Unit-I

Concept of Voltage

Electric Potential – When a body is charged, either electrons are supplied to it or they are removed from it, in both the cases, work is done. This work done is stored in the body in the form of electric Potential. Thus, the body has the ability to do work by exerting a force of attraction or repulsion on the other charged particles.

The capacity of a charged body to do work is called electric potential.

The capacity of a charged body to do work determines the electric potential on it, So, the measure of electric potential is the work done to charge a body the one coulomb.

Electric Potential= Work Done / charge

$V=W/Q$ =Joule/coulomb

Unit= Joule/coulomb or volt

A body is said to have an electric potential of 1 Volt if 1 joule of work is done to charge the body to one coulomb.

Potential Difference – When a body is charged to different electric potential as compared to other charged body the two bodies are said to have a potential difference Bothe the bodies are under stress & strain and try to attain minimum potential.

Thus the difference in the electric potential of 2 charged bodies is called potential difference.

Or

The amount of energy used by one coulomb of charge in moving from one point to the other is known as potential difference.

Concept of Current

In metals, a large no of free electrons are available which move from one atom to the other at random.

When an electric potential difference is applied across the metallic wire, the loosely attached free electrons start moving towards the positive terminal of the cell. This continuous flow of electrons constitutes the electric current.

Thus, a continuous flow of electrons in an electric circuit is called electric current.

Conventional direction of flow of current

It was considered that the matter flows from higher potential to lower potential i.e. positive terminal to negative terminal of the cell through external circuit.

This convention of flow of current is so firmly established that it is still in use. Thus, Conventional direction of flow of current is from A to B i.e. from +ve terminal of the cell to –ve terminal through the external circuit.

Mathematically

Current, (I)=Q/T =Charge/Time

Unit- Ampere

Thus, a wire is said to carry a current of 1 ampere when charge flows through it at the rate of one coulomb per second.

Resistance – When a potential difference is applied across a conductor, the free electrons start moving in a particular direction. While moving through the material these electrons collide with other atoms and molecules. They oppose the flow of electrons through it. This opposition is called resistance. Heat is produced because of the collision of moving electrons with the other atoms and molecules.

The opposition offered to the flow of current (free electrons) is called Resistance.

Unit- Resistance is measured in ohms or kilo ohms

A wire is said to have a resistance of one ohm, if one ampere current passing through it produces a heat of 0.24 calories.

Laws of Resistance

(i) It is directly proportional to its length i.e. $R \alpha l$
(ii) It is inversely proportional to its area of cross section, A i.e.

$R \alpha l/a$

(iii) It depends upon the nature (i.e. atomic structure) of the materials of which the wire is made.
(iv) It also depends upon the temperature of the wire.

$R \alpha l/a$, $R=\rho.l/a$

Where ρ is Resistivity proportionality constant

Resistivity- The resistance offered between the opposite two faces of one metre cube of the given material is called the resistivity of the material.

Unit=ohm-m (ohm-metre)

Effect of temperature on Resistance-

(i) **Pure Metals**- When the resistance is made of some pure metal (like copper, aluminium, silver), its resistance increases with the increase in temperature.
(ii) **Alloys**- When the resistance is made of some alloy, its resistance increases with the increase in temperature, But the increase is very small & irregular.

(iii) **Semi Conductions, Insulators & Electrolytes**- The resistance of semiconductors, insulators and electrolytes (like silicon, glass, Varnish etc.) decreases with the increase in temperature.

Electrical Power- The rate at which work is done in an electrical circuit is called electrical power.

Hence Electrical Power = Work done in Electrical Circuit/Time

$P=V.I.t/t = V. I = I^2R$ or V^2/R

Unit of Power = Watt

The power consumed in an electrical ckt is said to be 1 watt, if one ampere current flows through the circuit. When a potential difference of 1 volt is applied across it.

1KW=1000Watt

Types of power

1) True power or Active power or Real power
2) Reactive power
3) Apparent power

1) **True Power**- The power which is actually consumed or utilised in an a.c circuit is called true power. Power is consumed in resistance. A pure inductor& capacitor do not consume any power. Eg-Heat in Heaters, light in lamps etc.
2) **Reactive Power**- The power which flows back and forth (i.e. both the directions in the ckt) or reacts upon itself is called Reactive power. It does not do any useful work in the circuit. Eg- Inverter Ratings

True power= Voltage × Current in phase with Voltage.

