IIT/EKLAVYA BATCH

THE GURUKUL INSTITUTE

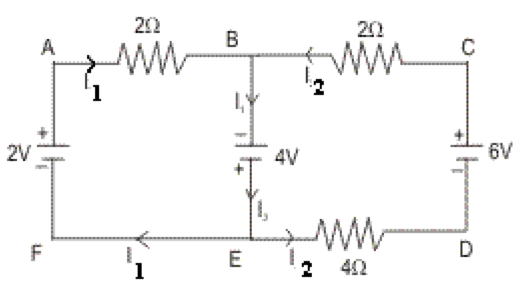
PLOT 5C, 2ND FLOOR, GANAPATI COMPLEX, SEC-13, OPP. JAIPURIA SCHOOL, VASUNDHARA, GHAZIABAD (U.P)PH. NO.9810780903

DAILY PRACTICE PROBLEM

ELECTROSTATICS

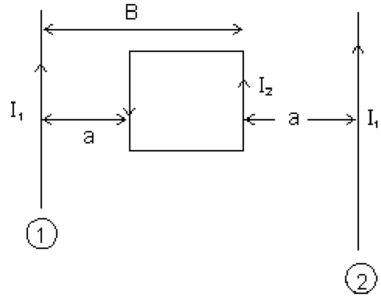
1. Write the S.I unit of : Electric field intensity and Electric dipole moment.
2. How does the coulomb force between two point charges depend upon the dielectric constant of the intervening medium?
3. Draw an equipotential surface for a system, consisting of two charges Q, -Q separated by a distance 'r' apart?
4. Show graphically the variation of charge 'q' with time 't' when a condenser is charged.
5. Electric charge is distributed uniformly on the surface of a spherical rubber balloon. Show how the value of electric intensity and potential vary
   a. On the surface
   b. Inside
   c. Outside
6. Explain the principle on which Van-de-Graaff generator operates. Draw a labeled schematic sketch and write briefly its working. A Van-de- Graaff type generator is capable of building up potential difference of 15×10^{6} V. The dielectric strength of the gas surrounding the electrode is 5×10^{7} Vm-1. What is the minimum radius of the spherical shell required?
7. An electric dipole is held in a uniform electric field.
   a. Show that no translatory force acts on it.
   b. Derive an expression for the torque acting on it.
   c. The dipole is aligned parallel to the field. Calculate the work done in rotating it through 180^{0}.

8. An electric dipole of length 10 cm having charges $\pm 6\times10^{-3}$ C, placed at 30^{0} with respect to a uniform electric field experiences a torque of $6\sqrt{3}$ N-m. Calculate:
   a. Magnitude of electric field
   b. The potential energy of the dipole.
9. Find the current in brand BE and potential difference V_{BD} in

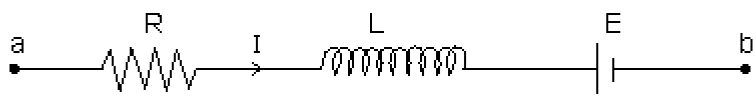


10. State Gauss's theorem in electrostatics. Apply this theorem to derive an expression for electric field intensity at a point near an infinitely long straight charged wire.
11. A non conducting sphere of radius R has a positive charge which is distributed over its volume with density $l = l_0\left(1-\frac{X}{R}\right)$ per unit volume, where x is distance from the center. If dielectric constant material the sphere is K=1, Calculate energy stored in surrounding space and total self energy of the sphere.
12. A non-Conducting disc of radius R and Surface charge density σ is placed on the ground with its axis vertical. A particle of mass m and positive charge q is dropped, along the axis of disc from height H with zero initial velocity. The particle has q/m= 4 e_0g/σ
    a) Find value of H if the particle just reaches the disc.
    b) Sketch the potential energy of the particle as a function of its height and find its equilibrium position.

