Subject: ELECTRICA AND ELECTRONIC'S ENGG
(MECH & CIVIL)

UNIT - I
ELECTRICAL CIRCUITS

* Basic deff: in ckt's :

* Voltage :

* According to the Structure of an atom, there are two types of charges they are positive & negative Charges.
* there Exists a froce of attraction b/w these positive & negitive Charges.
* All the opposite Charges pocess Certain amount of potential Energy because of the Seperation b/w them.
* The difference in potential Energy of the Charges is Called the potential difference.
* potential difference in Electrical terminology is Known as voltage.

Deff: of Voltage: the potential difference b/w two Charges or two points is Known as Voltage.

* it is denoted by "V"
* it is also defined as Energy per unit charge i.e,

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

where W = Energy in joules
Q = Charge in columbs
V = Voltage in Volts.

* One volt is the potential difference b/w 2 points when one joule of Energy is used to pass one Coulomb of Charge from one point to the Other.

* Example :-

if 70 j of Energy is avilable for Every 30 C of Charge, what is the voltage.

Sol :- we know that $V = \frac{W}{Q}$

here $W = 70 j$

$Q = 30 C$

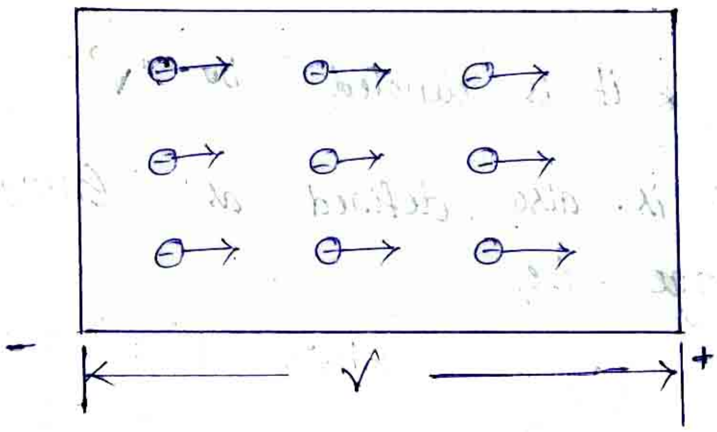
$\therefore V = 70/30 = 2.33 V$.

* Current :-

* There are free Electrons avilable in all Semiconductive and Conductive Materials.

* these free e^- move at random in all directions with in the Structure in the absence of External pressure or Voltage.

* if a Certain amount of Voltage is applied across the Material, all the free Electrons Move in one direction depending on the polarity of the applied voltage Shown in fig :-



* this Movement of e^- from one End of the Material to the other End Constitutes an Electric Current.

* the direction of Current flow is opposite to the flow of Electrons.

Deff: Of Current: it is defined as the rate of flow of Electrons in a Conductive or Semiconductive Material.

* it is Measured by the number of e^- that flow past a point in unit time.
* it is denoted by "I"
* it's units are Amperes; denoted by "A"
* it is Expressed Mathematically as

$$I = Q/t$$

Where I : Current ; Q : Charge of e^- ; t : time

* **Example:-**

five Coulombs of charge flow past a given point in a wire in 2 Sec. How Many amperes of Current is flowing.

Sol:- we Know that $I = Q/t$

here $I = ?$

$Q = 5C$

$t = 2\,sec$

$I = 5/2 = 2.5\,A.$

* Power :

* Capacity to do work is called Energy
* ∴ Energy is nothing but stored work.

Defn : of power :- it is defined as the rate of change of Energy.

* it is denoted by "p"

$$\text{power } (p) = \frac{\text{Energy}}{\text{time}} = \frac{w}{t} \quad (\text{or}) \quad p = \frac{dw}{dt}$$

where "dw" is change in Energy.
"dt" is change in time.

$$p = \frac{dw}{dt} \Rightarrow \frac{dw}{dv} \times \frac{dv}{dt}$$

$$\Rightarrow v \times i \Rightarrow vi$$

* its units are watts

* one watt is the amount of power generated when one joule of Energy is consumed in one second.

* Example :-

What is the power in watts if Energy equal to 50 J is used in 2.5 sec?

Sol: we know that $p = \frac{w}{t}$

here $w = 50j$
$t = 2.5 \text{ sec}$

$$p = 50/2.5$$

$$= 20w.$$

* Classification of Network Elements :-

* Broadly, Network Elements may be classified into four groups they are

1. Active Elements or passive Elements
2. unilateral or bilateral Elements.
3. Linear (or) Non-Linear Elements
4. Lumped (or) distributed Elements.

1 * Active Elements :-

* An Elements which is capable of supplying power to External Elements present in the circuit for infinate time period.
* then such Elements are called Active Elements.

Examples for Active Elements :-

* Voltage source
* Current Source.

* passive Elements :-

* Elements which accept or absorb power from External devices.
* Such Elements are called passive Elements.

Examples for passive Elements :-

* Resistor
* inductor
* Capacitor

(2) * Unilateral Elements :-

* Elements having different Voltage Current Relationship for Either direction of Current flow then Such Elements are Called unilateral Elements.

Examples of unilateral Elements :-

* Vacuum diodes * Silicon diodes * Metal rectifiers

* Bilateral Elements :-

Bilateral Elements are those Elements whose Voltage and Current relationship remains unaltered for Either polarity of Voltage & Current.

Examples of Bilateral Elements :-

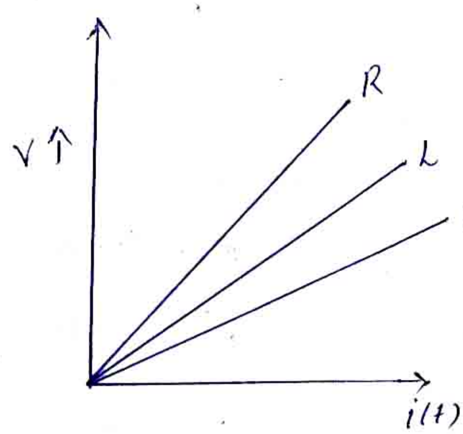
* Resistor.

(3) * Linear Elements :-

* The response of an Element which obey direct proportionality with voltage or current is Called linear Elements.

* An Element is Said to be linear Element, if its Voltage - Current char: is at all time a Stright line through the Origin.

* the term linear is Valid only for passive Elements.



Example for linear Elements :-

* Resistor
* inductor
* Capacitor.

* **NON linear Element :-**

An Element does not satisfy the direct proportionality b/w voltage & Current then such elements are called non-linear Elements.