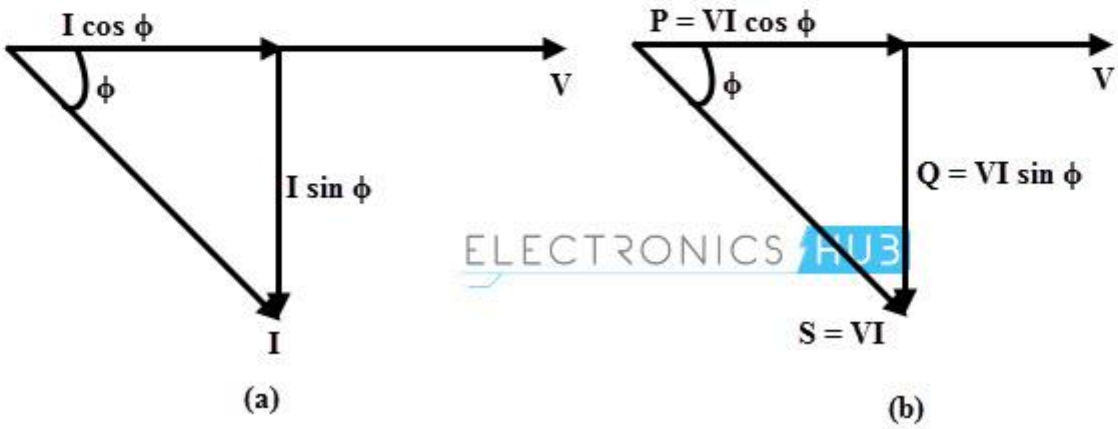
$P=V \times I\cos\phi$, unit=Watt

Reactive power- P_r=Voltage × Current 90° out of Phase with Voltage

$P_r=V \times I\sin\phi$

Apparent power- $P_a=V \times I$, Unit=VA

Phasor Diagram of power



Eg. -Transformer rating

Power Triangle- A right angled triangle whose base represents true power (V×Icosø) perpendicular represents Reactive power (V×ISinø) and apparent power(VI)Represents hypotenuse.

- **Capacitance** – The capability of a capacitor to store charge is called capacitance. The charge Q stored by capacitor is directly proportional to the potential difference (V) applied across it, I.e.

  $$Q \times V$$

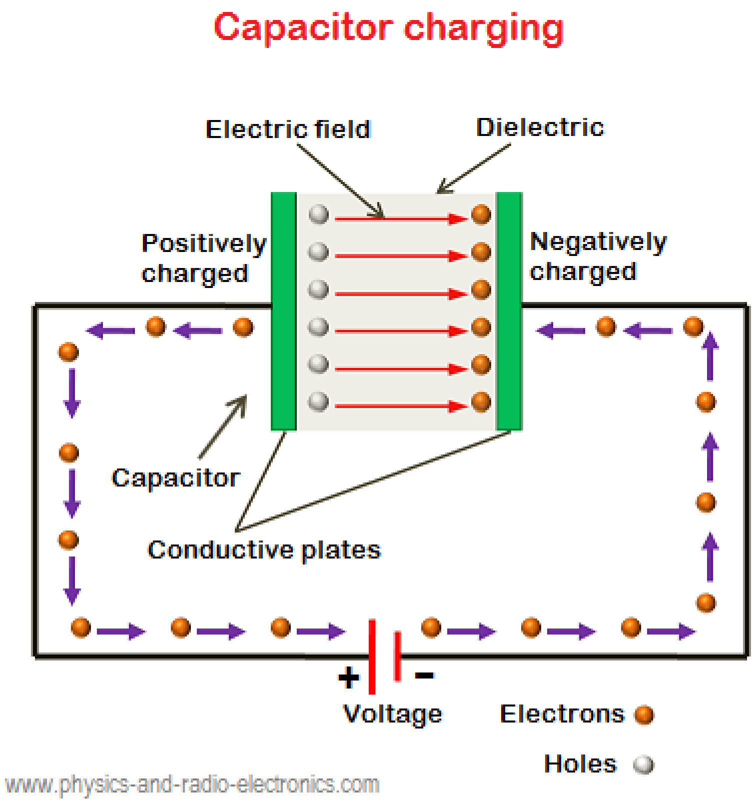
  $$Q/V=\text{Constant}=C$$

  Hence the charge on the capacitor plates per unit potential difference across the plates is called the capacitance of the capacitor.
  Unit of capacitor is farad (F)
  Hence, a capacitor is said to have a capacitance of 1 farad, if a charge of 1 coulomb accumulates on each plate when a potential difference of 1 volt is applied across the plates.

  $1\mu F=10^{-6}$ Farad
  Microfarad

- **Capacitor**- Two conducting surfaces separated by an insulating material or dielectric is called a capacitor or Condenser.
  Since the arrangement has the capacity to store electricity, it is named as capacitor.
- It is known as condenser due to the fact that when potential difference is applied across the conducting plates, the electric lines of force are condensed in the small space b/w them
  A capacitor is named after dielectric used i.e. air capacitor, paper capacitor, Mica capacitor, Ceramic capacitor etc.

