D.C Circuits

Basic Definitions:

Current: the directed flow of electrons (charge) called current. It is denoted by I. units are Amps

Electrical potential: charged body capacity to do work is known as its electrical potential.

Potential difference: difference in potentials of two charged bodies is called Potential difference

Power: the rate at which an electrical work done in electrical work is called power. It is denoted by P. units are Watt

Electrical work: Electrical work is said to be done when there is transfer of charge. It is denoted by W. units are joules.

Energy: capacity to do work is called energy.

Electrical Network: A combination of various electric elements (Resistor, Inductor, Capacitor, Voltage source, Current source) connected in any manner what so ever is called an electrical network

Classification of element:

We may classify circuit elements in two categories, passive and active elements.

Passive Element: The element which receives energy (or absorbs energy) and then either converts it into heat
(R) or stored it in an electric (C) or magnetic (L) field is called passive element.

Active Element: The elements that supply energy to the circuit is called active element. Examples of active elements include voltage and current sources, generators

Bilateral Element: Conduction of current in both directions in an element (example: Resistance; Inductance; Capacitance) with same magnitude is termed as bilateral element

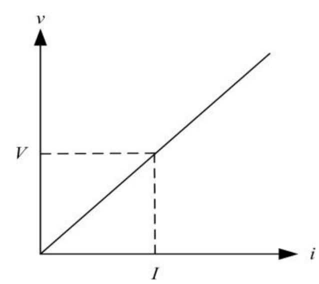
Unilateral Element: Conduction of current in one direction is termed as unilateral (example: Diode, Transistor) element

Ohms Law: At constant temperature potential difference across the conductor is directly proportional to current flowing through the conductor is called ohms law.

$$V \propto I$$

$$V = IR$$

where the constant of proportionality R is called the resistance or electrical resistance, measured in ohms (Ω). Graphically, the $V - I$ relationship for a resistor



according to Ohm"s law is depicted in Figure

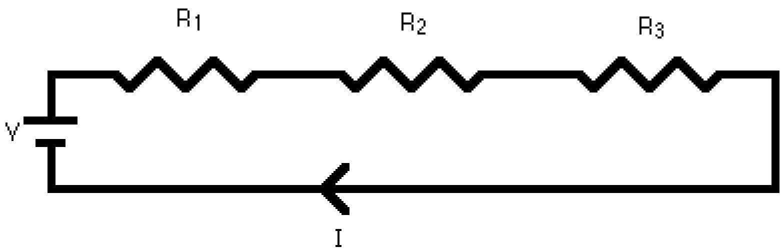
Figure $V - I$ relationship for a resistor according to Ohm"s law.

At any given point in the above graph, the ratio of voltage to current is always constant

Series circuits:

A series circuit is a circuit in which resistors are arranged in a chain, so the current has only one path to take. The current is the same through each resistor. The total resistance of the circuit is found by simply adding up the resistance values of the individual resistors:

equivalent resistance of resistors in series : $R = R_1 + R_2 + R_3 + ...$



A series circuit is shown in the diagram above. The current flows through each resistor in turn. If the values of the three resistors are:

$R_1 = 8\ \Omega$, $R_2 = 8\ \Omega$, and $R_3 = 4\ \Omega$, the total resistance is $8 + 8 + 4 = 20\ \Omega$.

With a 10 V battery, by V = I R the total current in the circuit is:

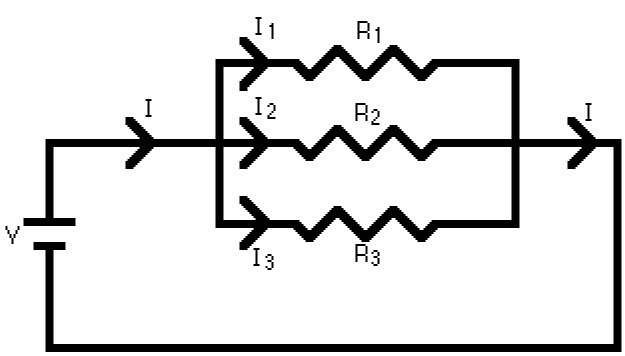
I = V / R = 10 / 20 = 0.5 A. The current through each resistor would be 0.5 A.

Parallel circuits:

A parallel circuit is a circuit in which the resistors are arranged with their heads connected together, and their tails connected together. The current in a parallel circuit breaks up, with some flowing along each parallel branch and re-combining when the branches meet again. The voltage across each resistor in parallel is the same.

The total resistance of a set of resistors in parallel is found by adding up the reciprocals of the resistance values, and then taking the reciprocal of the total:

equivalent resistance of resistors in parallel: $1 / R = 1 / R_1 + 1 / R_2 + 1 / R_3 + \ldots$



A parallel circuit is shown in the diagram above. In this case the current supplied by the battery splits up, and the amount going through each resistor depends on the resistance. If the values of the three resistors are:

$R_1 = 8\ \Omega$, $R_2 = 8\ \Omega$, and $R_3 = 4\ \Omega$, the total resistance is found by:

$1 / R = 1 / 8 + 1 / 8 + 1 / 4 = 1 / 2$. This gives $R = 2\ \Omega$.

With a 10 V battery, by V = I R the total current in the circuit is: I = V / R = 10 / 2 = 5 A.