Examples for non-linear Elements :-

* diode * transistor Etc.

(4) * **Lumped Elements :-**

* when it is possible to Seperate the Elements of a network physically like resistor, inductor, Capacitor. then such Elements are Called Lumped Elements.

* Kirchhoff's law are only applicable to ckt with lumped Elements.

* **Distributed Elements :-**

* when it is not possible to Seperate the Elements of a n/w physically the Elements are known as distributed Elements.

Examples for distributed Element's are :

* Transmission line.

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* **Resistance :-**

* when a Current flows in a Material, the free e^- move through the Material & Collide with Other atoms.

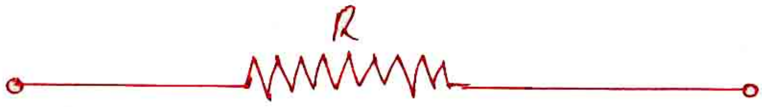
* These Collisions Cause the e^- to lose some of their Energy.

* This loss of Energy per unit Charge is the drop in potential across the Material

* this collisions resistrict the movement of the electrons.

Deff:- of Resistance :- The property of a material to restrict the flow of electrons is called Resistance.

* it is denoted by "R"
* the symbol of resistor is shown in the figure.



* the units of resistance is "Ohm" => Ω

* one ohm is the resistance offered by the material when a current of one ampere flows between two terminals with one volt applied across it.

* According to Ohm's law voltage across the resistor is given as

$$\boxed{V = IR}$$

* Current across resistor is

$$\boxed{I = V/R}$$

* power absorbed by the resistor is

$$P = Vi$$

$$= (iR)i = i^2R$$

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

* Energy lost in a resistor in time "t" is

$$W = \int_0^t p.dt$$

$\Rightarrow w = pt$

$= i^2 Rt$

$$\Rightarrow \boxed{W = V^2/R \cdot t}$$

where
- V is in Volts
- R is in Ohms
- t is in sec
- w is in joules

* the resistance of a conductor "R" varies directly with its length & inversely with the area of cross-section of the conductor, i.e,

$$R \propto \frac{l}{a}$$

$$\Rightarrow \boxed{R = \rho [l/a]}$$

where
- R is the resistance in Ω
- l is the length in m
- a is the area of cross-section in m^2
- ρ resistivity of material.

* Example :-

a current of 5A is passed through an aluminium wire whose cross-sectional area is $0.01\ cm^2$. if the resistivity of aluminium is $2.7 \times 10^{-6}\ \Omega\ cm$ & a voltage of 200V is applied across the coil, calculate the length of the wire.

Sol: given data

voltage applied $V = 200$ volts

Current $I = 5$ Amp

Area of cross-section $a = 0.01\ cm^2$

Resistivity of material $\rho = 2.7 \times 10^{-6}\ \Omega\ cm$

we know that $V = IR$

$$R = V/I$$

$$R = \frac{200}{5} = 40\Omega$$

But we have $R = \rho \cdot \frac{l}{a}$

$$\therefore l = \frac{R \times a}{\rho}$$

$$= \frac{40 \times 0.01}{2.7 \times 10^{-6}} = \frac{40}{2.7 \times 10^{4}}$$

$\therefore l = 14.815 \times 10^{4}$ cm

* Inductor :-

* A wire of contain length, when twisted into a coil becomes a basic inductor.
* if current is made to pass through an inductor, an Electromagnetic field is formed.
* A change in the magnitude of the current changes the Electromagnetic field.
* Increase in current Expands the fields, & decrease in current reduces the field.
* which induces a voltage across the coil according to faraday's law of Electromagnetic induction.

Deff: of inductance :-

The property of the coil which opposes the sudden change in current through it.

* It is the Symbol of inductance is Shown in the fig:

L

* it is denoted by "H".
* its units are henry
* the inductance is one henry when Current through the Coil, Changing at the rate of one ampere per Second, induces one Volt across the coil.
* The Current - Voltage relation in a inductor is given by

$$\boxed{V = L\frac{di}{dt}}$$

where V is Voltage across inductor
i is Current through "

we write the above Equation as

$$\boxed{di = \frac{1}{L} V\,dt}$$

Integrating both sides, we get

$$\int_0^t di = \frac{1}{L}\int_0^t V\,dt$$

$$i(t) - i(0) = \frac{1}{L}\int_0^t V\,dt$$

$$i(t) = \frac{1}{L}\int_0^t V\,dt + i(0)$$

$$\Rightarrow \boxed{i(t) = \frac{1}{L}\int_0^t V\,dt + i(0)}$$

* from the above Equation we note that the Current in an inductor is dependent upon the integral of the voltage across its terminals & initial Current in the Coil.

* power absorbed by inductor

$$p = vi$$

$$\boxed{p = Li \, di/dt \quad \text{watts}}$$

* Energy stored by the inductor

$$w = \int_0^t p.dt$$

$$w = \int_0^t Li \frac{di}{dt}.dt$$

$$\boxed{w = \frac{1}{2} Li^2}$$

* the induced voltage across an inductor is zero if the current through it is constant.
* an inductor acts as short cut to "DC".
* the inductor can store finite amount of energy, even if the voltage across the inductor is zero.
* A pure inductor never dissipates energy, so they are called non-dissipative passive elements.
* physical inductors dissipates power due to internal resistance.

* Example: the current in a 2H inductor varies at a rate of 2 Amp/sec. Find the voltage across the inductor & energy stored in magnetic field after 2 sec.

Sol:

$$L = 2H \; ; \; di/dt = 4 \; ;$$

$$V = L \, di/dt = 2 \times 4 = 8v$$

$$w = \frac{1}{2} Li^2 = \frac{1}{2} \times 2 \times (4)^2 = 16j$$

* **Capacitance :**

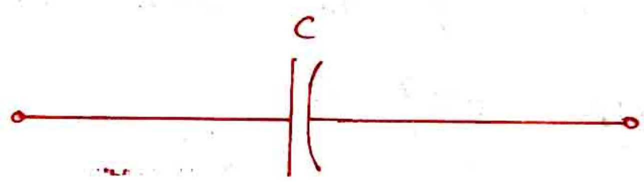
* Any two conducting surfaces seperated by a insulating medium exhibit the property of a capacitor.

* the conducting plates are called electrodes
* insulating medium is called dielectric.
* a capacitor stores energy in the form of an electric field or electrostatic field that established by the opposite charges on the two electrodes.