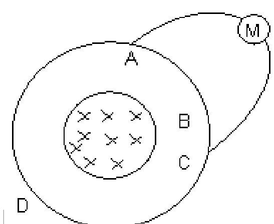
13. What is the work done in transferring the wire from position (1) to position(2) ?



14. In the circuit diagram shown in figure R = 10 Ω, L = 5 H, E = 20 V, I = 2 A. This current is decreasing at a rate of - 1 A/s. Find V_{ab} at this instant ?



15. A variable magentic field creater a constant e.m.f. E in a conductor ABCDA. The resistance of the portions ABC, CDA and AMC are R_1, $R_2$and R_3 respectively. What current will be shown by meter M ?



16. Find the self inductance of an ideal solenoid ?
17. Consider a cylindrical magnetic field which increases with time. Find out electric field at a distance r from its centre when
    (1) $r < R$
    (2) $r > R$
18. What orientation of an electric dipole in a uniform electric field would correspond to stable equilibrium?
19. If two similar plates, each of area A having surface charge densities $+\sigma$ and $-\sigma$ are separated by a distance'd' in air, write the expressions for
    i. The electric field at points between the two plates.
    ii. The potential difference between the plates.
    iii. The capacitance of the capacitor so formed.
20. A 20 µF capacitor is charged by a 30 V d.c. supply and then connected across an uncharged 50 µF capacitor. Calculate
    i. the final potential difference across the combination.
    ii. Initial and final energies. How will you account for the difference in energies?
21. A particle (mass = 2.5×10^{-15} kg) with a negative charge of 3.5×10^{-5} C is moved from the positive plate of a parallel plate capacitor to the negative plate, a distance of 2.5 cm.
    a. If the potential difference between the two plates is 15 volts, how much work is done in moving the particle?
    b. If the particle is released from the negative plate, it will accelerate toward the positive plate. What will be the velocity of the particle just before it strikes the positive plate?
    c. What is the strength of the electric field between the plates?

ECTROSTATICS

Questions having one mark each:

a. Write the S.I unit of
   i. electric field intensity
   ii. Electric dipole moment.
b. .
c. What orientation of an electric dipole in a uniform electric field would correspond to stable equilibrium?

Questions having 2 marks each:

a. Two point charges, q1 =10×10^{-8} C and q2 = -2×10^{-8} C are separated by a distance of 60 cm in air.
   i. Find at what distance from the 1st charge, q1, would the electric potential be zero.
   ii. Also calculate the electrostatic potential energy of the system.
b. Two capacitors of capacitance 6μF and 12μF are connected in series with a battery. The voltage across the 6μF capacitor is 2V. Compute the total battery voltage.
c. An electric dipole is free to move in a uniform electric field. Explain its motion when it is placed
   i. parallel to the field,
   ii. perpendicular to the field.
d. .An electric dipole of length 10 cm having charges ± 6×10^{-3} C, placed at 30^0 with respect to a uniform electric field experiences a torque of $6\sqrt{3}$ N-m. Calculate:
   i. Magnitude of electric field
   ii. The potential energy of the dipole
e. Electric charge is distributed uniformly on the surface of a spherical rubber balloon. Show how the value of electric intensity and potential vary
   i. on the surface
   ii. inside and
   iii. outside?

Questions having 3 mark each:

a. State Gauss's theorem in electrostatics. Apply this theorem to derive an expression for electric field intensity at a point near an infinitely long straight charged wire.
b. Explain the underlying principle of working of a parallel plate capacitor.
   If two similar plates, each of area A having surface charge densities $+\sigma$ and $-\sigma$ are separated by a distance'd' in air, write the expressions for
   i. The electric field at points between the two plates.
   ii. The potential difference between the plates.
   iii. The capacitance of the capacitor so formed.
c. A 20 μF capacitor is charged by a 30 V d.c. supply and then connected across an uncharged 50 μF capacitor. Calculate
   i. the final potential difference across the combination.
   ii. Initial and final energies. How will you account for the difference in energies?
d. The battery remains connected to a parallel plate capacitor and a dielectric slab is inserted between the plates. What will be the effect on its
   i. capacity
   ii. charge
   iii. potential difference
   iv. electric field
   v. energy stored?

e. Define the term electric potential due to a point charge. Calculate the electric potential at the centre of a square of side √2 m, having charges 100 µC, -50µC, and 20µC and-60µC at the four corners of a square.

