BASIC CIRCUIT LAWS

A brief introduction of basic circuit laws is presented in this lecture.

① **Ohms Law** :- states that voltage v across a resistor is directly proportional to the current i flowing through the resistor. i.e.

$$v \propto i$$

The constant of proportionality is defined by ohm as resistance (R)

$$\therefore \boxed{v = iR}$$ → Mathematical form of Ohms law.

Thus resistance of an element denotes its ability to resist the flow of current. It is measured in ohms(Ω). and we express it

as $R = \frac{v}{i}$; $1\Omega = \frac{1V}{1A}$

The current direction and voltage polarity must be paid full attention to state ohms law. The voltage polarity and current direction must conform the passive sign convention used earlier w.r.t. power.

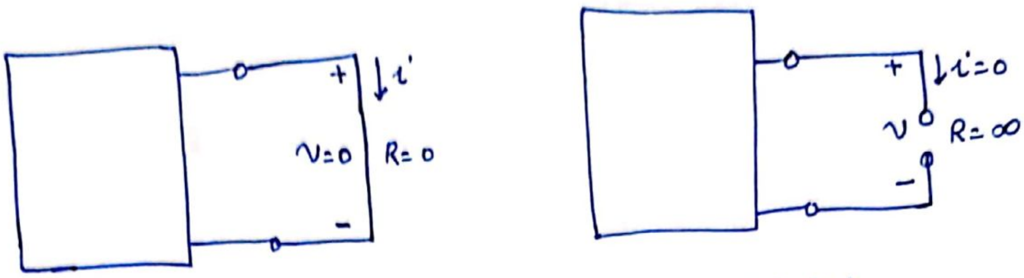


Fig (a) Fig (b).

This implies that current flows from higher potential to a lower potential in order for $v = iR$. If current flows from lower potential to higher potential $v = -iR$

The value of R ranges from zero to infinity. The two extreme possibles are considered in Fig (a) & Fig (b) above.

An element with $R = 0$, is referred to as short circuit (Fig a); $\boxed{v = iR = 0}$

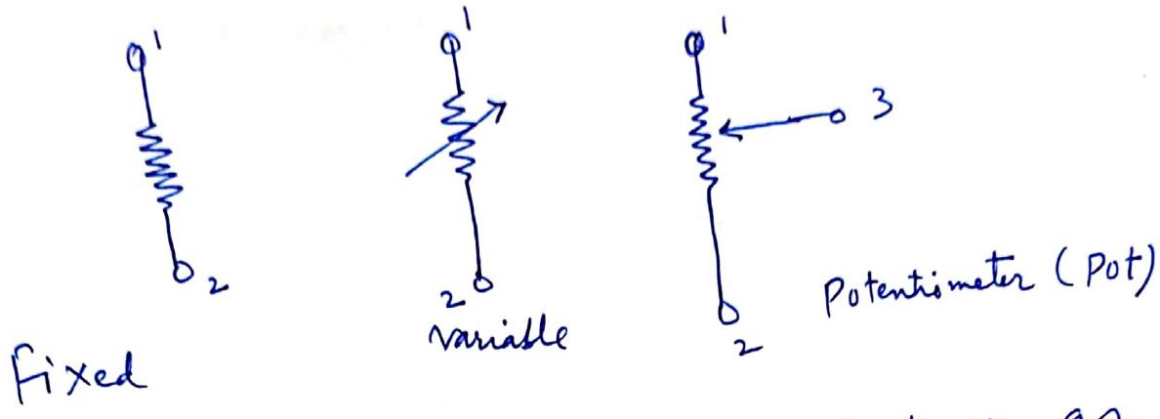
This shows that voltage is zero, where current could be any thing. Thus a short ckt is a circuit element with resistance approaching zero.

Similarly, an element with $R = \infty$ is known as open circuit as shown in Fig (b). For an open circuit

$$i = \lim_{R \to \infty} \frac{v}{R} = 0.$$

This shows that the current is zero though the voltage could be any thing. Thus an open circuit is a circuit element with resistance approaching infinity.