Defⁿ of Capacitance :

the amount of charge per unit voltage that a capacitor can store is its capacitance.

* the symbol of capacitance is shown in the fig:



* it is denoted by "C"
* its units are farad => "F"

* one farad is the amount of capacitance stored with when one coulomb of charge is one volt across the plates.

* a capacitor is said to have greater capacitance if it can store more energy or charge per unit voltage & the capacitance is given by

$$\boxed{C = Q/V}$$

where the above Eqⁿ in terms of current

$$i = C \cdot \frac{dv}{dt}$$

where v is voltage across it
i " current through it

$$dv = \frac{1}{C} i\,dt$$

integrating on both sides

$$\int_0^t dv = \frac{1}{C}\int_0^t i.dt$$

$$V(t) - V(0) = 1/C \int_0^t i.dt$$

$$V(t) = 1/C \int_0^t i\,dt + V(0)$$

$$\boxed{V(t) = 1/C \int_0^t i\,dt + V(0)}$$

* the voltage in a capacitor is depend's on the integral of the current through it & initial voltage across it.

* power absorbed by the capacitor

$$P = Vi$$

$$\boxed{P = VC\frac{dv}{dt}}$$

* Energy stored by the capacitor

$$W = \int_0^t P.dt$$

$$= \int_0^t VC\frac{dv}{dt}.dt$$

$$\boxed{W = 1/2\, CV^2}$$

* Current through the Capacitor is zero if the voltage across it is Constant.
* Capacitor acts as open ckt for "DC".

Example: A Capacitor having a capacitance 2μF is charged to a voltage of 1000V. Calculate the stored energy in joules.

Sol:

$$W = \frac{1}{2} C V^2$$

$$= \frac{1}{2} \times 2 \times 10^{-6} \times (1000)^2$$

$$= 1 \text{ joule.}$$

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* Ohm's Law:

Defi/: Statement: At Constant temperature the Current passing through a conductor is directly proportional to the potential difference between the End of Conductor (or) Voltage applied across it.

from the above statement

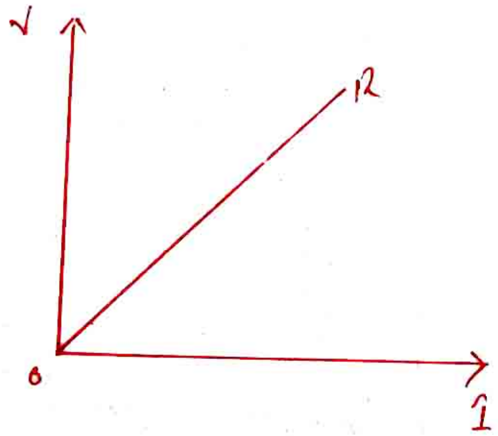
$$I \propto V \quad (or) \quad V \propto I$$

$$\boxed{V = IR}$$

where "R" is proporionality Constant

* This law in a DC ckt first discovered by german scientist "George Seimon Ohm."
* if the voltage is doubled then current is also doubled. So the ratio of "V/I" is constant
* where "R" is the resistance of the conductor.

* if we draw a graph b/w V & I it will be a Stright line passing through Origin. Shown in the fig:



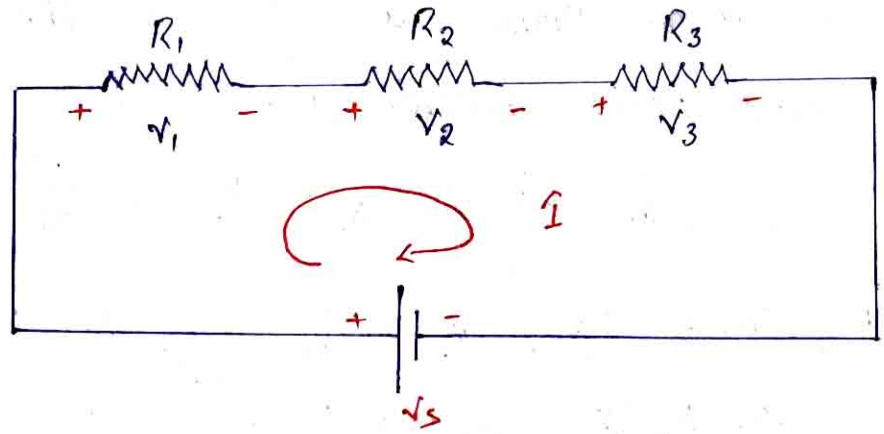
* Ohm's law can be applied for both A.C & D.C ckt if and only if the ckt Contain linear Elements.
* in Case of Ac ckt, Resistance is replaced by impedance.
* Resistance of Conductor depends on :-
  * Length of the Conductor.
  * area of cross section of conductor
  * Resistivity of the Material
  * temperature of the Conductor
* Limitations of Ohm's law :-
  * Ohm's law can't be applied under following Conditions.

1) When temperature of Material Varies
2) for non- linear Elements
3) Semi conductor devices.
4) Vaccum tubes & gas filled Values.
5) for florescent lamps.

* Kirchhoff's Voltage Law :-

Statement :- Kirchhoff's voltage law states that the algebraic sum of all branch voltages around any closed path in a circuit is always zero at all instant of time.

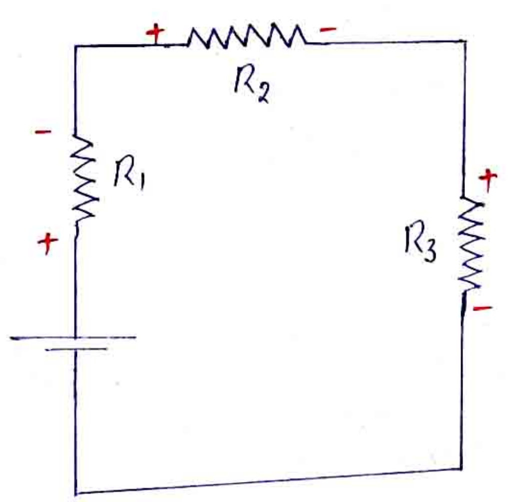
* When the current passes through a resistor, there is a loss of energy & therefore, a voltage drop.
* In any element, the current always flows from higher potential to lower potential.