Working of Capacitor – When a d.c supply is connected across a capacitor, it stores charge. A parallel plate capacitor having plates A&B is connected across a battery of Voltage V Volts through a key (K).



(i) When key (K) is open, the capacitor plates are neutral i.e. the plates are having no charge.
(ii) When key K is closed, the electrons from plate A are attracted by the positive terminals of the battery and reach the plate B through the battery. Thus the electrons detached from plate A start piling up on plate B. As a result, plate A attains more and more positive charge and plate B attain more & more negative charge. The process is called charging of capacitor
(iii) This flow of electrons continue from plate A to B through battery till the capacitor is charged to V Volts (i.e. equal to the supply Voltage) Once the capacitor is charged to V volts the flow of electrons ceases.
(iv) Now, if key 'K' is opened, the capacitor is charged& the charged is stored in the electrostatic field established b/w the plates in the dielectric.

Dielectric Constant or Relative Permittivity

The ability of an electric material to concentrate electric lines of force between plates of the capacitor is called dielectric constant or relative permittivity of the material.

Let V = potential difference applied across capacitor

Q= charge on the capacitor plates with air as insulating medium.

$C_{air}=Q/V$

Now, if Mica is used as insulating medium in the same capacitor, it can hold a charge of 6Q coulomb with the same Voltage V

C_{mica}= 6Q/V=6V/V=6C_{air}

C_{mica}/C_{air} =6 (dielectric constant of mica)

Factors affecting capacitance

The capacitance of a capacitor depends upon the following factors

(i) **Area of plates**- Larger the area of capacitor plates, the greater is the capacitance of the capacitor & vice versa. This is because larger plates can hold greater charge for a given P.d which increases the capacitance of capacitor.

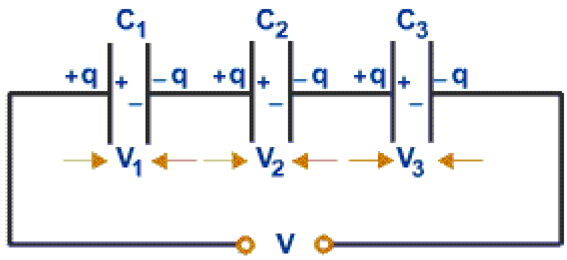
(ii) **Thickness of Dielectric** - The capacitance of capacitor is inversely proportional to the thickness of the dielectric i.e. distance b/w the plates. i.e., the smaller the thickness of dielectric, the greater the capacitance and vice-versa.

(iii) **Relative Permittivity of dielectric** – Capacitance of a capacitor depend upon the type of insulating material (or dielectric) placed b/w, the plate. The greater the value of relative permittivity of the insulating material, the greater will be the capacitance of the capacitor & vice-versa.

Types of capacitors – Capacitors are generally classified according to the dielectric medium applied b/w the plates.

1. **Air capacitor**- Air is used as dielectric medium. A variable air capacitor is also known as gauge condenser.
2. **Mica capacitor** – A mica capacitor consists of thin mica sheets stacked b/w tin foil section (I.e. plates). Alternate strips of tin foil are connected together and brought out as one terminal for one set of plates, while the opposite terminal in connected to the other set of plates.
3. **Paper capacitor** – It consists of two rolls of tin foils (plates) separated by a paper sheet and rolled into a compact cylinder.
4. **Ceramic capacitor** –It consists of a disc of ceramic material whose opposite faces are coated with metallic silver. The ceramic disc acts as dielectric of high relative permittivity and silver coating on plates.
5. **Electrolytic capacitor** – It consists of two aluminium foils with an oxide film and the other without, the foils being separated by a material such as paper saturated with suitable electrolyte.

Capacitors in series – Consider three capacitor having capacitances C1, C2, C3 farad respectively connected in series. When a p.d of V volts is applied across the grouping, a charging current flows through the ckt which develops the same charge Q on each capacitor at different p.d V1, V2 &V3 respectively.



V_1

Now, Supply Voltage=Sum of p.d across each capacitor

$V=V_1+V_2+V_3$

$=Q/C_1+Q/C_2+Q/C_3$

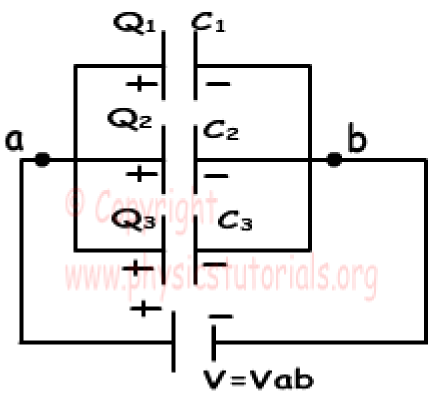
$V=Q(1/C_1+1/C_2+1/C_3)$

$V/Q=1/C_1+1/C_2+1/C_3)$

$1/C_T=1/C_1+1/C_2+1/C_3$

Capacitance in Parallel

Consider 3 capacitances C_1, C_2, C_3 farad connected in parallel. When a p.d of 'V' volts is applied across the grouping different charging current flow in each branch and the capacitors attain different charge i.e. Q_1, Q_2, Q_3 respectively



