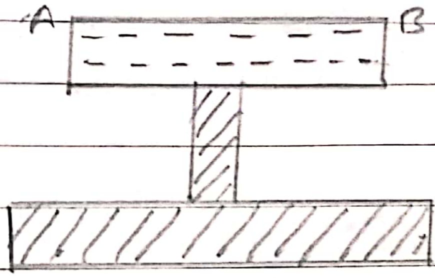


fig (d)

- Step 1: At first, A glass rod is rubbed with silk and placed close to conductor AB as shown in fig (a).
  It is clearly seen that bound charge and free charge is setup at two end of conductor.
  Step 2: The phenomena of grounding is applied from B such that positive charge are grounded.
  Step 3: As shown in fig (c) we removed the effect of grounding.
  Step 4: At last when we remove glass rod there is no effect of induced phenomena such that conductor becomes negative.

Linear Charge Density

The amount of charge per unit length of any conductor is known as linear charge density. It is denoted by 'λ' i.e. $\lambda = \frac{q}{l}$

Its unit is Cm^{-1}.

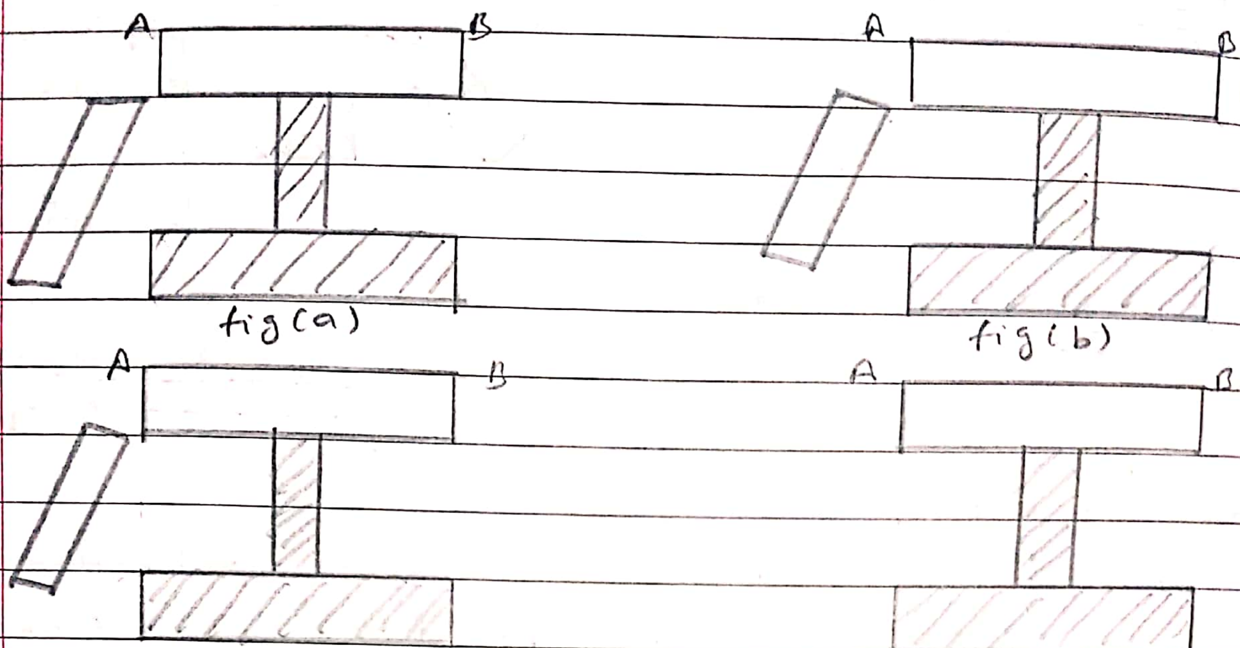


fig (c) fig (d)

Step: 1 At first the ebonite rod is rubbed with fur and placed close to conductor AB as shown in the figure (a). It is clearly seen that the bound charge and free charge is set up at two end of conductor.

Step: 2 The phenomena of grounding is applied from second (b) end such that negative charge are grounded.

Step: 3 As shown in fig (c) we remove the effect of grounding.

Step: 4 At last when we remove ebonite and there is no effect of Induced phenomena such that the conductor become negative.

The Surface Charge Density (δ)

The distribution of the charge particle along ~~the~~ any particular cross section area A is known as surface charge density.

Mathematically,

Surface Charge Density = $\frac{\text{Total charge along crosssection}}{\text{Area of crosssection}}$

$$= \frac{Q}{A}$$

It is denoted by σ.

It's unit is Cm^{-2}.

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Coulomb's Law

In 1875, the french scientist experimented verified the force of attraction and force of repulsion between two charge particle when it is placed at a certain distance so called Coulomb's law which states that:

The force of attraction & repulsion between two charges Q_1 and Q_2 at distance 'r' is ~~directly~~ inversely proportional to square of the distance between them.

i.e.

Q_1 ——— r ——— Q_2

$$F \propto Q_1 Q_2 \quad \text{——— (a)}$$

& $$F \propto \frac{1}{r^2} \quad \text{——— (b)}$$

Combining (a) and (b) we get;

$$F \propto \frac{Q_1 Q_2}{r^2}$$

$$F = k \frac{Q_1 Q_2}{r^2} \quad \text{——— (c)}$$

Where, k is proportionality constant which represent the state of medium used. In vaccum or free space (air) the value of k in S.I. unit is $k = \frac{1}{4\pi\varepsilon_0}$

Where, $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2N^{-1}m^{-2}$ is called permitivity of vacuum.

Then eq. © becomes,

$$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2}$$

which is required expression for Coulomb's force. But in case of CGS units, $k=1$ then $F = \frac{Q_1Q_2}{r^2}$ is required Coulomb's force.

$$\vec{F_{12}} = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r_{12}^2}\hat{r}_{12} = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r_{12}^3}\vec{r}$$

$$\hat{a} = \frac{\vec{a}}{|a|}$$

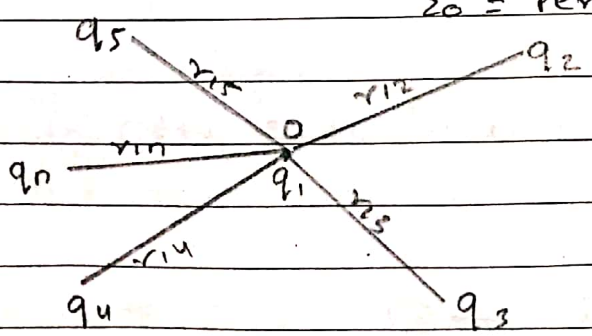
Relative Permitivity

Relative permitivity of any medium is defined as the ratio of permitivity of medium to permitivity of vacuum.

It is also called dielectric constant (k).

i.e. $K = \frac{\varepsilon}{\varepsilon_0}$ where, ε = Permitivity of medium

ε_0 = Permitivity of vacuum



Let us suppose point charge q_1 is at point O such that it experience multiple force $F_1, F_2, F_3 \ldots\ldots F_n$ due to presence of multiple charge.

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$q_1, q_2, q_3 \ldots q_n$ separated distance of $r_{12}, r_{13} \ldots r_n$ respectively. Then the total force exerted by point charge q is calculated by using principle of super position. i.e. net force is equal to vector sum of individual force.

i.e.

$$\vec{F} = \vec{F_1} + \vec{F_2} + \vec{F_3} + \vec{F_4} \ldots \vec{F_n}.$$

Chapter-20 Electric Field.

Electric Lines of Force.

The imaginary line due to any point charge (either +ve or -ve) from where if we draw tangent gives the direction for electric field is known as electric line of force.

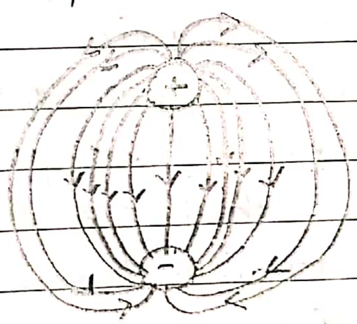

fig:- Electric line of force

Properties:

↳ It is imaginary line of force due charge

↳ It never intersect with each other.

↳ It starts from positive and end on negative charge.

Electric Field

The force experienced by unit point charge when it is placed inside the electric line of force is called

Electric Field. It is ~~dont~~ denoted by E. Point of charge q_0 is placed inside line of force F then electric field is defined as:

$$E = \frac{\text{Force due to charge}}{\text{Charge}}$$

$$E = \frac{F}{q_0}.$$

It's SI unit is NC^{-1}.

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Electric field due to point charge (q_0)

~~Let us~~ fig: Electric field due to point charge

Let us consider any charge particle having magnitude q is placed at point O. Another point charge q_0 is placed at point P at a distance of r from O. From point charge q_0 there are multiple line of force that can be drawn from where if we draw tangent we can assure the direction of electric field E.

The force exerted by point charge q_0 and charge q is given by Coulomb's law as

$$F = \frac{1}{4\pi\varepsilon_0}\frac{qq_0}{r^2}$$

Due to force F, there is certain value of electric field is generated which is $E = \frac{F}{q_0}$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q\cancel{q_0}}{r^2} \times \frac{1}{\cancel{q_0}}$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$

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which is required Expression for Electric Field due to point charge.

If point charge is placed at any medium having permitivity ε then.

$$E = \frac{1}{4\pi\varepsilon}\frac{q}{r^2} \quad \left(K = \frac{\varepsilon}{\varepsilon_0} \text{ or } \varepsilon = K\varepsilon_0\right)$$

$$E = \frac{1}{4\pi K\varepsilon_0}\frac{q}{r^2}$$

There are multiple charges $Q_1, Q_2, Q_3 \dots Q_n$ are present at a distance $r_{12}, r_{13}, r_{14} \dots r_n$ then the respective value of electric field is given by supperposition principle i.e.

$$\vec{E} = \vec{E_1} + \vec{E_2} + E_3 + \dots E_n$$

Electric Flux.

The total number of electric line of force passing through the surface Area when it is held perpendicularly to lines of force is known as electric flux.