Questions having 5 marks each:

a. Explain the principle on which Van-de-Graaff generator operates. Draw a labeled schematic sketch and write briefly its working. A Van-de- Graaff type generator is capable of building up potential difference of 15×10^6 V. The dielectric strength of the gas surrounding the electrode is 5×10^7 Vm-1. What is the minimum radius of the spherical shell required?

b. An electric dipole is held in a uniform electric field.

   i. Show that no translatory force acts on it
   ii. Derive an expression for the torque acting on it.
   iii. The dipole is aligned parallel to the field. Calculate the work done in rotating it through 180^0

Questions: 1. An electrostatic charge of 21 u C is placed at a distance in air of 15 cm
From a second charge. The force of attraction between the two charges is 26 N.

A. Calculate the magnitude of the second charge.

Sol) $q_1 = 21$ u C $= 21 \times 10^{-6}$ C
$q_2 = ?$, F = 26N, R = 15cm = 0.15m
Using $F = q_1 q_2 / 4\pi\varepsilon_o R^2$
$1/4\pi\varepsilon_o = 9 \times 10^9$ N-m^2-C^{-2}
Thus $F = 9 \times 10^9 q_1 q_2 / (0.15)^2$
or $26 = 9 \times 10^9 q_1 q_2 / (0.15)^2$
or $26 = 9 \times 10^9 \times 21 \times 10^{-6} q_2 / (0.15)^2 = 1.89 \times 10^5 q_2 / (0.15)^2$
or $q_2 = 26 \times (0.15)^2 / 1.89 \times 10^5$

or $q_2 = 3.1 \times 10^{-6}$ C = 3.1 µC

B If the distance between the charges is decreased to 5.0 cm, calculate the magnitude of the new force acting on each ball.

Sol) Force between the balls when distance is 15cm = F_1 = 26N, R_1 = 15cm
Let force between the balls when distance is 5cm be = F_2 , R_2 = 5cm
Using relation, $F = q_1 q_2 / 4\pi\varepsilon_o R^2$
we have $F_1 = q_1 q_2 / 4\pi\varepsilon_o R_1^{\ 2}$
and $F_2 = q_1 q_2 / 4\pi\varepsilon_o R_2^{\ 2}$
Thus $F_1 / F_2 = R_2^{\ 2} / R_1^{\ 2}$
or $26 / F_2 = 5^2 / 15^2 = 25 / 225 = 1/9$
or $F_2 = 26*9 = 234$ N

Now

2. An electron, moving through an electric field, experiences an acceleration of 6.3×10^3 m/s^2.

A. How much electrostatic force is acting on the electron?

Sol) Acceleration $a = 6.3 \times 10^3$ m/s^2.
Charge of electron = e = 1.6×10^{-19} C
Mass of electron = 9.1×10^{-31} Kg
Let Electric force be = F
Now F = ma
or $F = 9.1 \times 10^{-31} \times 6.3 \times 10^3 = 5.73 \times 10^{-27}$ N

B. What is the strength of the electric field?

Sol) Let strength of electric field be E
Now F = e E

but $F = 5.73 \times 10^{-27}$ N (as calculated above in part A)
or $E = F/e = 5.73 \times 10^{-27} / 1.6 \times 10^{-19}$
or $E = 3.58 \times 10^{-8}$ N/C

4. A 3.75×10^{-9} F capacitor carries a charge of 1.75×10^{-8} C

A. What is the potential difference across the plates?

Sol) $C = 3.75 \times 10^{-9}$ F
$Q = 1.75 \times 10^{-8}$ C
Now Using $Q = CV$ we have $V = Q/C = 1.75 \times 10^{-8} / 3.75 \times 10^{-9} = 4.67$ V