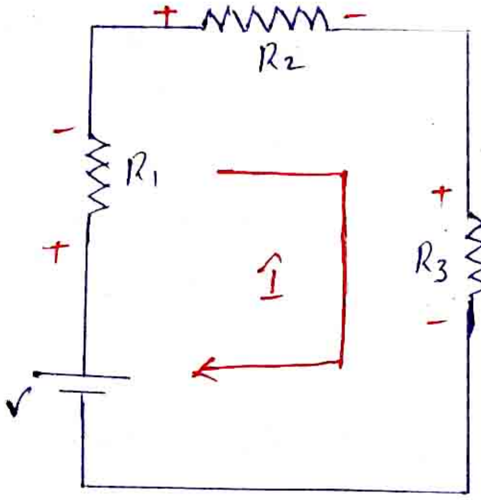
* Consider the ckt shown in the fig:-
* the sum of the voltage drop around the loop is equal to the total voltage in that loop.

$$V_s = V_1 + V_2 + V_3$$

* Consider the ckt shown in the below fig finding out the current supplied by the source "V"



* first step is to assume the reference current direction and to indicate the polarities for different elements. shown in the fig:



By using ohm's law, we find the voltages across each resistor as follows:

$$V_{R_1} = IR_1 \; ; \; V_{R_2} = IR_2 \; ; \; V_{R_3} = IR_3$$

* where V_{R_1}, V_{R_2} & V_{R_3} are the voltages across R_1, R_2, R_3 respectively.

* By applying KVL we can form a equation

$$V = V_{R_1} + V_{R_2} + V_{R_3}$$

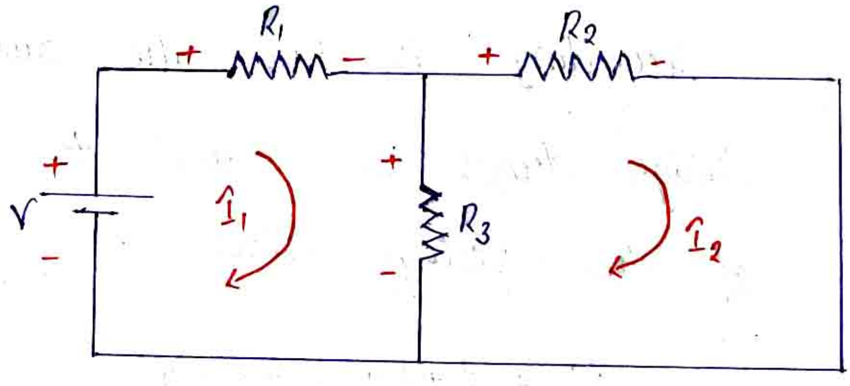
$$V = IR_1 + IR_2 + IR_3$$

* from the above equation the current delivered from the source is

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

* **Sequential Steps for KVL:**

* Consider the ckt show in the fig: & write the loop equations



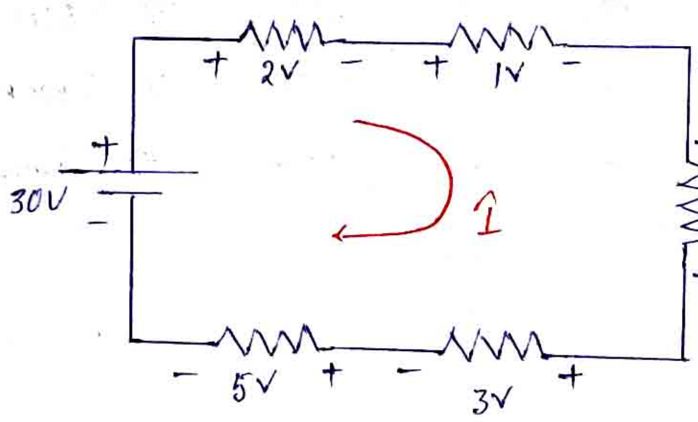
* trace the no: of closed paths in a given ckt.
* Assume the direction of currents in different loops.
* Apply KVL to every loop & write the loop equation for voltage.
* By loop currents we can find branch current also.
* if there are "n" loops then "n" equations are required for determining the loop current.
* the polarity of the voltage is taken as "+ve" at the point where current enters into element.
* Applying KVL for Loop (1) in the fig:

$$V = I_1 R_1 + R_3 [I_1 - I_2]$$

* Applying KVL for loop (2) in the fig

$$0 = I_2 R_2 + R_3 [I_2 - I_1]$$

* Example:- for the ckt shown in the fig:- determine the unknown voltage drop "V_1":

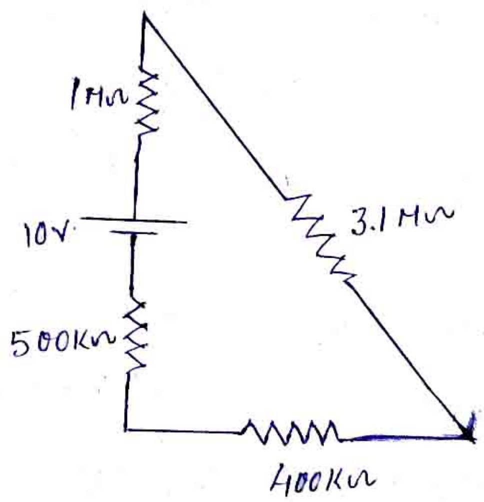


Sol: According to KVL, the sum of the voltage drops is equal to the sum of the voltage rises.

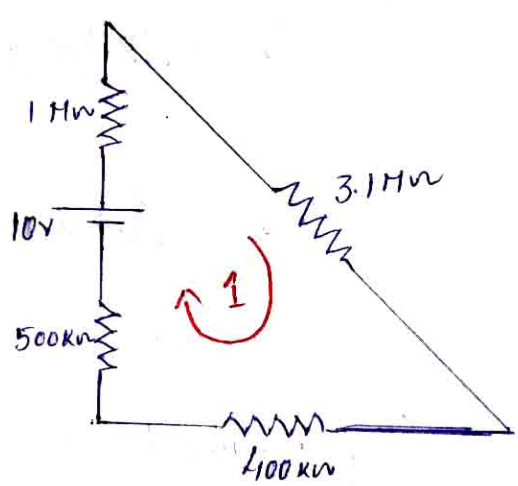
$$\therefore \quad 30 = 2 + 1 + V_1 + 3 + 5$$

$$V_1 = 30 - 11 = 19 \text{ volts}$$

* **Example:** What is the current in the ckt shown in the fig: determine the voltage across each resistor.



Sol: We assume current "I" in the clockwise direction & indicate polarities as shown in below fig:



* By using Ohm's law, we find the voltage drop's across each resistor.