It is denoted by ϕ.

It indicate the magnitude of electric field. It means that more the electric flux more will electric field and vice-versa.

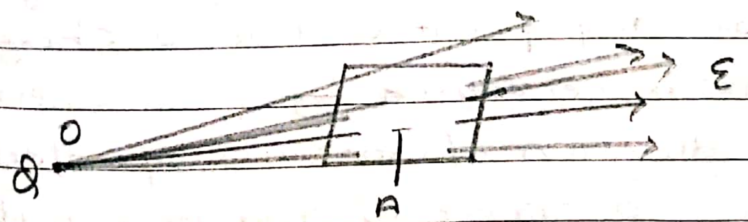

fig:- Electric flux

Let us consider point charge Q_0 is at point O which generate electric lines of force and allows to pass on surface area A perpendicularly then value of electric

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field will be.

$$E = \frac{\phi}{A}$$

i.e. $\phi = E \times A$

The unit of Electric Flux is $NC\,m^2$

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Gauss's Theorem

It states that total electric flux at any closed surface is equal to $\frac{1}{\varepsilon_0}$ times amount of charge present at that closed surface.

i.e. $\phi_c = \frac{1}{\varepsilon_0} \times Q$

$$\therefore \phi = \frac{Q}{\varepsilon_0}$$

Proof: (Electric flux due to point charge)

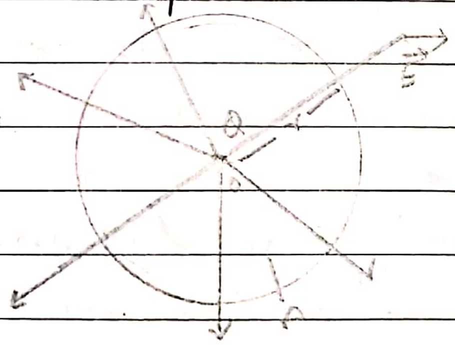

fig: Electric flux due to point charge.

Let us consider a point charge having charge Q is placed at any point O. Due to charge electric lines of force is generated ~~by~~ from where we can predict the direction of intensity of electric field. Let us suppose a sphere of radius r is drawn from point O such that Electric flux is measured in surface area A.

Then, electric flux ϕ is given by,

$$\phi = E \times A \quad \text{—(1)}$$

The total surface Area of sphere.

$$A = 4\pi r^2 \quad \text{--- (ii)}$$

& intensity of electric field due to point charge Q

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2} \quad \text{--- (iii)}$$

Using (ii) and (iii) in Eq. (i).

$$\phi = E \times A$$

$$= \frac{1}{\cancel{4\pi}\varepsilon_0}\frac{Q}{\cancel{r^2}} \times \cancel{4\pi r^2}$$

$$\therefore \phi = \frac{Q}{\varepsilon_0}$$

Electric field due to charged sphere.

i) When point lies outside sphere.

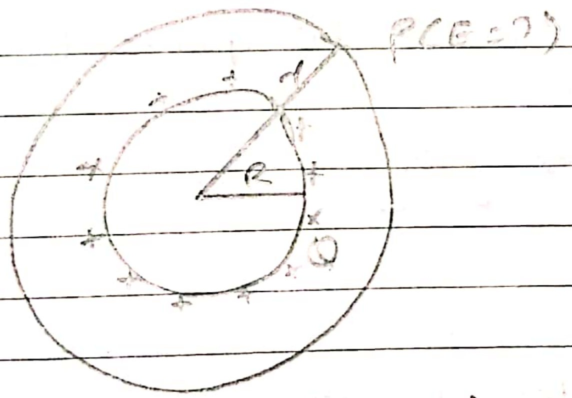

fig:- field when point is outside the sphere.

· Let us consider a charged sphere of radius R where total charge Q is distributed uniformly. Consider any point P outside the charged sphere with concentric radius 'r' from center O. The surface area covered by radius 'r' is consider as Gaussian sphere where total electric flux is distributed due to charge Q of charged sphere of R.

$$\phi = E \times A \quad \text{---(i)}$$

where,

$$A = 4\pi r^2$$

Acc. to gauses theorem the total electric flux is given by;

$$\phi = \frac{Q}{\varepsilon_0} \quad \text{---(ii)}$$

Equating (i) and (ii)

$$\phi = \phi$$

$$E \times 4\pi r^2 = \frac{Q}{\varepsilon_0}$$

$$E = \frac{1}{4\pi r^2 \varepsilon_0}$$

which is req^n Exp^n for electric field due to charged sphere when point lies outside sphere.

ii) When point lies at the sphere $(r = R)$

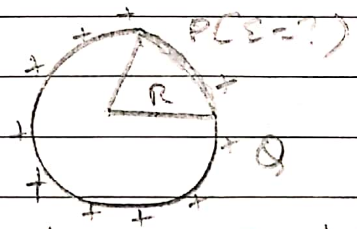

fig:- field when point is at the sphere.

Let us consider a charged ~~par~~ sphere of radius R where total charge Q is distributed uniformly. Consider any point p at charged ~~surface~~ sphere. The surface are covered by the radius r is considered as Gaussian sphere where total electric flux ϕ is distributed due to charge Q of charge sphere of R.

$$\phi = E \times A \quad \text{—(i)}$$

Where,

$$A = 4\pi R^2$$

Acc. to ~~gausses~~ gausses theorem the total electric flux is given by;

$$\phi = \frac{Q}{\varepsilon_0} \quad \text{—(ii)}$$

Equating eq (i) and (ii)

$$\phi = \phi$$

$$E \times 4\pi R^2 = \frac{Q}{\varepsilon_0}$$

$$E = \frac{1}{4\pi R^2 \varepsilon_0} Q$$

which is required expr for electric field due to charged ~~surface~~ sphere when point lies at the sphere.

iii) When point lies inside the sphere $(r<R)$

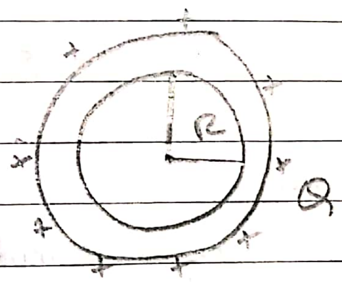

fig: field when point is inside the sphere.

Let us consider a charged sphere of radius R where total charge Q is distributed uniformly. Consider any point P inside the charge sphere with concentric radius 'r'. The area covered by small sphere (radius r) with area $(A = 4\pi r^2)$ is considered as Gaussian sphere. Since Gaussian surface doesn't enclosed any charge particle as shown in figure, then

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$$\Phi = E \times A \quad \text{--- (i)}$$

Where, $A = 4\pi r^2$

According to Gauss theorem the total Electric flux is given by:

$$\phi = \frac{Q}{\varepsilon_0}$$

Equating (i) and (ii)

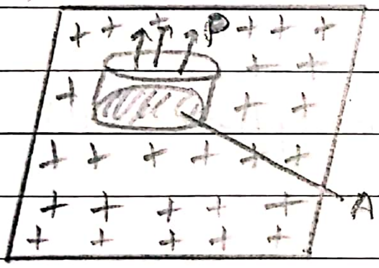
$$\Phi = \phi$$

$$E \times 4\pi r^2 = \frac{Q}{\varepsilon_0} \quad [Q=0]$$

$$E \times 4\pi r^2 = 0$$

$$\therefore E = 0$$

Electric field due to plane charged conductor.



Surface charge density

$$\sigma = \frac{Q}{A}$$

$$Q = \sigma \times A$$

fig: field due to plane conductor

Let us suppose plane charge conductor having charge Q in its upper surface. If P be any point outside the surface where Electric Field is to be determine.

For that let us assume two cylinderical outside the plane conductor which is perpendicular to plane and lower cylinderical surface is parallel to curve surface area. Let σ be surface charged density for cylinderical A therefore total amount of

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charge Q is $\sigma = \frac{Q}{A}$

$$\therefore Q = \sigma \times A \quad \text{— (i)}$$

If E be the electric field in the cylinderical area A then total flux in the plane conductor outside the surface is

$$\phi = E \times A \quad \text{— (ii)}$$

Then,

From Gauss's Theorem

$$\phi = \frac{Q}{\varepsilon_0}$$

or $E \times \cancel{A} = \frac{\sigma \times \cancel{A}}{\varepsilon_0}$

$$\boxed{\therefore E = \frac{\sigma}{\varepsilon_0}}$$

which is required expression for electric field due to plane charged conductor.

Electric field due Linear Charge Conductor

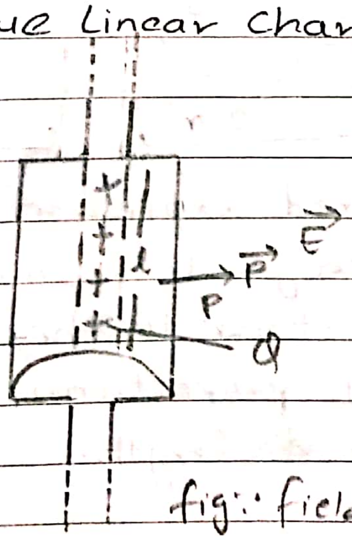

fig: field due to line charge.

Let us consider an infinitely long charge conductor as shown in figure. Our task is to calculate the electric field at any point P outside the conductor.

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for the length (l).

Let us draw a cylindrical surface at radius 'r' where linear charge create the field; we consider these area as gaussian surface.

If Q be total amount of charge over length 'l' then linear charge density 'λ' is given by:-

$$\lambda = \frac{Q}{l}$$

$$Q = \lambda \times l \quad \text{— (i)}$$

Since, carved surface area of cylinder is the Gaussian surface where electric lines of force passes normally then, tota total number of flux is given by:

$$\phi = E \times A$$

$$\phi = E \times 2\pi r l \quad \text{— (ii)}$$

Using Gauss's theorem

$$\phi = \frac{Q}{\varepsilon_0} \qquad [\text{using (i) \& (ii)}].$$

$$E \times 2\pi r \cancel{l} = \frac{\lambda \times \cancel{l}}{\varepsilon_0}$$

~~which is~~ $\cancel{\boxed{E = \frac{\lambda}{2\pi\varepsilon_0}}}$ $\boxed{E = \frac{\lambda}{2\pi r \varepsilon_0}}$

which is required expression for electric field due to linear charge. It seems that electric field is inversely proportional to the radius of gauss's surface & directly proportional to the amount of charge for given length.