B. If the plates are 6.50×10^{-4} m a part, what is the strength of the Electric field between them?

Sol) Distance between the plates, $d = 6.50 \times 10^{-4}$ m
$V = 4.67$ V (as calculated above in part A)
Thus $E = V/d = 4.67 / 6.50 \times 10^{-4} = 7.18 \times 10^{3}$ V/m

5. A charge of –3.00 u C is fixed at the centre of a compass. Two Additional charges are fixed on the circle of the compass (radius = 0.100m). The charges on the circle are – 4.00 u C at the position due north and + 5.00 u C at a position due east. What is the magnitude and direction of the net electrostatic force acting on the charge at the centre?

Sol) $q = –3.00$ u C $= -3 \times 10^{-6}$ C
Bsdsd

A
C(q)
Here BC = AC = 0.1m
here charge q is placed at C (shown in above figure)
Let at point B which is north to C charge put be $= q_1 = -4$ uC $= -4 \times 10^{-6}$ C
also at point A which is east to C charge kept $= q_2 = 5 \times 10^{-6}$ C

Forces at charge q placed at point C due to charges at B and A are mutually perpendicular to each other.
$F_B = 9 \times 10^9 \, q.q_1 / R^2$
or $F_B = 9 \times 10^9 \times (-3 \times 10^{-6}) \times (-4 \times 10^{-6}) / (0.1)^2$
or $F_B = 10.8$ N long BC
Similarly force on q due to q_2 at B $= F_A = 9 \times 10^9 \, q.q_2 / R^2$
or $F_A = 9 \times 10^9 \times (-3 \times 10^{-6}) \times (5 \times 10^{-6}) / (0.1)^2$
or $F_A = 13.5$ N along CA
Thus total force F on charge q placed at C is given by
$F = 17.28$ N
The direction of the force is such that it makes an angle θ with CA given by
$\theta = \tan^{-1} F_A/F_B = \tan^{-1} 13.5/10.8 = \tan^{-1} 1.25$
or $\theta = 51.34$ degrees.
Hence the direction of the force F = 17.28 N is such that it makes an angle 51.34 deg with CA

6. A particle (mass $= 2.5 \times 10^{-15}$ kg) with a negative charge of 3.5×10^{-5} C is moved from the positive plate of a parallel plate capacitor to the negative plate, a distance of 2.5 cm.
A. If the potential difference between the two plates is 15 volts, how much work is done in moving the particle?
Sol) $m = 2.5 \times 10^{-15}$ kg
$q = -3.5 \times 10^{-5}$ C
Distance between the capacitor plates, d = 2.5 cm = 0.025 m
Potential difference between the plates, V = 15 volts

Thus intensity of electric field E = V/d = 15/0.025 = 600 V/m
Work done in moving the particle = W = F.d = qE.d
or W = qE.d = $3.5 \times 10^{-5} \times 600 \times 0.025 = 5.25 \times 10^{-4}$ J is the amount of work done in moving the particle.

B. If the particle is released from the negative plate, it will accelerate toward the positive plate. What will be the velocity of the particle just before it strikes the positive plate?

Sol) $m = 2.5 \times 10^{-15}$ kg
$q = -3.5 \times 10^{-5}$ C
V = 15 volts
E = 600V/m (as calculated above)
Now acceleration of the charged particle = a = qE/m
or $a = 3.5 \times 10^{-5} \times 600 / 2.5 \times 10^{-15}$
or $a = 8.4 \times 10^{12}$ m/s^2
Using the relation $v^2 - u^2 = 2aS$
here S = d = 0.025 m
u = 0
Thus $v^2 - 0 = 2 \times 8.4 \times 10^{12} \times 0.025$
or $v^2 = 4.2 \times 10^{11}$ m/s
or $v = 6.48 \times 10^5$ m/s