Voltage drop across 1M resistor $= I$

Voltage drop across 3.1MΩ $\Rightarrow V_{3.1M} = 3.1\,I$

" " " 500KΩ $\Rightarrow V_{500K} = 0.5\,I$

" " " 400KΩ $\Rightarrow V_{400K} = 0.4\,I$

Now by Applying the KVL we form Eau:-

$$10 = \hat{I} + 3.1\hat{I} + 0.5\hat{I} + 0.4\hat{I}$$

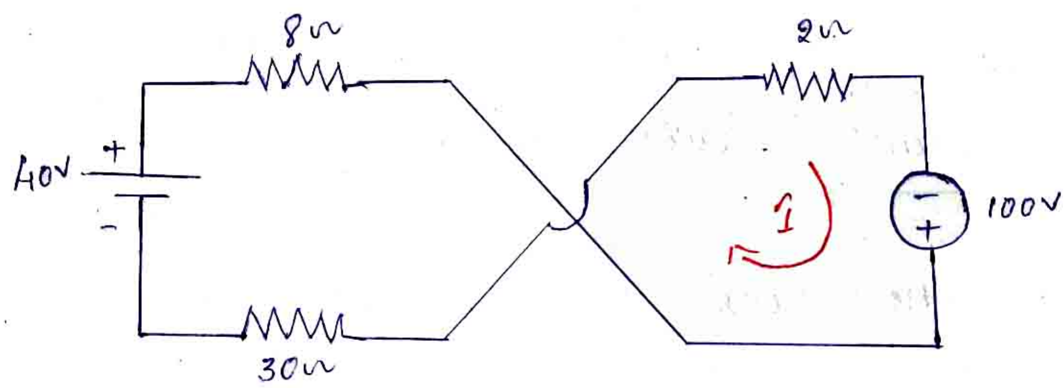
$$5\hat{I} = 10$$

$$\hat{I} = 2\ \mu Amp.$$

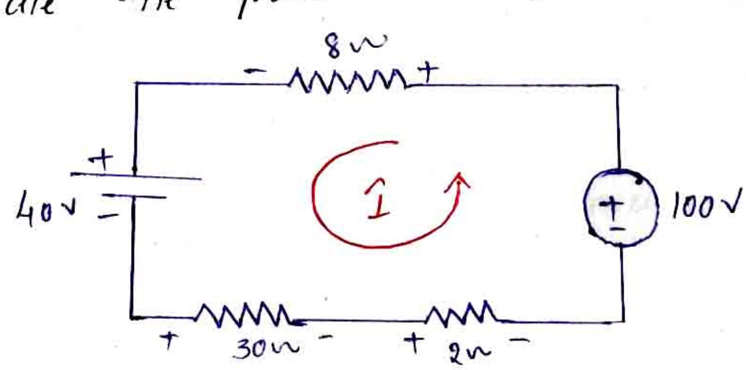
∴ Voltage across Each resistor is

$$V_{1M} = 1 \times 2 = 2V$$
$$V_{3.1} = 3.1 \times 2 = 6.2V$$
$$V_{400K} = 0.4 \times 2 = 0.8V$$
$$V_{500K} = 0.5 \times 2 = 1V$$

* Example: From the ckt shown below find (a) the current $\hat{I}$ (b) Voltage across 30Ω.



Sol: we redraw the ckt as shown in the below fig: by assume current direction & indicate the polarities of resistors.



By using Ohms law the voltage across each resistor

$$V_8 = 8\hat{I}$$
$$V_{30} = 30\hat{I}$$
$$V_2 = 2\hat{I}$$

By applying Kirchhoff's law

$$100 = 8I + 40 + 30I + 2I$$

$$40I = 60$$

$$I = 1.5A$$

$\therefore$ Voltage drop across 30Ω

$$V_{30} = 30 \times 1.5 = 45V$$

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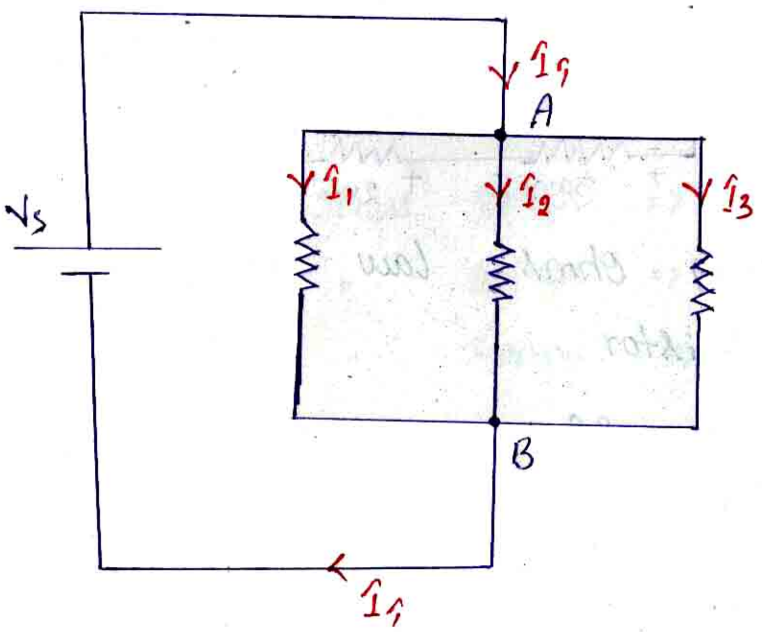
* Kirchhoff's Current law :-

Statement :- Kirchhoff's current law states that the sum of the currents entering into any node is equal to the sum of the currents leaving that node.

* The node may be interconnection of two or more branches.

* In parallel Ckt, the node is a junction point of two or more branches.

* Total current entering into a node is equal to the current leaving that node.



* Consider the ckt shown in the fig. which contains two nodes "A" & "B".

* the total current "I_T" entering node "A" is divided into I_1, I_2 & I_3.

* these currents flow out of node "A".