The individual currents can also be found using I = V / R. The voltage across each resistor is 10 V, so:

I_1 = 10 / 8 = 1.25 A
I_2 = 10 / 8 = 1.25 A
I_3=10 / 4 = 2.5 A

Note that the currents add together to 5A, the total current.

Kirchoff's Laws:-

Kirchoff's current law or point law (KCL)

Statement:- In any electrical network, the algebraic sum of the currents meeting at a point is zero.
$\Sigma I = 0$ ……………………at a junction or node

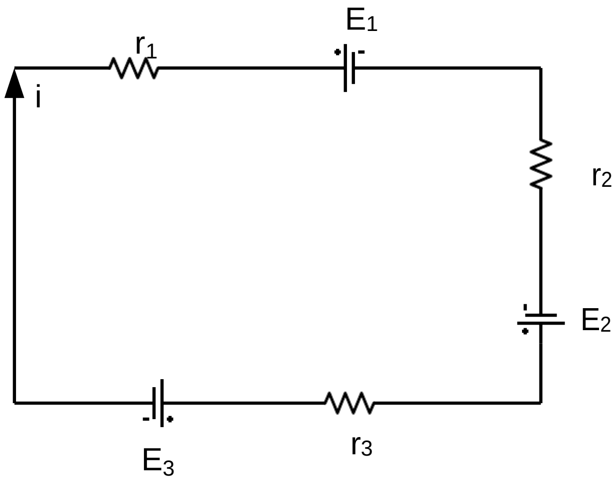
Assumption:- Incoming current = positive

Outgoing current = negative

Kirchoff's voltage law or mesh law (KVL)

Statement:- The algebraic sum of the products of currents and resistances in each of the conductors in any closed path (or mesh) in a network plus the algebraic sum of the emfs in that path is zero.
$\Sigma IR + \Sigma emf = 0$ …………………………..round the mesh
Assumption:- i) Rise in voltage (If we go from negative terminal of the battery to positive terminal) = positive
ii) Fall in voltage (If we go from positive terminal of the battery to negative terminal) = negative
iii) If we go through the resistor in the same direction as current then there is a fall in potential. Hence this voltage is taken as negative.
iv)If we go through the resistor against the direction of current then there is a rise in potential. Hence this voltage drop is taken as positive.

Example:- Write the loop equation for the given circuit below



Solution: Apply KVL to the loop,

$$-ir_1 - E_1 - ir_2 \square E_2 \square ir_3 - E_3 = 0$$

$$\Rightarrow E_1 - E_2 \square E_3 = -ir_1 \square ir_2 \square ir_3$$

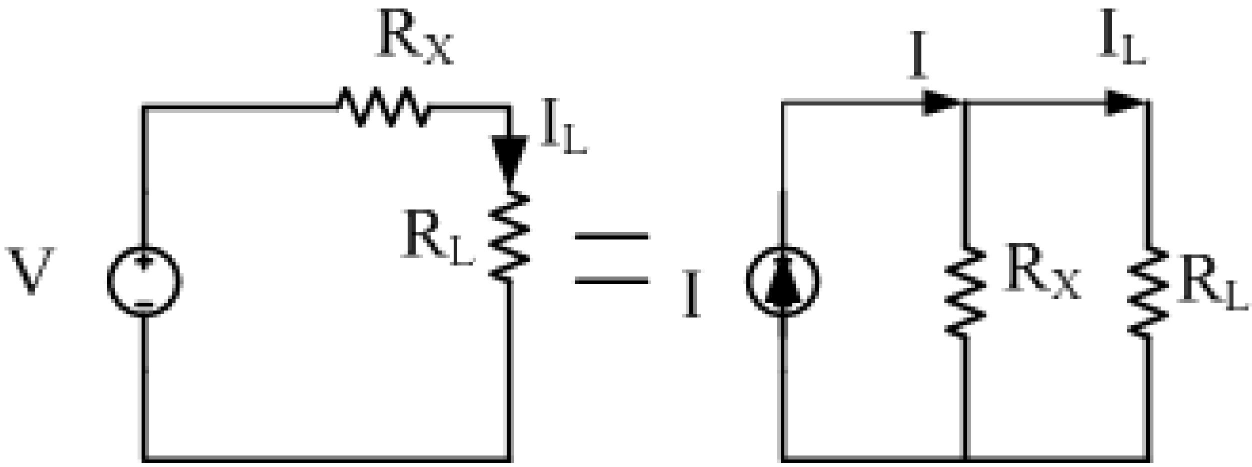
$$\Rightarrow E_1 - E_2 \square E_3 = -i\left(r_1 \square r_2 + r_3\right)$$

R

<u>**SOURCE CONVERSION**</u>:-

Statement: A voltage source (V) with a series resistance (R) can be converted to a current source (I=V/R) with a parallel resistance (R) and vice-versa.

Proof:-



$$I_L = \frac{V}{R_X + R_L} \qquad (1)$$

$$I_L = I\frac{R_X}{R_X + R_L} \qquad (2)$$

From Eq. (1) & (2)

$$V = IR_X \qquad (3)$$

- **STATEMENT**: The two circuits are said to be electrically equivalent if they supply equal load currents with the same resistance connected across their terminals.
- voltage source having a voltage V and source resistance Rx can be replaced by I(= V/Rx) and a source resistance Rx in parallel with current source.
- Current source I and source resistance Rx can be replaced by a voltage source V (=IRx) and a source resistance Rx in series with V.