C. What is the strength of the electric field between the plates?

Sol) Electric field between the plates E = V/d = 15/0.025
or E = 600 V/m

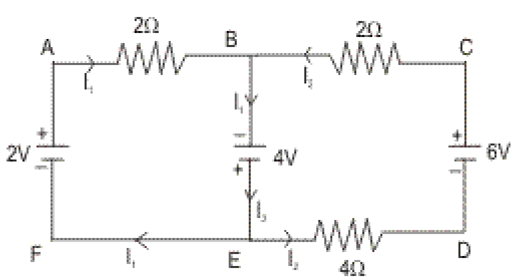
D. What force will be applied to the particle as it accelerates toward the Negative plate?

Sol) Force on the particle F is given by
F = qE
Here, $q = -3.5 \times 10^{-5}$ C

E = 600 V/m
Thus $F = 3.5 \times 10^{-5} \times 600$ N $= 2.1 \times 10^{-2}$ N = 0.021 N

ELECTRICITY

Illustration - 3. Find the current in brand BE and potential difference V_{BD} in.



Assume the shown current distribution.
We can choose arbitarily any type of distribution as we like.
Applying kirchoff's junction law at B (or at E).
We get : $I_1 + I_2 = I_3$ .... (1)
Applying kirchof's voltage law in the loop ABEFA: (clockwise direction)
We get :

$$2 - 2I_1 + 4 = 0$$
$$\Rightarrow 6 = 2I_1$$
$$\therefore I_1 = 3A \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Applying kirchoff's voltage law in BCDEB (Clockwise direction)
We get :

$$-4 + 2I_2 - 6 + 4I_2 = 0$$

$$\Rightarrow \quad 6I_2 = 10$$

$$\therefore \quad I_2 = \frac{5}{3}\ A \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

on solving (1), (2) and (3) :

$$I_3 = \frac{14}{3}\ A \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

For potential drop across V_{BD} :

$$V_{BC} = V_B - V_D$$

Let us search from B to D via C :

$$V_B + 2 \times \frac{5}{3} - 6 = V_D$$

$$\therefore \quad V_B - V_D = V_{BD} = 6 - \frac{10}{3}$$

$$= \frac{8}{3}\ V$$

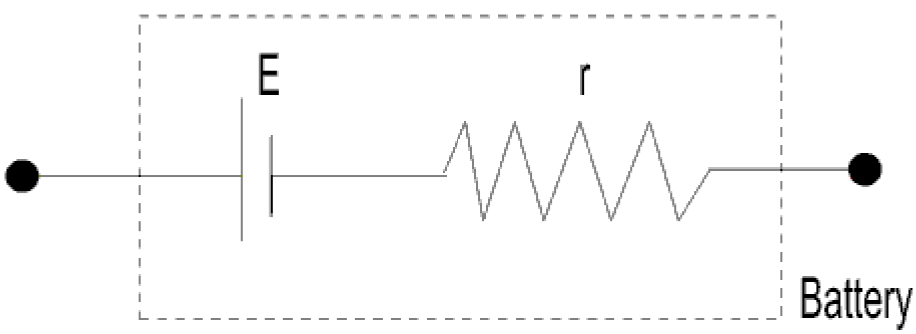
Question :-
route which connects B and D. It is recommended to go via shortest possible route to avoid long calculations and maping problem more complex.

Internal resistance of a battery $\rightarrow$
The potential difference across a real source in a circuit is not equal to the e.m.f of the cell,

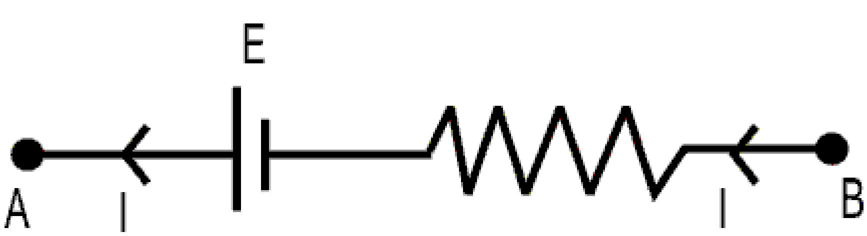
Dumb question :- Why this happens ?