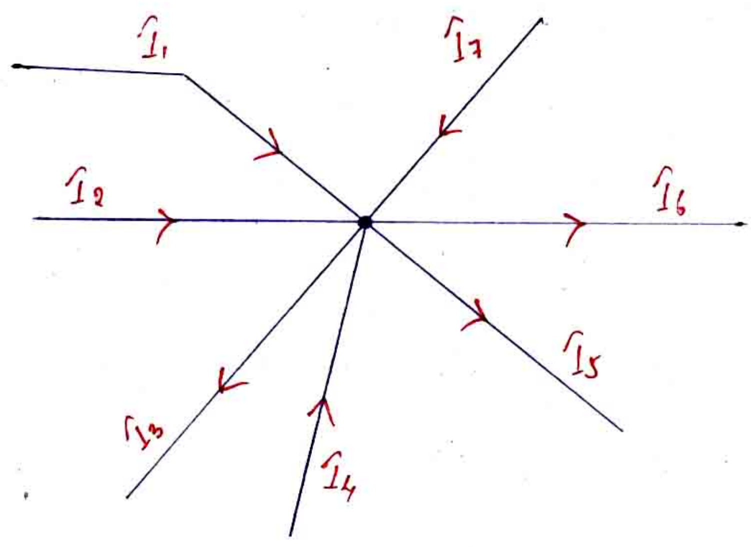
* According to KCL, the current into node "A" is equal to the total current out of node "A".

i.e, $I_T = I_1 + I_2 + I_3$

* If we consider node "B", all three currents I_1, I_2, I_3 are entering B, & the total current "I_T" is leaving node B.

* $\therefore$ KCL at Node "B" is same as node "A"

$$\boxed{I_T = I_1 + I_2 + I_3}$$



* In general, sum of the currents entering any point or node or junction equal to sum of the currents leaving from the point or node or junction. Shown in fig:

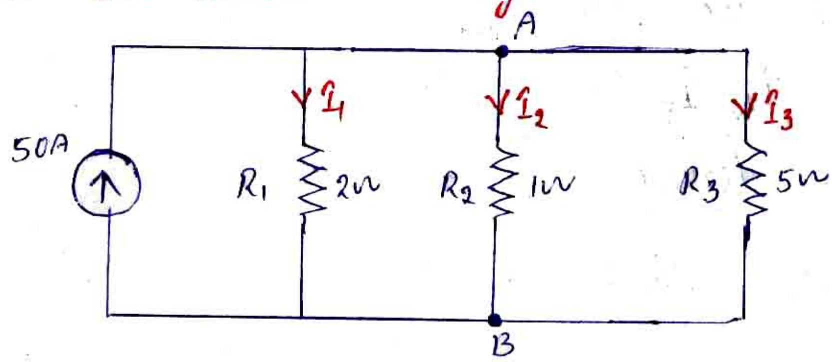
$$I_1 + I_2 + I_4 + I_7 = I_3 + I_5 + I_6$$

* if all the terms on the right side are brought over to the left side, then the above Equation can be written as

$$\boxed{I_1 + I_2 + I_4 + I_7 - I_3 - I_5 - I_6 = 0}$$

* this mean's the algebraic sum of all the currents meeting at a junction is Equal to zero.

* **Example:** Determine the current in all resistors in the cut shown in fig:



Sol: the above cut consists of single Node "A" with refference node "B".

According to Ohms law current passing through Each Element.

$$I_1 = V/2 \; ; \; I_2 = V/1 \; ; \; I_3 = V/5$$

By applying KCL we have

$$I = I_1 + I_2 + I_3$$

$$I = V/2 + V/1 + V/5$$

$$50 = V\left[1/2 + 1/1 + 1/5\right]$$

$$50 = V\left[0.5 + 1 + 0.2\right]$$

$$V = 50/1.7 = \frac{500}{17} = 29.41V.$$

if we know the Voltage at node "A" then we can find currents across each element by using K.C Ohm's law

Current in 2Ω resistor

$$I_1 = 29.41/2 = 14.705A$$

$$I_2 = V/R_2 = V/1 = 29.41A$$

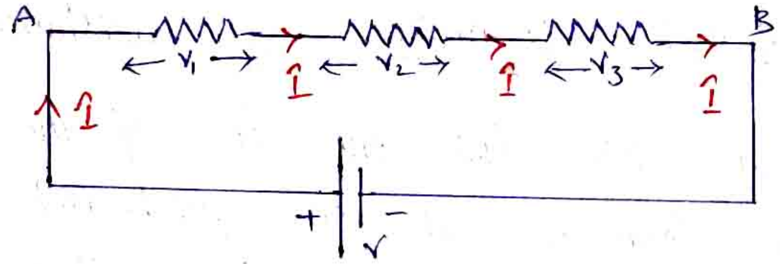
$$I_3 = \frac{29.41}{5} = 5.882\ A$$

---

* Series and parallel ckt's :-

* Series Connection of Resistance :-

* The ckt in which resistances are connected end to end is known as series ckt.
* There is only one path of current to flow in a series ckt. Shown in the fig:



Applying Ohms law to individual resistors

Voltage across "R_1" is $V_1 = IR_1$

" " "R_2" " $V_2 = IR_2$

" " "R_3" " $V_3 = IR_3$

Total Voltage V = Sum of individual Voltage

$$V = V_1 + V_2 + V_3$$

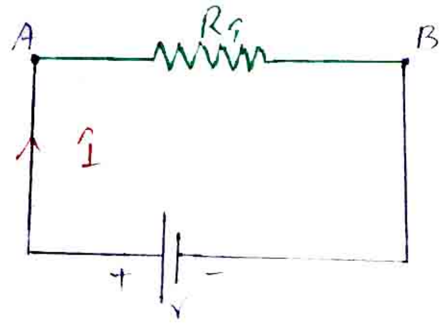
$$= IR_1 + IR_2 + IR_3$$

$$V = I[R_1 + R_2 + R_3]$$

$$V/I = R_1 + R_2 + R_3$$

$$\therefore \text{ Total resistance} = R_T = R_1 + R_2 + R_3$$

* the ckt shown in the previous page can be redrawn as shown below.



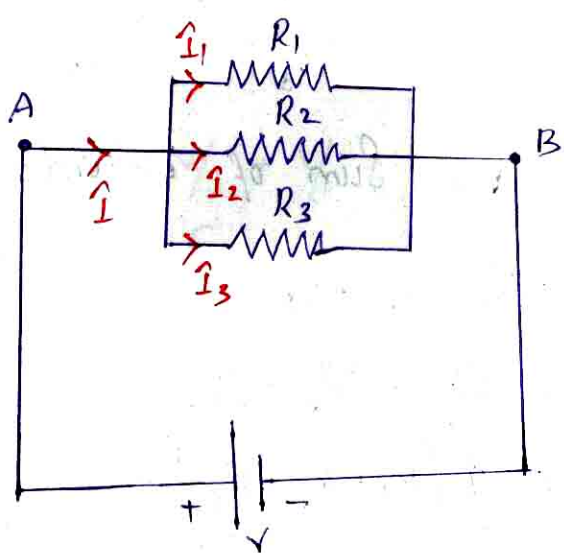
where R_T is Total resistance

* In Series connection current is same through out the ckt.
* In series connection voltage is different across each element.