Electric Potential

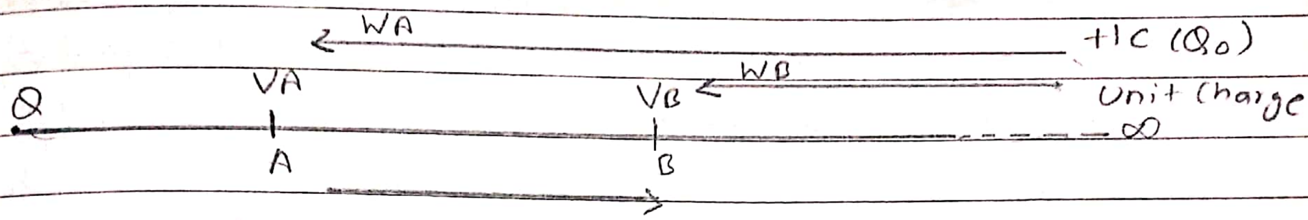

fig:- Electric potential

The amount of work done required to bring unit charge (test charge) in the region of electric field due to point charge Q from infinity is called Electric Potential. Let WA and WB be the amount of workdone due to unit charge when we bring it from infinity to point A and point B then respective potential due to point charge Q is given by VA and VB i.e.

Potential at point A $= \frac{W_A}{Q_0}$

Potential at point B $= \frac{W_B}{Q_0}$

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Electric Potential at point due to point charge.

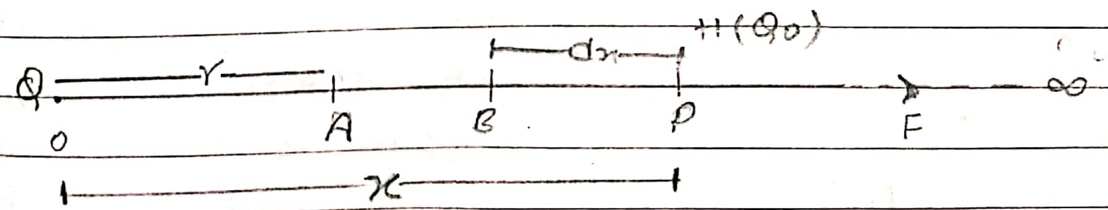

fig:- Electric Potential at point due to point charge.

Let us consider a point charge Q lies at point O which generate the electric field upto infinity. Consider a point P at distance 'r' where electric potential is to

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be determine. for that consider ~~two different point A and B.~~ test charge (unit charge) at a distance of x from point charge O. Also consider another point B at very ~~point B~~ small distance dx. If $W_{\infty A}$ be the amount of work done when we bring Q_0 from infinity point A. The coulomb's force due to charge Q_0 and Q is given by:

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q.1}{x^2} \quad \text{—(i)}$$

Since force cover small distance dx then small work done is given by.

$$dW = -F \times dx$$

Where, -ve sign indicates that work ~~done~~ is done against electrostatic force.

Total workdone from infinity to point A i.e. (at r)

$$W = \int_{\infty}^{r} dw$$

$$= \int_{\infty}^{r} -f dx = \int_{\infty}^{r} \frac{-1}{4\pi\varepsilon_0} \cdot \frac{Q}{x^2} \cdot dx$$

$$= \frac{-Q}{4\pi\varepsilon_0} \int_{\infty}^{r} \frac{1}{x^2} dx$$

$$W = \frac{Q}{4\pi\varepsilon_0} \left. \frac{x^{-2+1}}{-2+1} \right|_{\infty}^{r}$$

$$= \frac{Q}{4\pi\varepsilon_0} \left(\frac{1}{x} \right|_{\infty}^{r}$$

$$= \frac{Q}{4\pi\varepsilon_0} \left(\frac{1}{r} - \frac{1}{\infty} \right)$$

$$W_{\infty A} = \frac{Q}{4\pi\varepsilon_0 r} \quad \text{—(ii)}$$

But from the definition Electrical Potential is Equal to workdone (∞ - point)

$$V_A = W_{\infty A}$$

$$\therefore \boxed{V_A = \frac{Q}{4\pi\varepsilon_0 r}}$$

$\therefore$ This ~~the~~ is the required ~~equation~~ expression for the electric potential at point due to point charge.

* Potential difference betn two points.

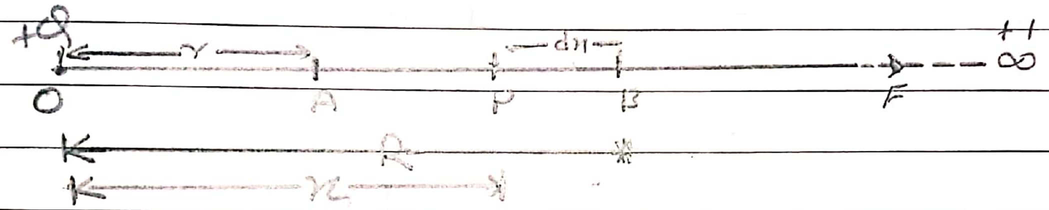

fig: Electric potential due to two points.

Let us suppose point charge Q is at point O which generate the electric line of force where Coulomb's force are active upto infinity. Let us consider two points A and B at a distance of r and R from point charge Q. The potential difference betn point A and B is equal to the amount of work done on bringing test charge (unit charge) from infinity & given by V_A & V_B.

i.e. $V_A - V_B = W_{BA}$ —— (i)

Let us consider small distance dx from point B to point P. Then small amount of workdone is given by dw i.e.

$$dw = -f dx \quad \text{—— (ii)}$$

Where, -ve sign indicate that work is done against electrostatic force. Total workdone due to test charge when we bring it from infinity to two different point at distance r and R is.

$$W_{BA} = \int_R^r dW$$

$$= \int_R^r -f\,dx \quad (\text{Using (ii)})$$

$$= \int_R^r -\frac{1}{4\pi\varepsilon_0}\frac{Q}{x^2}\,dx$$

$$= \frac{-Q}{4\pi\varepsilon_0}\int_R^r \frac{1}{x^2}\,dx$$

$$= \frac{-Q}{4\pi\varepsilon_0}\left.\frac{x^{-2+1}}{-2+1}\right|_R^r$$

$$\therefore W_{BA} = \frac{Q}{4\pi\varepsilon_0}\left.\frac{1}{x}\right|_R^r$$

$$W_{BA} = \frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{r}-\frac{1}{R}\right) \quad \text{--- (iii)}$$

from Eq. (ii) and (iii)

$$V_A - V_B = W_{BA}$$

$$\boxed{V_A - V_B = \frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{r}-\frac{1}{R}\right)}$$

which is reqd. Expn for p.d. for two pt. A & B.

* Potential gradients:

The differential value of potential difference with respect to distance (x,y,z) is known as potential gradient. i.e.

$$\text{Potential gradient} = \frac{dV}{dx} \Big/ \frac{dV}{dy} \Big/ \frac{dV}{dz}$$

Its unit is volt per meter (Vm^{-1})

$1J = 10^7 erg$

$\boxed{1 \text{ coulomb} = 3\times10^9 \text{ stat coulomb}}$

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* Unit of potential difference

from the definition of potential difference

Potential difference = $\frac{\text{Work done}}{\text{Charge}}$.

i.e. $V = \frac{W}{q}$

Since unit of W is Joule and unit of charge is coulombs. Then

$V = \frac{\text{Joule}}{\text{coulomb}} = \text{Volts}$.

for exam S.Q.

Define one Volts

Since from definition of potential;

$V = \frac{W}{c}$

if $W = 1J$ and $c = 1C$. then $V = 1$ volts.

Therefore, amount of energy generated due to bringing of 1 coulomb charge using 1 Joule (work done) is known as 1 volts.

* Relation between Volts and stat Volts.

Since,

$1V = \frac{1J}{1 \text{ coulomb}}$ ($1 \text{ cou} = 3\times10^9$ stat.coulo
$1J = 10^7$ erg)

$1V = \frac{10^7 \text{ erg}}{3\times10^9 \text{ stat coulomb}}$

$1V = \frac{10^7 \text{ erg}}{300\times10^7 \text{ stat}\cdot\text{coulomb}}$

$\boxed{1V = \frac{1}{300} \text{ stat Volt.}}$

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* Relation betⁿ Electric field and potential gradients.

The potential difference due to charge q at a distance r from test charge / unit charge is given by

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r} \quad \text{—— i)}$$

It implies that potential difference is inversely proportional to distance.

The rate of change of potential w.r.t x is given by;

$$\frac{dv}{dr} = \frac{d}{dr}\left[\frac{1}{4\pi\varepsilon_0}\frac{q}{r}\right]$$

$$\frac{dv}{dr} = \frac{q}{4\pi\varepsilon_0}\frac{dr^{-1}}{dr}$$

$$\frac{dv}{dr} = \frac{q}{4\pi\varepsilon_0}\left(-1 r^{-1-1}\right) \qquad \left[\frac{dx^n}{dx} = nx^{n-1}\right]$$

$$\frac{dv}{dr} = -\left(\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\right)$$

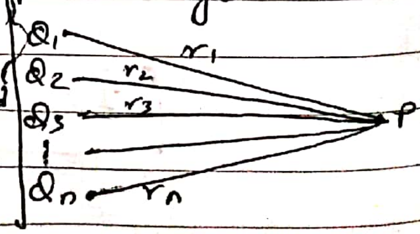
$$-\frac{dv}{dr} = E \quad \text{—— ii)}$$

where, $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$ is the amount of electric field at a point r.

Then from eqⁿ ii) it is clearly seen that electric field is equal to negative gradient of potential.

* Electric Potential due to multiple charges.