Solution :- The reason is that charge moving through the electrolyte of the cell encounters same resistance known as, internal resistance of the cell.

It is denoted by r. so, there is a potential drop across the ends of the e.m.f source.



Potential difference (V) across the terminals of a battery -
For an e.m.f source, the potential changes will be obtained as illustrated below :-



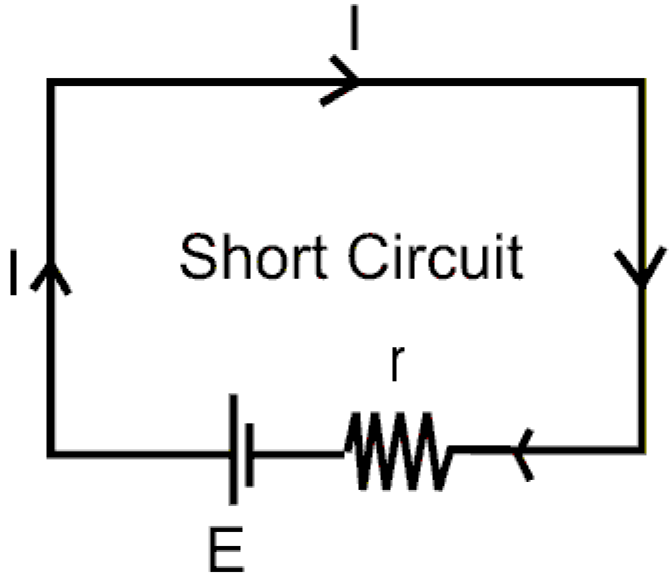
$$\Rightarrow \quad V_A - V_B = E - ir$$

Special Cases :-
1) It current flows in opposite direction then,
V = E + ir

2) V = E if current through the cell is zero.
3) V = 0 if the cell is short circuited.

<u>Dumb question - 8.</u>
Why V = 0 if the cell is short circuited ?

<u>Ans :-</u>



NOw in this case applying kirchoff's voltage loop law,

$$I = \frac{E}{r}$$

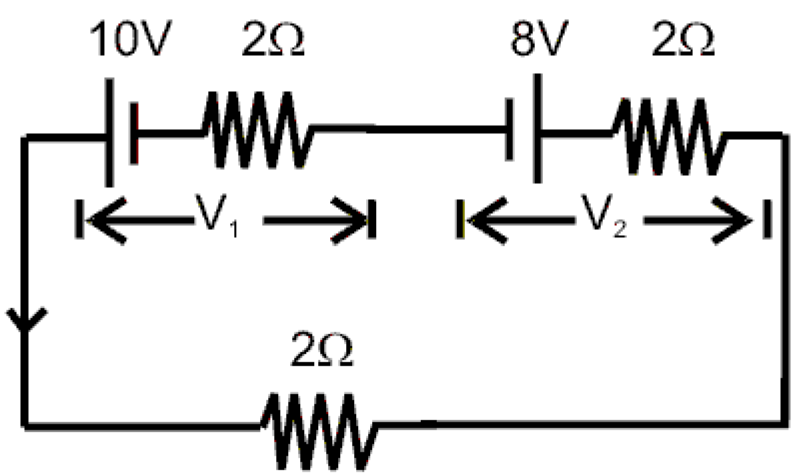
$$\therefore \quad E = Ir$$

Thus, $E - Ir = 0$

or $V = 0$

<u>llustration -</u> In the given circuit

$E_1 = 10$ V, $E_2 = 8$ V, $r_1 = r_2 = 2$ $2\ \Omega$ and $R = 2\ \Omega$.