---

* **parallel connection of resistance:-**

* In ‖le ckt one end of the all the elements are connected at one point (A) & similarly the other end of all the elements are brought to another point (B) which is shown in the fig:



Applying ohm's law to individual resistors

Current flowing through resistor R_1 is

$$I_1 = V/R_1$$

Current flowing through resistor R_2 is

$$I_2 = V/R_2$$

Current flowing through resistor R_3 is

$$I_3 = V/R_3$$

∴ Total Current in the ckt is Equal to Sum of individual Current flowing through resistors

$$I = I_1 + I_2 + I_3$$

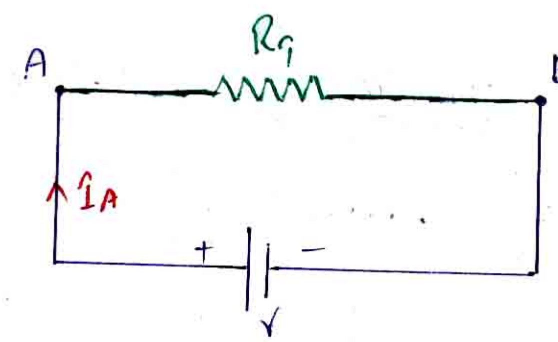
$$= V/R_1 + V/R_2 + V/R_3$$

$$= V\left[1/R_1 + 1/R_2 + 1/R_3\right]$$

$$I/V = 1/R_1 + 1/R_2 + 1/R_3$$

$$\boxed{1/R = 1/R_1 + 1/R_2 + 1/R_3}$$

∴ the ckt shown above can be redrawn as

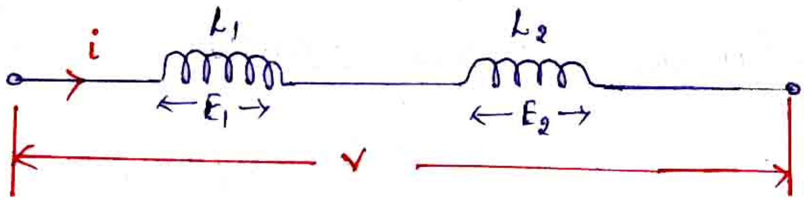


where "R_q" is Equal Resistance

* in ∥le connection Voltage is Same across Each resistor.

* in ∥le connection Current is differ through Each Element.

* Series Connection of inductance :



* Consider the above fig: where two inductances are connected in series.

Let "V" be the applied voltage $= E_1 + E_2$

where "E_1" & "E_2" are EMF induced in "L_1" & "L_2" respectively.

$\because$ EMF induced is back EMF we taken as $-[E_1+E_2]$

$$V = -(E_1 + E_2)$$

$$= L_1\, di/dt + L_2\, di/dt$$

$$= [L_1 + L_2]\, di/dt$$

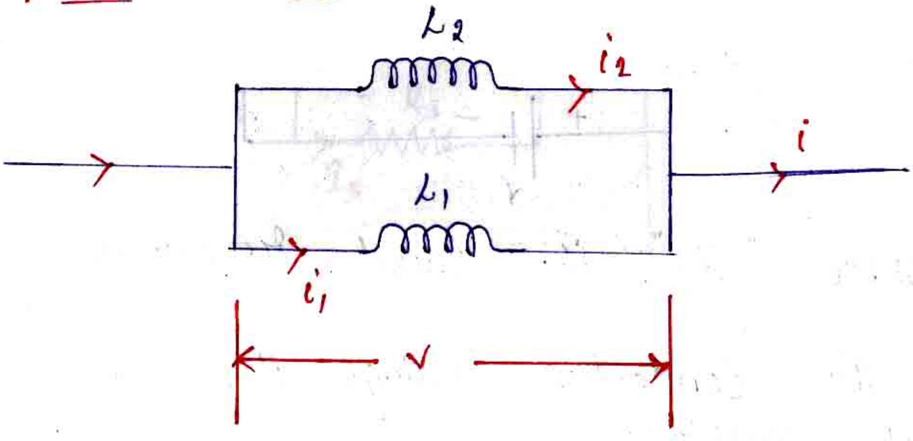
$$= L\, di/dt$$

where $L = L_1 + L_2$

$\therefore$ inductance connected in series, its equivalent inductance is given as

$$\boxed{L_T = L_1 + L_2}$$

* parallel Connection of inductance :

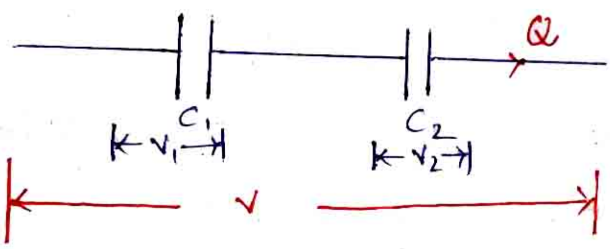


* Consider the above fig: where two inductances are connected in $\parallel^{le}$

Total inductance of the Combination is

$$\boxed{L = \frac{L_1 \times L_2}{L_1 + L_2}}$$

* **Series Connection of Capacitors :-**



Consider two Capacitors in Series as Shown in fig

$$V = V_1 + V_2$$

Let "Q" be the Charge through Each Capacitor

$$Q = C_1 V_1$$
$$Q = C_2 V_2$$

Let "C" be the Equivalent Capacitance of the Combination

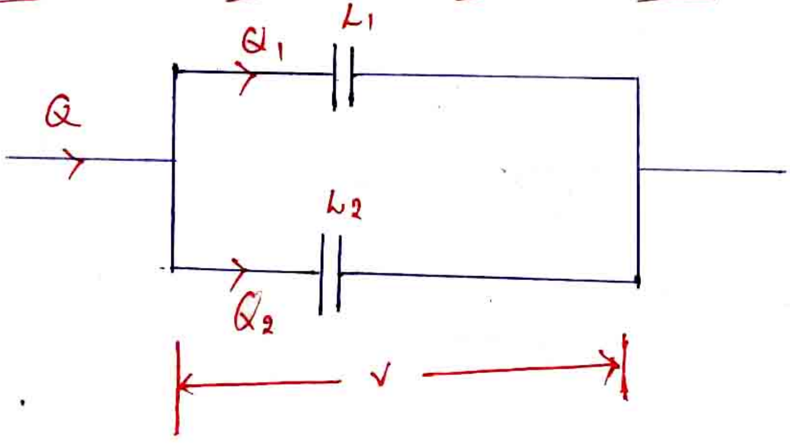
$$V = \frac{Q}{C_1} + \frac{Q}{C_2} = Q\left[\frac{C_1 C_2}{C_1 + C_2}\right] = QC$$

Where

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

The above show is the Equivalent Capacitance of Series Capacitor.