Consider a point 'P' where the multiple potential is developed due to charges $Q_1, Q_2, Q_3 \ldots Q_n$ at a distance of $r_1, r_2, r_3 \ldots r_n$.



{ lly → similarly }

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from P. If $V_1, V_2, \ldots V_n$ be the amount of potential developed at point P due to multiple charges then resultant potential V is given by the superposition principle which states that total/resultant potential is equal to the vector sum of individual potential i.e.

$$\vec{V} = \vec{V_1} + \vec{V_2} + \vec{V_3} + \ldots + \vec{V_n}$$

$$\vec{V} = \frac{1}{4\pi\varepsilon_0}\frac{Q_1}{\vec{r_1}} + \frac{1}{4\pi\varepsilon_0}\frac{Q_2}{\vec{r_2}} + \ldots + \frac{1}{4\pi\varepsilon_0}\frac{Q_n}{\vec{r_n}}$$

$$\vec{V} = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{\vec{r_1}} + \frac{Q_2}{\vec{r_2}} + \ldots + \frac{Q_n}{\vec{r_n}}\right]$$

which is required potential due to $Q_1, Q_2 \ldots Q_n$.

* Equipotential Surface

The surface where the value of potential is equal everywhere throughout the surface is known as Equipotential surface. Meaning that if we assume two point A and B on the Equipotential surface the from the definition;

$$V_A = V_B \quad \text{—— a)}$$

If any test charge is brought from point B to point A with the application of workdone W_{BA} (force due to charge Q) then amount of potential setup is.

$$V_{AB} = V_B - V_A \quad \text{—— (i)}$$

lly, $V_{AB} = W_{BA}$ —— (ii)

$$W_{BA} = V_B - V_A$$

$$W_{BA} = \cancel{V_B} - \cancel{V_B} \quad [V_A = V_B]$$

$$W_{BA} = 0$$

Hence throughout the Equipotential surface workdone is zero.

Capacitor

Every physical quantity in the nature possess some characterstics that tends to capture the charge in their body according as their nature, shape & size and distance between insulating medium. Such property of matter which try to store the charge in their body is called capacitance. The device used to store the charge is called capacitor. Capacitor consists of two plate separated by insulating medium like ~~micke~~ mica or air as below:-

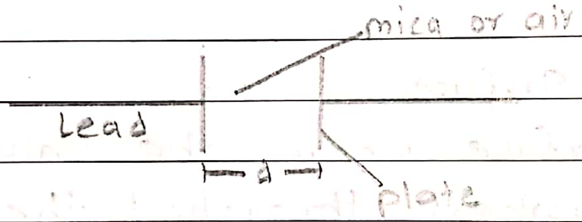

fig:- capacitor/symbol

The horizontal line connected On either side of plate is called lead. which is used to provide external voltage source.

* Capacitances of any capacitor.

Let us assume any capacitor of capacitances C is connected to the battery of potential difference 'V' then.

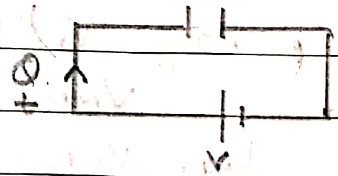

fig:- Capacitances of capacitor

Experimentally it is found that the charge store in capacitor over time 't' is directly proportional to the amount of potential difference used i.e.

$$Q \propto V$$

$\cancel{Q = \epsilon V}$ $\quad Q = CV$ — i)

where, c is proportionality constant so called capacitances of capacitor depend upon medium, shape & size and distance betn insulating medium.

From Eq. i)

$$Q = CV$$

$$C = \frac{Q}{V}$$

i.e. capacitances of any capacitor is mathematically Equal to the ratio of charged store per unit volt.

* Unit of Capacitor.

Since the capacitances is ratio of charge stored to the applied potential difference then,

$$C = \frac{Q}{V}$$

Since, Q is measured in Coulomb and p.d is in volts, the SI unit of c is CV^{-1}. It is ~~use~~ called farad (f). Since, farad is extremely large unit of capacitor. In practical purpose, we use micro farad (μf = ~~1~~ $10^{-6} f$)

$$1 \mu f = 10^{-6} f$$

$$1 \mu\mu f = 10^{-6} \times 10^{-6} f$$

$$= 10^{-12} f$$

$$= 1 pf$$

Since, $C = Q/V$

Capacitances of the capacitor in which capacitor store 1 coulomb of charge using 1 volt is called 1 farad.

i.e. $\boxed{C = \frac{1C}{1V} = 1f}$

Imp.

* Capacitances betn two parallel plate.

Let us consider two identical metallic parallel plate X and Y each having area A, with charge density σ. The metallic

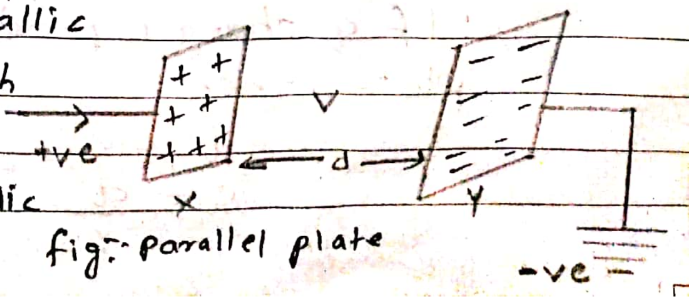

fig:- parallel plate

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plate Y is grounded whereas plate X is charged with positive source such that throughout the surface of X positive charges flows. As we know that whenever positive charges flows on neighbouring plate then there is induction of negative charge on plate Y such that there is V potential is setup between plate separated by distance of d. The amount of electric field E due to potential V is :-

$$E = \frac{V}{d} \quad \text{--- i)}$$

The Electric Field in plane conductor (x) using Gauss's theorems is given by

$$E = \frac{\sigma}{\varepsilon_0} \quad \text{--- ii)}$$

where, ε_0 is the permitivity of vacuum.
Since the relation ~~betn~~ of σ, q and A is

$$\sigma = \frac{q}{A} \quad \text{--- iii)}$$

Then, from Eq. i), ii) & iii)

$$E = \frac{\sigma}{\varepsilon_0}$$

$$\text{or, } E = \frac{q}{A\varepsilon_0}$$

$$\text{or, } \frac{V}{d} \ \cancel{\text{or } \frac{\sigma}{\varepsilon_0}} = \frac{q}{A\varepsilon_0}$$

$$\therefore \boxed{V = \frac{qd}{A\varepsilon_0}} \quad \text{--- iv)}$$

If q charges produces V potential on parallel plate then,

$$q = CV$$

$$\therefore C = \frac{q}{\frac{qd}{A\varepsilon_0}}$$

$$\boxed{\therefore C = \frac{A\varepsilon_0}{d}} \quad \text{--- v)}$$

which is required capacitances of parallel plate.
from eq^n v) it can be infer that capacitances increase when
i) Area of plate increase
ii) increase with ε_0, i.e. depends on medium.
iii) With decrease the distance bet^n plate.

Uses of Capacitor
i) Capacitor is mostly used in research purposes.
ii) It is mostly used in telecommunication for transmission and reception.
iii) It is used in electronic filter circuit.
iv) It is used in alternatic current (AC) circuit.

Types of Capacitor:
i) Cylindrical ~~Capaci~~ Plate capacitor
ii) spherical Plate Capacitor
iii) Parallel Plate capacitor

Elactances
The reciprocal of capacitance is called elactance. It is denoted by 'S' i.e.

$$\text{electance (S)} = \frac{1}{\text{Capacitance (C)}}$$

→ It's unit is F^{-1}.

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V.V.I

Combination of Capacitor

The arrangement of any capacitor by parallel or series means for desirable value of capacitance is known as combination of capacitor.

There are two types of combinations:-

(i) Series combination
(ii) Parallel Combination

V.V.I

(i) Series Combination

The combinations of capacitor in which 2nd terminal of first capacitor is connected to 1st terminal

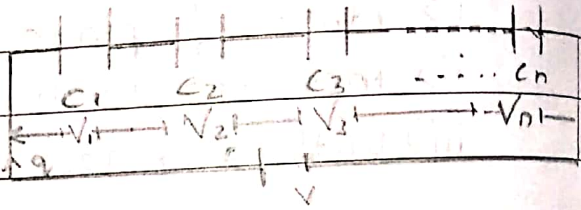

Fig:- Series Combination

of 2nd capacitor and so on is known as series combinations. Such that the connection is end to end. In such condition the same amount of charge is stored in all capacitor.

Let us consider different capacitor of capacitance $C_1, C_2, \ldots C_n$ is connected in series with battery source of potential difference V, such that q amount of charge flows through all capacitor. But in this case potential is drop along each capacitor by $V_1, V_2, \ldots V_n$ as shown in figure.

Then, total amount of potential in series combination is

$$V = V_1 + V_2 + V_3 + \ldots V_n \quad \text{——— (i)}$$

Since, the value of:

$$V_1 = \frac{q}{C_1}$$

$$V_2 = \frac{q}{C_2} \qquad [\text{since } Q = CV]$$

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$$V_n = \frac{q}{C_n}$$

If total capacitance of combination is given by C then total potential is reduced at $V = \frac{q}{C}$.

Then Eq (i) becomes,

$$V = V_1 + V_2 + \dots V_n$$

or, $\frac{q}{C} = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3} + \dots + \frac{q}{C_n}$

or, $\frac{q}{C} = q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots + \frac{1}{C_n}\right]$

or, $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots + \frac{1}{C_n}$

This is the required expression for total capacitance of series combination. If there are two capacitor of capacitance C_1 and C_2 are used in series. Then,

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\frac{1}{C} = \frac{C_2 + C_1}{C_1 C_2}$$

$$\boxed{\therefore C = \frac{\text{Product of capacitor}}{\text{Sum of capacitor}}}$$

Find capacitance when 7 Microfarad (μf) and 8 μf are connected in series.