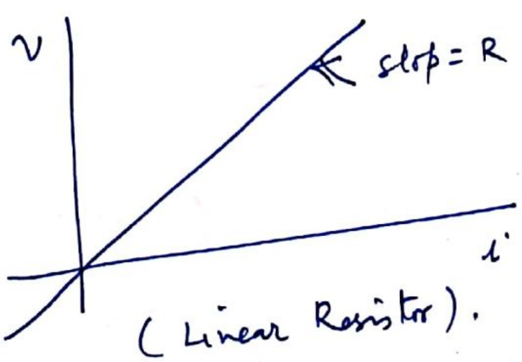
Resistance can be fixed or variable. Represented as



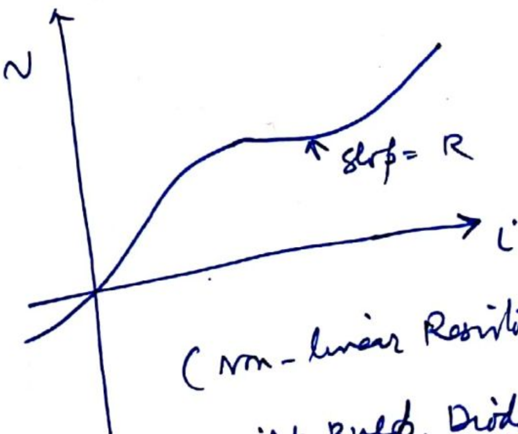
A common variable resistance is known as potentiometer or pot (A three terminal element with sliding contact or a wiper terminal & the fixed terminals.

Types — wire wound — resistance value mentioned
- Carbon type — colour coded
- surface mounted / integrated — ICs.

Resistors → Linear Resistors (Obey ohms law)
Resistors → Non-linear Resistors (Does not obey ohms law).



(Linear Resistor).



(Non-linear Resistor)
(Light Bulb, Diode) etc.

Conductance (G):-

A useful quantity in circuit analysis is the reciprocal of resistance R, known as conductance G; Thus

$$G = \frac{1}{R} = \frac{i}{v}$$

The conductance is a measure of how well an element will conduct electric current. Its unit is mho or ohm^{-1} represented $\mho$. SI unit of conductance is Siemens (S);

$$1\,S = 1\,\mho = 1\,A/1\,V$$

Conductance is the ability of an element to conduct electric current. Measured in mhos ($\mho$) or siemens (S).

$$i = Gv$$

Power Dissipated in a Resistor

we know

$$P = vi = iR \cdot i = i^2 R$$

Also $$P = v \cdot \frac{v}{R} = \frac{v^2}{R}$$

In terms of conductance G;

$$P = vi = v^2 G$$
$$P = \frac{i}{G} \cdot i = \frac{i^2}{G}$$

Thus power consumed in a resistor is a non-linear function of either current or voltage.

Since R & G are +ve quantities, the power dissipated in a resistor is always positive. Thus a resistor always absorbs power from the circuit. Thus resistor is regarded as a passive element.

The resistance of any material with a uniform cross sectional Area A depends on its length l and area of cross section.

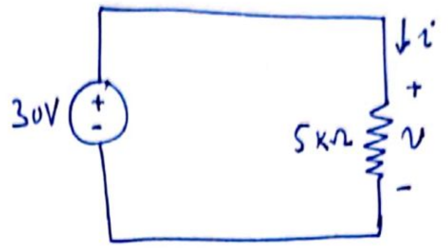
$$R = \frac{\rho l}{A}$$

ρ = resistivity of material in (ohm-mts)

Good Conductors like Al, Copper have very low ρ whereas insulators like mica, paper have high resistivity

Resistors are usually made of mettalic alloys and Carbon compounds.

Example:



Calculate i, G and power p.

The resistor and voltage source are connected in parall. so voltage across the resistor is same as the voltage of voltage source. Thus

$$i = \frac{v}{R} = \frac{30V}{5\times10^3\,\Omega} = 6\,mA$$

i = 6 mill Amps

$$G = \frac{1}{R} = \frac{1}{5\times10^3} = 0.2 \text{ mill mho.}$$

G = 0.2 m℧

power can be calculated in many ways.

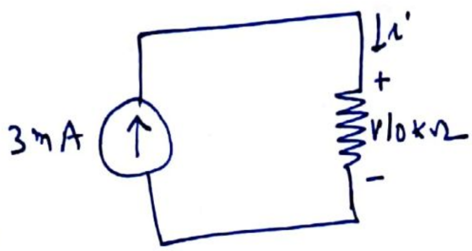
$$p = vi = 30 \times 6\times10^{-3} = 180\,mW$$

$$p = i^2R = (6\times10^{-3})^2 \times 5\times10^3 = 180\,mW.$$

$$p = v^2G = (30)^2 \times 0.2\times10^{-3} = 180\,mW.$$

Exp:

Find, v, G and p.