Applying kirchoff's voltage law in the circuit (moving anticlockwise)

$$\Rightarrow \quad 10 - 2I - 2I - 8 - 2I = 0$$

$$\Rightarrow \quad 2 = 6I$$

$$\therefore \quad I = \frac{1}{3}\ A.$$

Thus $V_1 = E_1 - ir_1$

$$= 10 - \frac{1}{3} \times 2$$

$$= \frac{30 - 2}{3} = \frac{28}{3} \text{ V} = 9.33 \text{ V.}$$

$$V_2 = E_2 + ir_2$$

$$= 8 + \frac{1}{3} \times 2$$

Gruping of Resistances :

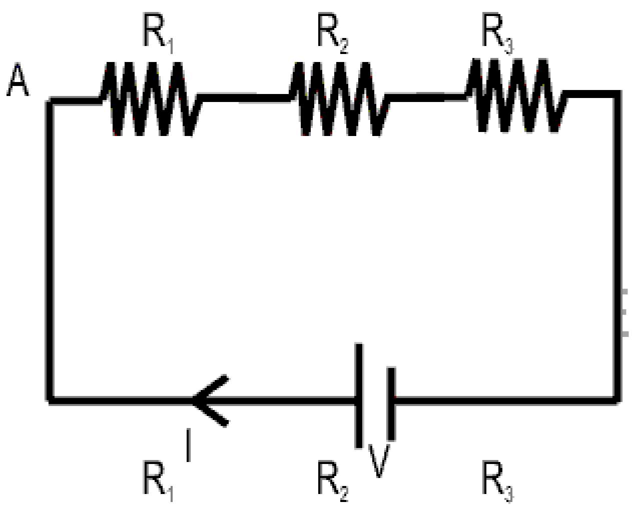
1) In series : $R_{eq} = R_1 + R_2 + R_3 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots R_n$

Equivalent resistance is defined as :

$$R_{eq} = \frac{V}{I}$$

where V = Voltage of battery

I = Current following through battery.



Using kirchoff's loop rule in clockwise direction we get:

$$V = IR_1 + IR_2 + IR_3$$

$$\Rightarrow R_1 + R_2 + R_3 = \frac{V}{I}$$

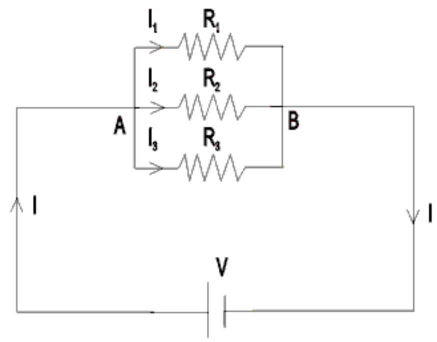
$$\therefore R_{eq} = \frac{V}{I} = R_1 + R_2 + R_3$$

Thus, R_{eq} across AB = $R_1 + R_2 + R_3$ further if battery has any internal resistance it will be added to give total resistance.

2) In parallel $R_{eq} = R_1 + R_2 + R_3 + \ldots\ldots\ldots + R_n$

Here also,
$$R_{eq} = \frac{V}{I}$$

Suppose, in the given figure we have to find R_{eq} across AB :



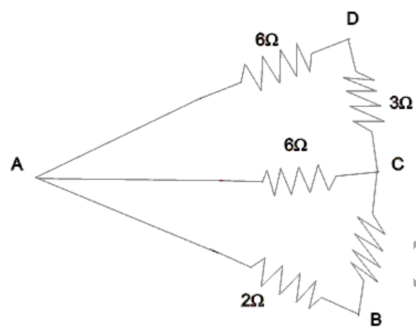
Assuming the following distribution of current as shown.
Applying kirchiff's Junction Law at A.

$$I = I_1 + I_2 + I_3$$

$$\Rightarrow \quad \frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

(Because potential drop across each are same being in parrallel.)

$$\therefore \quad \frac{V}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$



Ans:- Resistance AB and BC are in series.