Ans Soln,

Given: $C_1 = 7\mu f$

$C_2 = 8\mu f$

So, $C = \frac{C_1 C_2}{C_1 + C_2} = \frac{7 \times 8}{7+8} = \frac{56}{15} = 3.73\mu f$

V.V.I

(ii) Parallel Combination

The kind of combination of capacitor in such a way that all first terminal of capacitor are connected to first common point and all second terminal of capacitor connected to second common point of battery so that potential is same in all capacitor and charges is divided is known as parallel combinations.

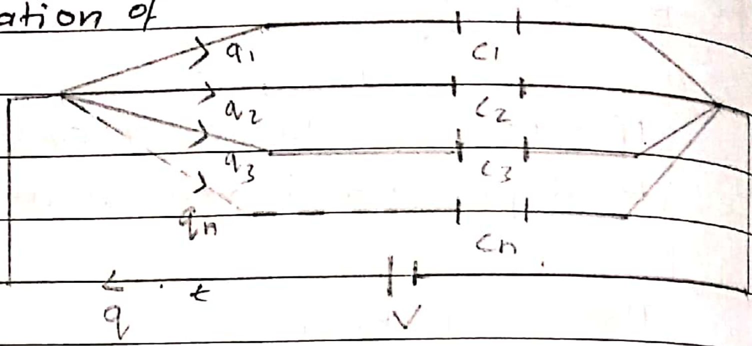

fig:- Parallel Combination

Let us consider a capacitor $C_1, C_2, \ldots C_n$ are connected in paralled combination with battery of emf V. Let q be amount of charge flowing in time 't' which is divided into $q_1, q_2 \ldots q_n$ such that potential in all capacitor is constant.

Therefore,

$$q = q_1 + q_2 + q_3 + \ldots + q_n \text{ --- Eq. (i)}$$

Since, $q = CV$

$q_1 = C_1 V$

$q_2 = C_2 V$

$\vdots \quad \vdots$

$q_n = C_n V$

Then Eq (i) becomes

$$q = q_1 + q_2 + \ldots q_n$$

$$CV = C_1 V + C_2 V + \ldots C_n V$$

$$C\cancel{V} = \cancel{V}(C_1 + C_2 + \ldots C_n)$$

$$\boxed{C = C_1 + C_2 + \ldots C_n} \text{ --- (ii)}$$

Hence, Equivalent Capacitance C is the sum of individual capacitor in parallel combinations.

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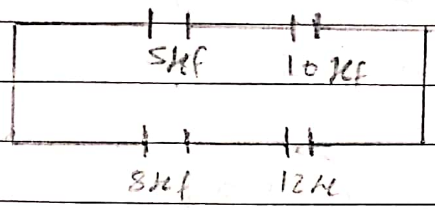
Imp Qn Calculate total capacitances of given circuit.



Soln,

$$C_{12} = \frac{C_1 C_2}{C_1 + C_2}$$

$$= \frac{5 \times 10}{5+10} = \frac{150}{15} = \frac{10}{3} \mu f$$

Also,

$$C_{34} = \frac{C_3 C_4}{C_3 + C_4} = \frac{8 \times 12}{8+12} = \frac{\cancel{8}^{2} \times 12}{\cancel{20}_{5}} = \frac{24}{5} \mu f$$

Therefore,

$$C_T = C_{12} + C_{34}$$

$$= \frac{10}{3} + \frac{24}{5}$$

$$= \frac{50+72}{15} = \frac{122}{15} \mu f$$

Imp.

Energy Store in Capacitor (3 marks)

Let us consider capacitor of capacitance (c) is connected to a battery of emf(V) such that Q amount of charge is stored in the capacitor such the value of capacitance is :-

$$q = CV$$

$$C = \frac{q}{V} \quad \text{—(i)}$$

If small charge ~~d(Q)~~ dq is stored in capacitor by small work done dW provided by voltage source of battery.

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$\therefore dw = v\,dq$ — (ii) $\left[\because V = \frac{W}{dq}\right]$

Total amount of work done to store charge of q is given by

$$\int_0^W dW = \int_0^q v\,dq$$

or, $$W = \int_0^q \frac{q}{c}\cdot dq = \frac{1}{c}\,\frac{q^2}{2}\Big|_0^q$$

$$\boxed{\therefore W = \frac{1}{2c}q^2} \longrightarrow a)$$

or, $$W = \frac{1}{2c}\cdot c^2v^2$$

$$\boxed{\therefore W = \frac{1}{2}cv^2} \longrightarrow b)$$

Also, we can write,

$$W = \frac{1}{2}(cv)\,v$$

$$\boxed{W = \frac{1}{2}qv} \longrightarrow c)$$

Eq. (a), (b) & (c) is the required work done which is stored in capacitor in the form of electrical energy.

Energy Density (u)

The energy stored by capacitor per unit volume is known as energy density. It is denoted by 'u' and its unit is J/m^3.

Q^n Prove that energy density of any capacitor is $U = \frac{1}{2}\varepsilon E^2$

Ans Let us consider two parallel plate capacitor such

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that there is d separation between the plate. If it q amount of charge is stored in the capacitor by the application of voltage V such that 'E' electric field is developed between the plate.

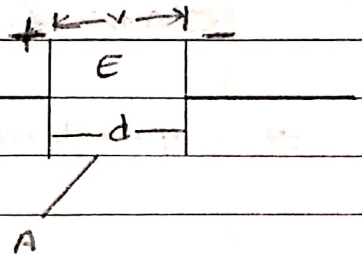

fig:- Energy density of capacitor

Then energy stored in capacitor per unit volume i.e. Energy density is:-

$$U = \frac{\text{Energy stored}}{\text{Volume}}$$

$$U = \frac{\frac{1}{2}CV^2}{V} \quad \text{--- Eq. (i)}$$

The capacitance between two parallel plate is:-

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

from Eq (i)

$$U = \frac{\frac{1}{2}CV^2}{A \cdot d}$$

or, $$U = \frac{1 \cdot CV^2}{2Ad}$$

or, $$U = \frac{1}{2Ad}\left(\frac{\varepsilon_0 A}{d}\right) \cdot V^2$$

or, $$U = \frac{1}{2}\varepsilon_0\left(\frac{V}{d}\right)^2$$

$$\boxed{\therefore U = \frac{1}{2}\varepsilon_0 E^2} \quad \left[\because E = \frac{V}{d}\right]$$

for any medium

$$\boxed{U = \frac{1}{2}\varepsilon E^2}$$

Hence, Energy density depends upon medium and

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electric field between the plate.

~~# Capacitance due to spherical capacitor~~

Electric Current

Electrical Current:-

The rate of change of charge flowing in any particular directions for some interval of time is known as electrical current.

Mathematically,

$$\text{Electrical current} = \frac{\text{Charge}(Q)}{\text{time}(t)}$$

It's unit is Cs^{-1} or Ampere.

From quantization of charge

$$Q = ne$$

Then, $$I = \frac{Q}{t}$$

$$I = \frac{ne}{t}$$

Hence, current is rate of flow of n number of electron.

Qn Why current cannot consider as vector even though it has direction?

Ans: Electric current doesn't follow law of vector algebra that's why it cannot consider as vector even though it has direction.

- The instanteous value of carrent is $\frac{dq}{dt} = dI$

Q^n Define 1 Ampere current.

Ans 1 ampere current is defined as flow of 1 coulomb charge per 1 sec throughout the electric circuit.

i.e. $I = \frac{Q}{t}$

$I = \frac{1C}{1sec} = 1$ Ampere.

Types of Current

There are two types of current on the basis of flow of current regarding the direction or frequency.

i) Direct Current:-

The type of current in which direction and magnitude remain constant for any interval of time.

Or,

Current with 0 frequency is known as DC.

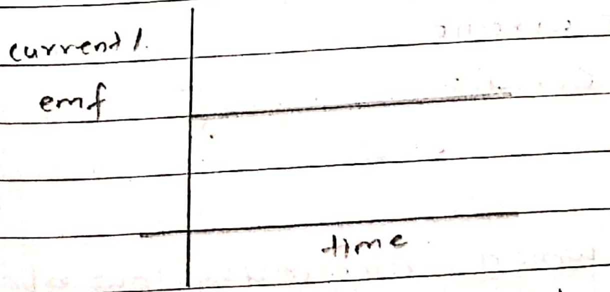
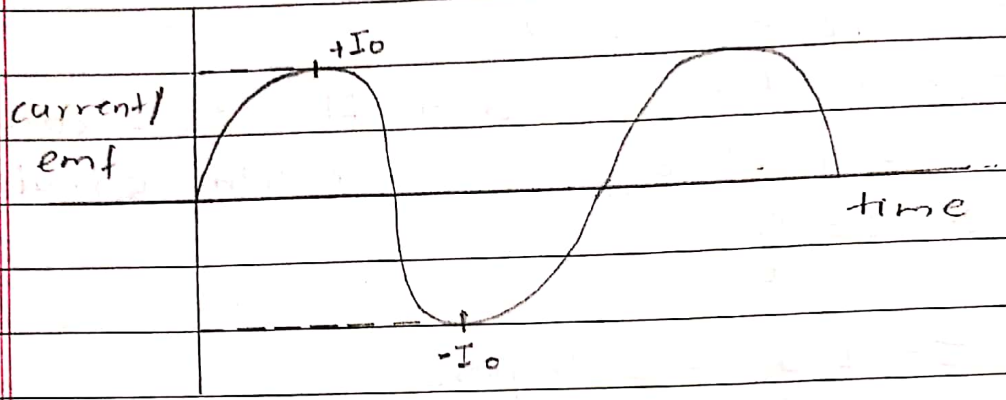


fig:- Direct current

ii) Alternating current (AC)

The type of current in which direction and magnitude reverse periodically is known as AC, Reason - It is due to the fact that alternating current has finite value of frequency.



Io = Peak value

Conventional flow of current.

It was believed that generally current flows from positive terminal to negative terminal. i.e. high voltage to low voltage. These kind of behaving the direction of current is known as conventional flow of current.

Electric Circuit

The path followed by electric current is called electric ~~current~~ circuit. There are two types of electric circuit.

i) Close Circuit
ii) Open Circuit

i) Close Circuit:

Circuit in which continuous flow of current makes load working is called close circuit.

ii) Open Circuit:

Circuit in which load doesn't work properly

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due to absence of current is known as open circuit.