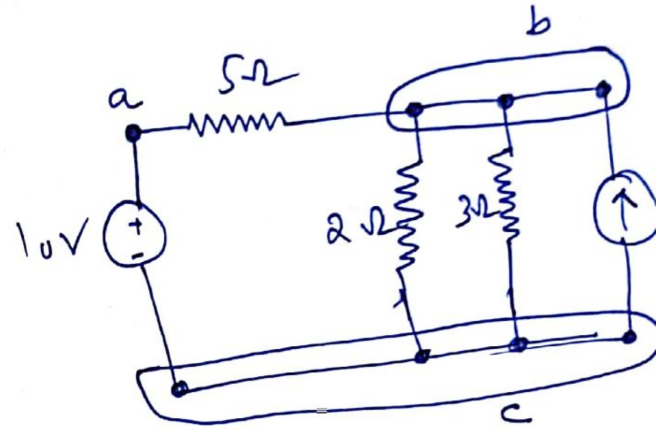


(Do it yourself).

Nodes, Branches & Loops/Meshes

The terms circuits and networks have been used in circuit analysis, representing an interconnection of various circuit elements both active & passive.

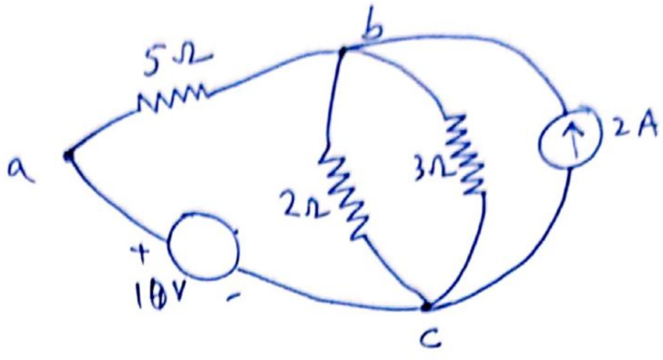
Due to this interconnection we have many nodes, branches & loop/meshes which we need to identify.



Branch: Represents a single element such as voltage source, a current source or a resistor. i.e. it represents any two terminal element.
There are five branches in the above circuit. voltage source, current source & three resistors.

Node A point of connection between two or more branches. usually indicated by a dot (•). If a connecting link connects two or more nodes, (short ckt). all these nodes constitute a single node.
The circuit has three nodes, a, b & c.
Pl note that three nodes are connecting by links, therefore a single node b and similarly 4 nodes form a node c.

Thus we can redraw the circuit as follows.



<u>Loop.</u> Loop is any closed path in a circuit.

Loop is formed by starting from a ~~point~~ node, passing through a set of nodes and returning to the starting node without passing through any node more than once.

<u>Independant Loop</u>: It contains atleast one branch which is not a part of any other independant loop.

For the above figure, a b c a with 2 Ω resistor is independant loop. b c b [3 Ω with current source] is also independant. The third loop could be one with 2 Ω resistor & 3 Ω resistor in parallel (b c b). is also independant. These are set of independant loops.

b = no. of branches
n = nodes
l = independant loops

than $(b = l + n - 1)$

Example.
$b = 5$
$n = 3$
$5 = l + 3 - 1$
$= l + 2$
$\therefore l = 3$

Series and parallel Connections

Series.

Two or more elements are in series if they exclusively share a single node and consequently carry the same current. [end to end connection].

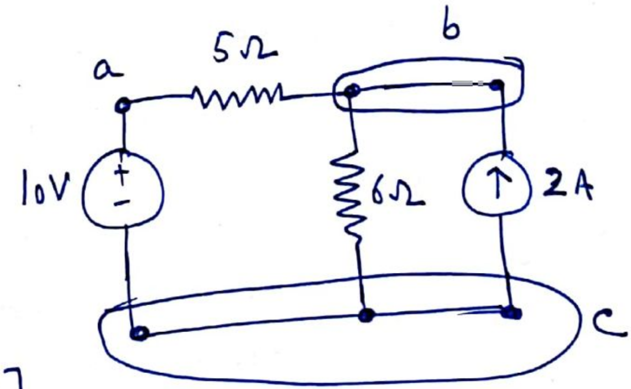
Parallel.

Two or more ~~as~~ are in parallel if they are connected to the same two nodes and consequently have the same voltage across them.

e.g. the figure given;

* the voltage source and 5Ω resistor are in series.
* 2Ω resistor, 3Ω resistor and 2A current source are in parallel.

The 5Ω and 2Ω are neither series nor parallel.



Exp.

Series → 10V & 5Ω

parallel – 6Ω & 2A

Three nodes $n = 3$ [a, b, c]

branches $b = 4$

$l = 2$

$b = l + n - 1$
$4 = 2 + 3 - 1$
$= 2 + 2$
$4 = 4$

Kirchhoff's Laws

Kirchhoff's Laws are a power full tools for analyzing large variety of electric circuits. Introduced in 1847, by German physicist Gustav Robert Kirchhoff (1824-1887). These are known as Kirchhoff's current law (KCL) and Kirchhoff's voltage law (KVL).