* **parallel Combination of Capacitors :-**



Consider the Capacitors Connected in $\parallel^{le}$ as shown in fig.

$$Q = Q_1 + Q_2$$
$$= C_1 V_1 + C_2 V_2$$
$$= (C_1 + C_2) V$$
$$= CV$$

Where $C = C_1 + C_2$

the Equivalent Capacitance of Capacitor in $\parallel^{le}$

$$\boxed{C_{equ} = C_1 + C_2}$$

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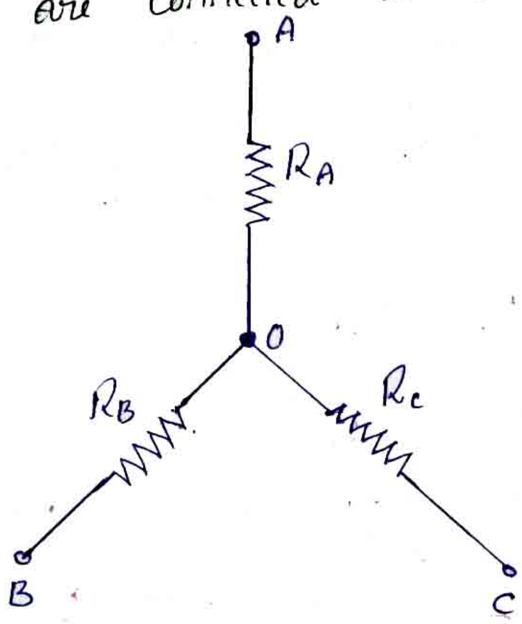
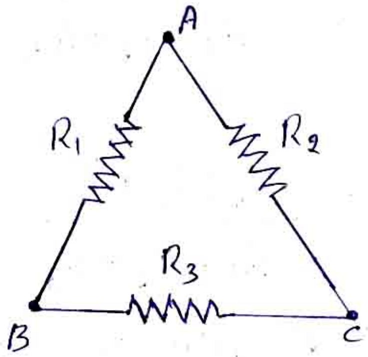
* Star to Delta Transformation :-

* Star to delta transformation is another technique useful in solving complex Networks.
* Basically, any three ckt Elements i.e, resistor, inductor, capacitor, May be connected in two different ways.
* One way of connecting these Elements is called the Star Connection or the "Y" Connection.
* the Other way of connecting these Elements is called the delta (Δ) Connection.
* the ckt is said to be Star Connection, if three Elements are Connected as shown in fig:



* the ckt is said to be in della connection, if three elements are connected as shown in fig.



* the above two ckt are equal if their respective resistances from the terminals AB, BC & CA are equal.

* consider the star connected ckt in fig:
* the resistance from the terminals AB, BC & CA respectively are

$$R_{AB}(Y) = R_A + R_B$$

$$R_{BC}(Y) = R_B + R_C$$

$$R_{CA}(Y) = R_C + R_A$$

* Similarly, in the delta connected N/w shown in fig: the resistances seen from the terminals AB, BC & CA respectively are

$$R_{AB}(\Delta) = R_1 \parallel (R_2 + R_3) = \frac{R_1(R_2+R_3)}{R_1+R_2+R_3}$$

$$R_{BC}(\Delta) = R_3 \parallel (R_1 + R_2) = \frac{R_3(R_1+R_2)}{R_1+R_2+R_3}$$

$$R_{CA}(\Delta) = R_2 \parallel (R_1 + R_3) = \frac{R_2(R_1+R_3)}{R_1+R_2+R_3}$$

* Now, if we equate the resistances of star & della ckt, we get

$$R_A + R_B = \frac{R_1(R_2+R_3)}{R_1+R_2+R_3} \longrightarrow (1)$$

$$R_B + R_C = \frac{R_3 (R_1 + R_2)}{R_1 + R_2 + R_3} \longrightarrow (2)$$

$$R_C + R_A = \frac{R_2 (R_1 + R_3)}{R_1 + R_2 + R_3} \longrightarrow (3)$$

* Subtracting Eq: (2) from (1), & adding Eq: (3) to the resultant, we have

$$R_A = \frac{R_1 R_2}{R_1 + R_2 + R_3} \longrightarrow (4)$$

$$R_B = \frac{R_1 R_3}{R_1 + R_2 + R_3} \longrightarrow (5)$$

$$R_C = \frac{R_2 R_3}{R_1 + R_2 + R_3} \longrightarrow (6)$$

thus, a delta connection of R_1, R_2 & R_3 may be replaced by a star connection of R_A, R_B & R_C from the above Equations.

* Now if we Multiply the Equ: (4) & (5), (5) & (6), (6) & (4) & add the three, we get the final Equ as

$$R_A R_B + R_B R_C + R_C R_A = \frac{R_1^2 R_2 R_3 + R_3^2 R_1 R_2 + R_2^2 R_1 R_3}{(R_1 + R_2 + R_3)^2} \longrightarrow (7)$$

In Equ: (7) dividing the L.H.S by "R_A" gives "R_3"
dividing the L.H.S by "R_B" gives "R_2"
dividing the L.H.S by "R_C" gives "R_1"

$$R_1 = \frac{R_A R_B + R_B R_C + R_C R_A}{R_C}$$

$$R_2 = \frac{R_A R_B + R_B R_C + R_C R_A}{R_B}$$

$$R_3 = \frac{R_A R_B + R_B R_C + R_C R_A}{R_A}$$

* from the above results, we can say that a star connected ckt can be transformed into a delta connected ckt & vice-versa.

* **Delta to Star transform :-**

$R_A = \dfrac{R_1 R_2}{R_1 + R_2 + R_3}$
$R_B = \dfrac{R_1 R_3}{R_1 + R_2 + R_3}$
$R_C = \dfrac{R_2 R_3}{R_1 + R_2 + R_3}$

* **Star to delta transform :-**

$R_1 = \dfrac{R_A R_B + R_B R_C + R_C R_A}{R_C}$
$R_2 = \dfrac{R_A R_B + R_B R_C + R_C R_A}{R_B}$
$R_3 = \dfrac{R_A R_B + R_B R_C + R_C R_A}{R_A}$