Different symbols-

Bulb

Open Circuit

Closed Circuit

Resistor

Variable Resistor

Battery/Cell

Potential Divider

Capacitor

Inductor

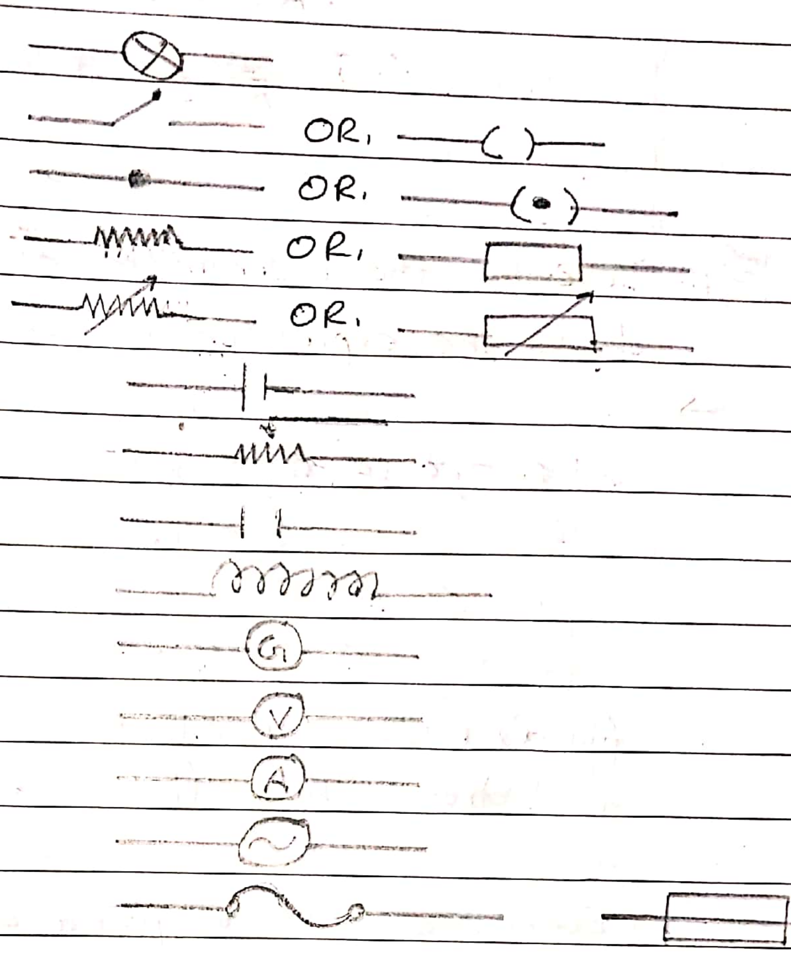
Galvanometer

Voltmeter

Ammeter

Alternating Current (AC)

Fuse



Current density

The physical parameter used to define the ratio of current per unit Area (A) of any electric circuits is known as current density.

It is denoted by J.

Mathematically,

$$J = \frac{I}{A}$$

Its SI unit is Ampere per m^2 (Am^{-2})

If we place any conductor A normally to the direction of current then:

$$\therefore A = \cos\theta$$

$$\therefore J = \frac{I}{A\cos\theta}$$

Imp # Describe the mechanism of metallic conduction and hence derive the expression for drift velocity.

→

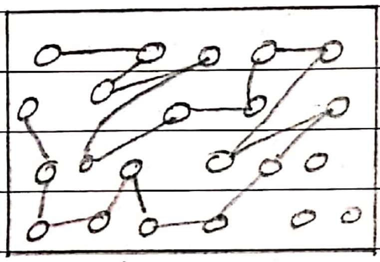


fig a) Random motion of electron without field.

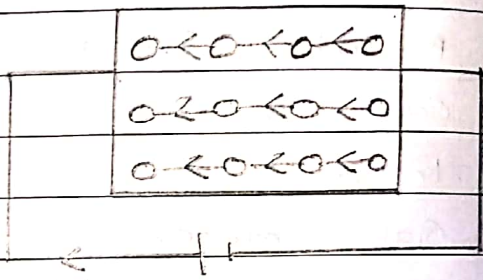


fig b) Motion of electron after Electric field

Every metal is composed of the neutron, proton and electron. Neutron is chargeless, Proton is positively charged and electron is negatively charged particle. Since electron is responsible for metallic conduction, there are about $10^{28} - 10^{31}$ free electron present in metal. If each and every free exite due to thermal collision. It start to move randomly in any direction as shown in fig (A) such that, net effect is zero. Therefore, no electric conduction is possible without electric field.

When we apply electric field all the electrons are alligned in particular direction such that every free electron start to move with the velocity opposite to applied electric field. These velocity is known as drift velocity. These velocity generate some K.E. which is converted into electric energy such that metallic conduction is possible due to the presence of electric field.

Relation betn drift velocity, ~~ant~~ current and current density ($J = nevA$).

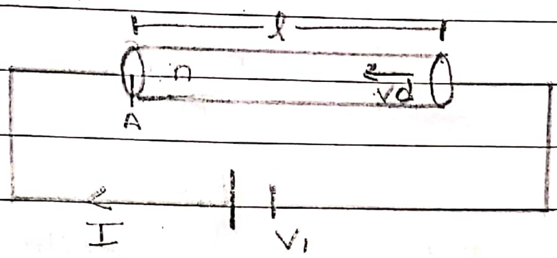


fig:- Drift Velocity

Let us suppose metallic conductor of length (L) and cross section Area (A) is connected to electric field of battery such that (I) amount of current flows through above circuits. The metallic conductor consists of n, no. of density which is the ratio of total number of electron to that volume. Then,

Volume of conductor (V) = $A \times l$

Total charge of metallic conductor (Q) = $N \times e$

Total no. of electron (N) = $n.Al$

Then, amount of current is given by,

$$I = \frac{q}{T}$$

$$I = \frac{Ne}{t}$$

$$I = \frac{nAle}{t}$$

$$I = nAe\left(\frac{l}{t}\right)$$

$\therefore I = nevA$, where, $v = \frac{l}{t}$.

which is required current due to ~~electric~~ drift velocity V_B.

Similarly,

$$\text{Current density } (J) = \frac{I}{A}$$

$$= \frac{nev\cancel{A}}{\cancel{A}}$$

$$= nev$$

which is required current density due to drift velocity V_B.

Ohm's Law:-

German scientist George simon Ohm's in year 1826 discovered the experimental verification for current and potential difference across the metallic conductor which states that "The potential difference betn two terminal of any conductor is directly proportional to the flow of current." i.e.

$$V \propto I$$

$$V = IR \quad \text{— Eq (i)}$$

Where, R is proportionality constant called Resistance which depends upon nature, length and Area of material.

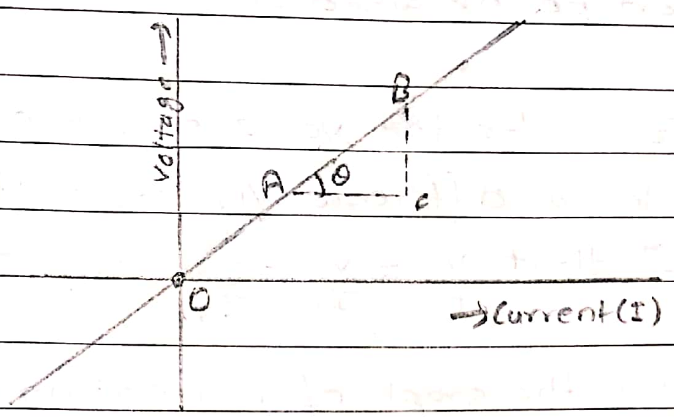
i.e. $R = \left(\frac{\rho L}{A}\right)$ ~~— Eq (ii)~~

If $I = 1$ Ampere

$V = R$

Hence, resistance of any material is the amount of potential difference when 1 ampere current ~~pass~~ flow through it.

The eqⁿ (I) is in the form of straight line passing through origin where in Y-axis we plot potential difference and in X-axis we plot current so that the given I vs V is



From the graph,

$$\tan\theta = \frac{BC}{AC}$$

The slope $\tan\theta$ gives the value for resistance. ($m = \tan\theta = R$)

Experimental Verification of Ohm's Law.

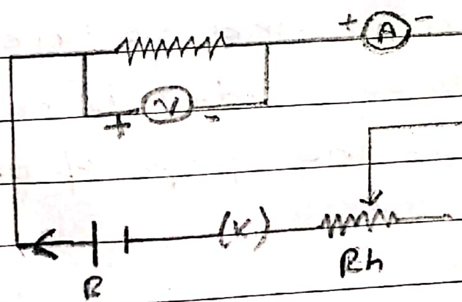


fig a) Current diagram for Ohms Law.

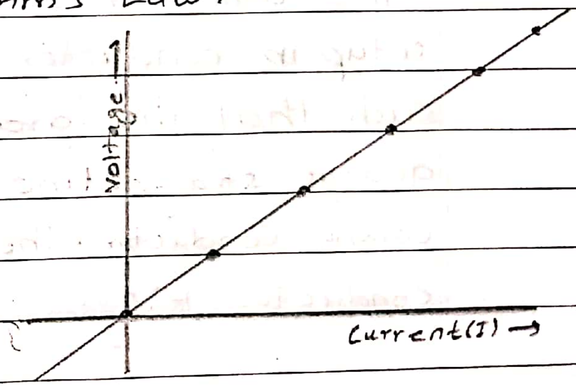


fig b) Graph of I Vs V.