KCL states that the algebric sum of currents entering a node is zero.

Mathematically; KCL means

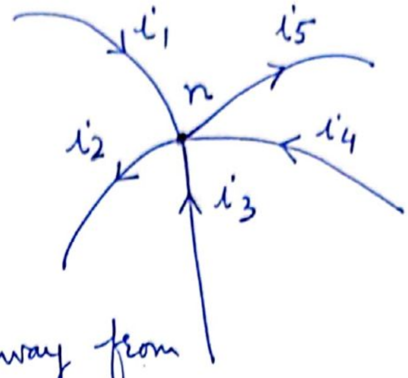
$$\sum_{n=1}^{N} i_n = 0$$

N = no. of branches connected to node
i_n = ~~nth~~ current entering or leaving the n^{th} node.

The law can also expressed as " The sum of currents entering a node is equal to the sum of currents leaving a node".

Convention: we may consider currents towards node as +ve and currents away from node as -ve. or vice versa.

At node n



i_1, i_3, i_4 are directed towards the node.

& i_2 and i_5 → directed away from the node.

KCL at node n → $i_1 + i_3 + i_4 - i_2 - i_5 = 0$.

or $\boxed{i_1 + i_3 + i_4 = i_2 + i_5}$

$i_1 + i_3 + i_4$ → Sum of currents entering the node.

$i_2 + i_5$ → Sum of currents leaving the node.

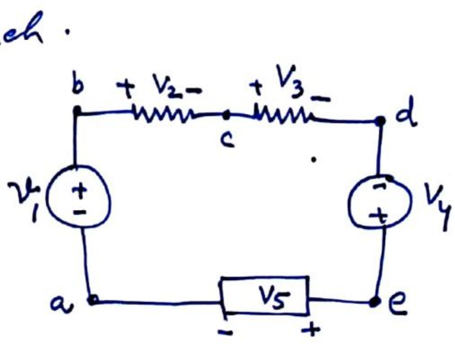
KVL

States that the algebric sum of voltages arround a closed path (loop) is zero.

Mathematically;
$$\sum_{m=1}^{M} v_m = 0$$

M = no. of voltages in the loop (no. of branches in the loop).

v_m = voltage of m^{th} branch.



If we start from point a and move clockwise - abcdea.

a to b → voltage rise (− to +)
b to c — voltage drop (+ to −)
c to d → voltage drop (+ to −)
d − e → voltage rise (− to +)
e − a → voltage drop (+ to −);

Convention : We given +ve sign to voltage rise and −ve sign to voltage drop or vice versa.

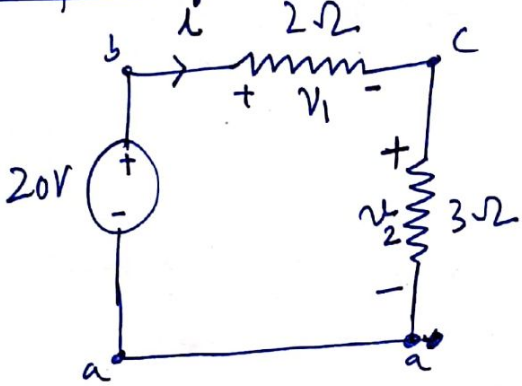
$$V_1 - V_2 - V_3 + V_4 - V_5 = 0.$$

or

$$\boxed{v_1 + V_4 = V_2 + V_3 + V_5}$$

Sum of voltage rises = Sum of voltage drops.

Example :



$v_1 = i \times 2 = 2i$

$v_2 = i \times 3 = 3i$

Apply KVL

$+20 - v_1 - v_2 = 0$

$v_1 + v_2 = 20$

$2i + 3i = 20$

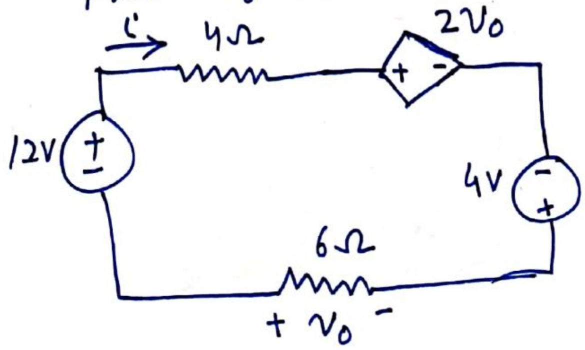
$5i = 20$

$i = 4\ A$;

There $v_1 = 2 \times 4 = 8V$

$v_2 = 3 \times 4 = 12V$

Exp. Find v_0 and i in the ckt shown below



(Do it yourself).

END.