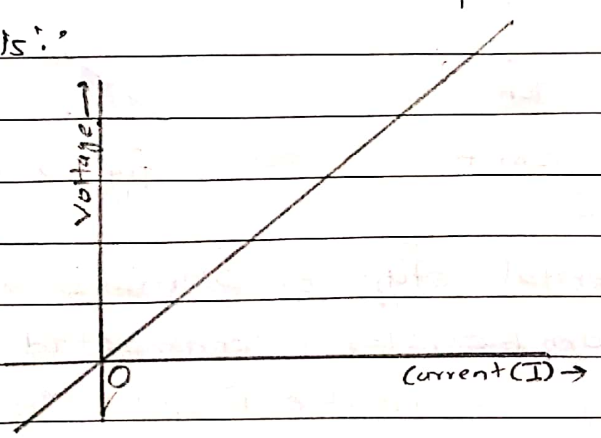
The experimental setup for ohm's law is given in figure above in which Resistor is connected in series with Battery (B), Key (K), variable Resistor (Rh) and finally with Ammeter (A). The volt meter is connected in parallel with Resistor so that voltage across R can be noted. Ammeter is used for detection of current. When key (k) is closed, the current is developed in Resistor (R) and corresponding value of voltage is noted. This process is repeated by maintaining different value of current. so that different voltage can be obtained at constant resistance (R).

Let I_1, I_2 ..... be the value of current for respective ~~poten~~ potential difference V_1, V_2..... at constant value of R such that $\frac{V_1}{I_1} = \frac{V_2}{I_2} = \frac{V_3}{I_3}$ ...... = Constant.

If we plot the graph of current and voltage in x and Y-axis respectively then, the nature of the graph is obtained as shown in fig (b) which is eq^n^ of straight line passing through origin. This expression confirms Ohm's Law.

Ohmic Conductor

The conductor which follows Ohm's Law i.e. voltage setup in conductor is directly proportional to current such that the graph of current and voltage is always straight line passing through origin is known as Ohmic Conductor. The nature of the graph of ohmic conductor is:-



Example:- Copper, Silver, Iron, Zinc, Gold, etc.

Non- Ohmic Conductor

The conductor ~~is directly proportional~~ which doesn't follow Ohm's law such that there is no linear relationship between Voltage and current is known as Non-Ohmic conductor. For example:- semiconductor, transistor, vacuum tube etc.

The I-V curve of Non-Ohmic conductor is:-

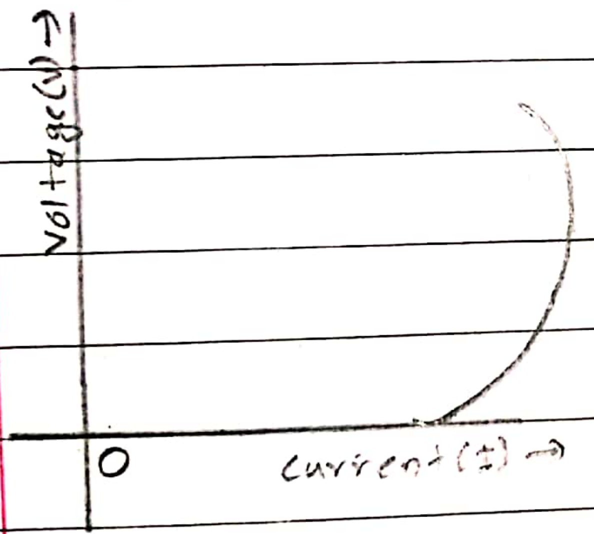


fig:- Semi-conductor

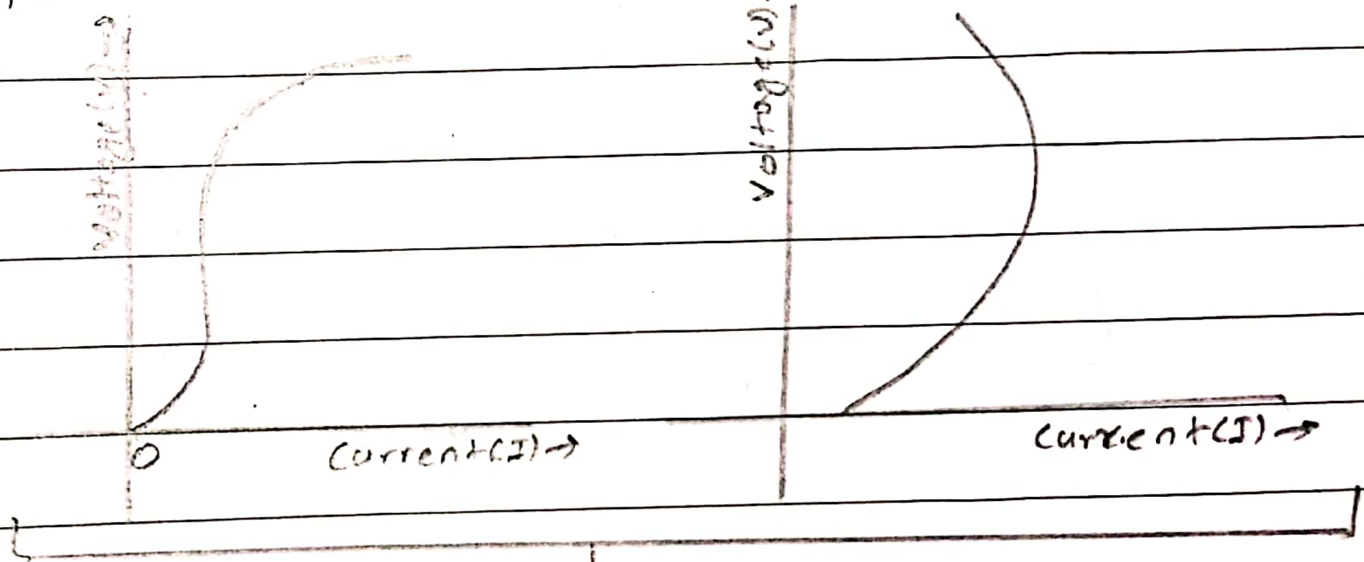


fig:- filament

V.V.IMP

* Combination of Resistor.

i) Series Combination of Resistor.

The combination of two or more than two resistors in which each and every resistors are connected to by end-to-end connection such that same amount of current flows through each resistor. is known as Series Combination

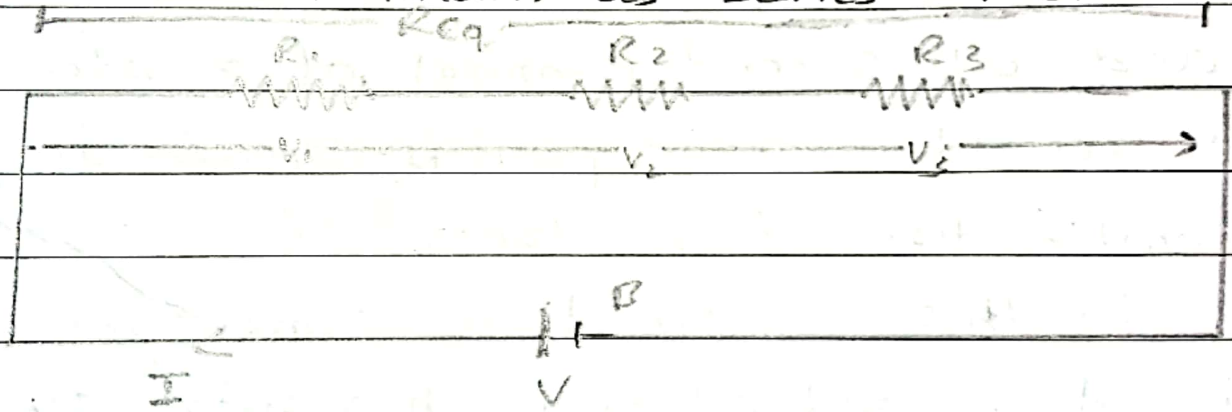


fig:- Series Combinations of resistor

Let us consider three resistors R_1, R_2 and R_3 are connected in series with battery of emf 'V' such that I amount of current flows through each resistor R_1, R_2 and R_3. In

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Eq. (ii) represents the Equivalent Resistance of parallel combinations of Resistors.

For two Resistors R_1 and R_2

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

or $$\frac{1}{R} = \frac{R_1 + R_2}{R_1 R_2}$$

$$\boxed{R = \frac{R_1 R_2}{R_1 + R_2} = \frac{\text{Product}}{\text{Sum}}}$$

Internal Resistance (r)

The total resistance offered by the battery or source is known as internal resistance (r). It is generally small value so in most of the case it is neglected.

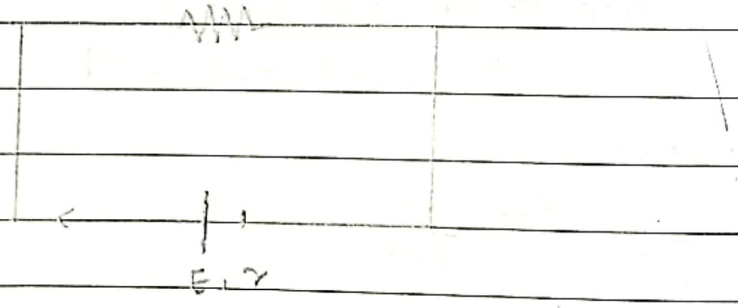


fig: Internal Resistance

Circuit formula / Relation betn E, V & r.

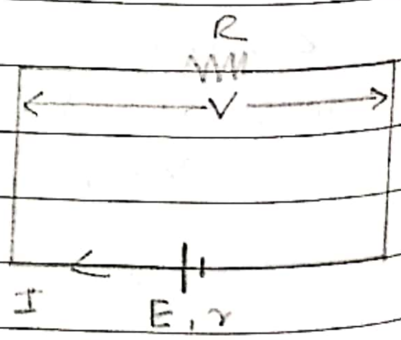


fig: Circuit formula

Let us consider a battery of emf E such that it oppose some amount of current with the value 'r' called internal resistance is connected to external resistor R. If V be the drop in potential at external resistance R.

then, from Ohm's Law.

$$E = I(R+r) \quad \text{——(i)}$$

$$I = \frac{E}{R+r} \quad \text{——(a)}$$

Since, Some potential gets dropped in resistor R then,

$$V = IR$$

Again, from Eq. (i)

$$E = I(R+r)$$

$$E = IR + Ir$$

$$E = V + Ir$$

$$I = \frac{E-V}{r} \quad \text{——(b)}$$

From Eq^n (a) and (b)

$$\frac{E}{R+r} = \frac{E-V}{r}$$

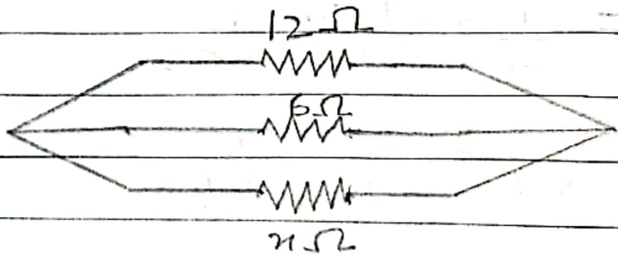
or $\cancel{Er} = ER - VR + \cancel{Er} - Vr$

or $Vr = R(E-V)$

or $\boxed{r = \frac{R(E-V)}{V}}$ ——(ii)

Hence, Equation (ii) is the required expression for circuit formula which gives the rel^n between emf E, potential V and External Resistance R.

Numerical



If Equivalent Resistance is 3 Ω, find x.

$$1/R = 1/R_1 + 1/R_2 + 1/R_3$$

$$\frac{1}{3} = \frac{1}{12} + \frac{1}{6} + \frac{1}{x}$$

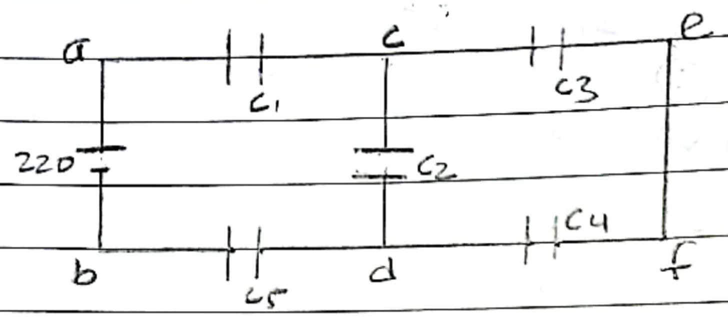
$$\frac{1}{3} = \frac{1+12}{12} + \frac{1}{x}$$

$$\frac{1}{x} = \frac{1}{3} - \frac{13}{12}$$

$$= \frac{4-3}{12}$$

$$\therefore x = 12\,\Omega$$

#



If $C_1 = C_5 = 8.4\,\mu f$

$C_1 = C_3 = C_4 = 4.2\,\mu f$

a) Find Eq. Capacitor between a and b.

b) What is the value of total charge.

⇒ Sol^n,

$$C_{ef} = \frac{C_3 \cdot C_4}{C_3+C_4} = \frac{4.2^2}{2\times 4^2} = \frac{4.2}{2} = 2.1\,\mu f$$

$\therefore$ Since C_2 and C_{cd} are in parallel.

$$C_{cd} = C_2 \parallel C_{ef}$$

$$= C_2 + C_{ef}$$

$$= 4.2 + 2.1$$

$$= 6.3\,\mu f$$

Now,

$$\text{or } \frac{1}{C_{ab}} = \frac{1}{C_1} + \frac{1}{C_{cd}} + \frac{1}{C_5}$$

$$\frac{1}{C_{ab}} = \frac{1}{8.4} + \frac{1}{6.3} + \frac{1}{8.4}$$

$$\therefore \frac{1}{C_{ab}} = 0.39\,\mu f.$$

Now,

$$Q = CV$$
$$= 0.39 \times 10^{-6} \times 220$$
$$= 8.58 \times 10^{-5} C$$

Potential Divider

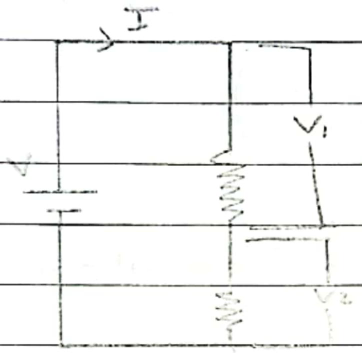


fig:- Potential Divider

Any Electrical circuits in which total Potential gets drop into different resistor is known as Potential Divider.

Consider two resistor R_1 and R_2 be connected in series with potential source of emf V in series as in figure.

Then total resistance of the circuit is

$$R = R_1 + R_2$$

Then the value of current is

$$V = IR$$
$$V = I(R_1 + R_2)$$
$$\therefore I = \frac{V}{R_1 + R_2}$$

Then, potential drop along R_1 is

$$V_1 = IR_2$$
$$V_1 = \left(\frac{R_2}{R_1 + R_2}\right) V \quad \text{--- (i)}$$

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Similarly, Potential drop along R_2 is

$$V_2 = I R_2$$
$$= \left(\frac{R_2}{R_1+R_2}\right) V \longrightarrow ii)$$

So,

$$V_1+V_2 = \left(\frac{R_1}{R_1+R_2}\right) V + \left(\frac{R_2}{R_1+R_2}\right) V$$
$$= V \left(\frac{R_1+R_2}{R_1+R_2}\right)$$
$$\therefore V_1+V_2 = V$$

∴ The Equations (i) and (ii) are the required value of divided potential.

Heating Effect of Current [Joules Law of Heating].

In ~~air~~ year 1841, Joule's experimentally verified that, when electric current is passed through any resistor, then certain amount of heat is generated in the resistor. These phenomena of heating of electrical component due to the presence of electric current is known as Joule's Law of Heating.

Joule's Law of Heating for any Resistor for certain amount of time, amount of heat is:

a) Directly proportional to square of Electric current i.e. $H \propto I^2$ — (i)

b) Directly Proportional to the Resistance of any resistor i.e. $H \propto R$ — (ii)

c) Directly proportional to the time for which Electric Current is passed i.e. $H \propto t$ — (iii)

Combining Eq. (i), (ii) & (iii), We get.

$H \propto I^2Rt$

$H = k I^2 Rt$

[where: k is proportionality constant in SI unit].

$\boxed{\therefore H = I^2Rt}$,

which is required value of heat energy due to Joule's Law of Heating.

In CGS Unit, $k = \frac{1}{J}$ then

$$\boxed{H = \frac{I^2Rt}{J}}$$

where, J is known as Joule's Mechanical Equivalent. Its value is 4.18 J/calorie (J/cal)

Electric Power

The rate of ~~charge~~ change of energy for any resistor due to the applications of electric current is known as electric power i.e. ~~Electric~~

Electric Power = $\frac{\text{Heat Energy (J.L.H.E)}}{\text{time}}$

$$P = \frac{I^2Rt}{t}$$

$$\boxed{P = I^2R}$$

Also,

$$P = I \cdot IR$$

$$\boxed{P = IV}$$

Finally,

$$P = I^2R$$

$$= \frac{V^2}{R^2} R$$

$$\boxed{\therefore P = \frac{V^2}{R}}$$

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Gravitation

The force of attraction between two heavenly bodies is known as gravitation.

Newton's Law of Gravitation

In year 1687, Newton's put forward the theory of gravitations in such a way that force of attractions between two mass m_1 and m_2 separated by distance R is directly proportional to product of mass and inversely proportional to square of the distances between them.

i.e. $F \propto m_1 m_2$ —— i)

$F \propto \frac{1}{R^2}$ —— ii)

then,

$$F \propto \frac{m_1 m_2}{R^2}$$

$$F = \frac{G m_1 m_2}{R^2}$$

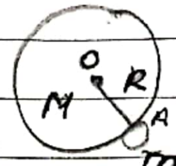
where, G is universal Gravitational constant with value $6.67 \times 10^{-11}\ Nm^2 kg^{-2}$.

Gravity :-

The force of attraction by heavenly body on another object ~~toward~~ toward its centre is called gravity.

~~Force~~

Force exerted on a body due to gravity is called weight.



Let us consider earth of mass $M (\approx 10^{24} kg)$,

fig:- ~~weight~~ calculation of g.

Also consider any object of mass 'm' at a distance 'R' from the ~~surface~~ centre of the earth. For any object there are two types of force, one is due to gravitational force and another one is due to gravity.

i.e. At point A;

wt = force of gravitation

$$\cancel{m}g = \frac{GM\cancel{m}}{R^2}$$

$$\boxed{g = \frac{GM}{R^2}} \longrightarrow i)$$

which is the required Expression for the acceleration due to gravity. It is clearly seen that g is function of Mass and Radius

From Equation i),

If Earth is ~~sr~~ considered as spherical with density ρ,

Since,

$$\rho = \frac{M}{V}$$

$$\rho = \frac{M}{\frac{4}{3}\pi R^3}$$

$$M = \frac{4}{3}\pi R^3 \rho$$

then. Eq i) Reduces as,

$$g = \frac{G\frac{4}{3}\pi R^3 \rho}{R^2} = \frac{4}{3}\pi R \rho G$$

$$\therefore \boxed{g = \frac{4}{3}\pi R \rho G}$$

This is the required expression interms of density for gravity 'g'.

Variation of g

① With altitude (height)

Let us assume, object of mass 'm' is placed at height 'h' from the surface of the earth. Then,

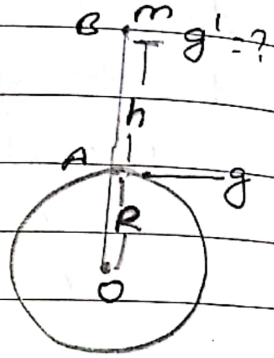


fig:- g due to h

Acceleration due to gravity at surface is:-

$$g = \frac{GM}{R^2} \quad \text{--- i)}$$

Then, Acceleration due to gravity at height (R+h) is

$$g' = \frac{GM}{(R+h)^2} \quad \text{--- (ii)}$$

Dividing (i) by (ii)

$$\cancel{\frac{g'}{g}} = \frac{g}{g'} = \frac{\frac{GM}{R^2}}{\frac{GM}{(R+h)^2}}$$

$$\frac{g}{g'} = \left(\frac{R+h}{R}\right)^2$$

$$\frac{g}{g'} = \left(1 + \frac{h}{R}\right)^2$$