Now, total charge shifted= sum of charge shifted on each capacitor

$Q = Q_1+Q_2+Q_3$

$=C_1V+C_2V+C_3V$

$Q=V(C_1+C_2+C_3)$

$Q/V= C_1+C_2+C_3$

$C_T=C_1+C_2+C_3$

- **Ohm's Law**- It states that the current flowing b/w any two point of a conductor (ckt) is directly proportional to the potential difference across them, provided physical conditions i.e. temperature etc. don't change.

  Mathematically

  IαV

  Or V/I=constant.

  V/I=R

  Proportionality constant or Resistance

  In other words, ohm's law can be stated as the ratio of potential difference across any two points of a conductor to the current flowing b/w them is always constant, provided the physical condition i.e. temperature etc. so not change.

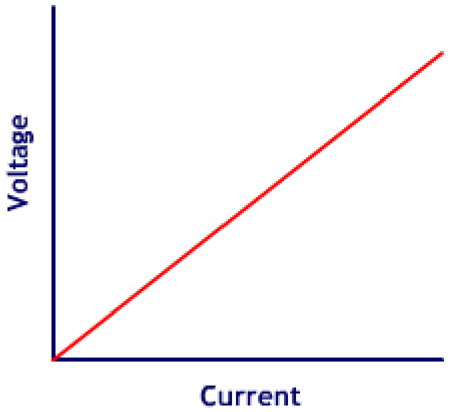
  This constant is called the resistance (R) of the conductor.

  V/I=R

  Or V=IR

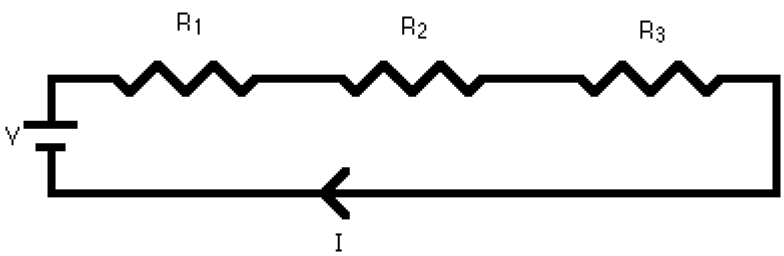
  In a circuit, when current flows through a resistor the p.d across the resistor is known as voltage drop across it i.e. =V=I.R

  Graphs showing results of ohm's low



  The graph shows the linear relationship b/w the voltage and current i.e. if voltage increases, current also increases and its Vice-versa.

  Series Circuit – The circuit in which number of resistors are connected end to end so that same current flows through them is called series circuit.



In the circuit, three resistors R_1, R_2&R_3 are connected in series across a supply voltage of 'V' volts. The same current (I)is flowing through all the three resistors. If V_1, V_2, V_3 are the voltage drops across the three Resistors.

Then

$$V=V_1+V_2+V_3$$

As per ohm's law

$V_1=I.R_1$ $V_2=I.R_2$

$V_3=I.R_3$

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

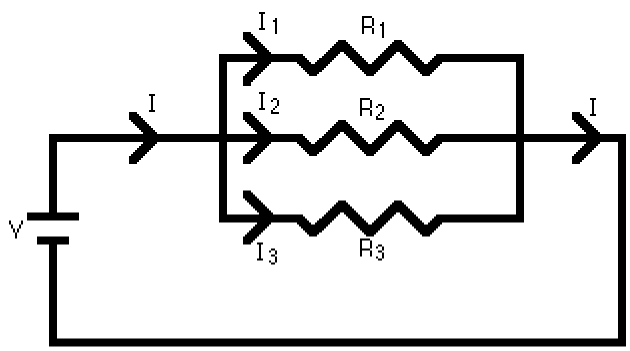
$V=I\ (R_1+R_2+R_3)$

$I.R=I(R_1+R_2+R_3)$ $V=I.R$

$$R_s=R_1+R_2+R_3$$

Total Resistance=Sum of Individual Resistances.

Parallel Circuit- The circuit in which one end of all the resistors is joined to a common point and the other ends are also joined to another common point so that different current flows through them is called Parallel circuit.



Three resistors R_1, R_2&R_3 are connected in parallel across a supply voltage of V volts.

The current flowing through them is I_1,I_2&I_3 respectively.

The total current drawn by the circuit

$I=I_1+I_2+I_3$

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

According to ohm's law

$I_1=V/R_1$,$I_2=V/R_2$,$I_3=V/R_3$

$$I=V/R$$

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

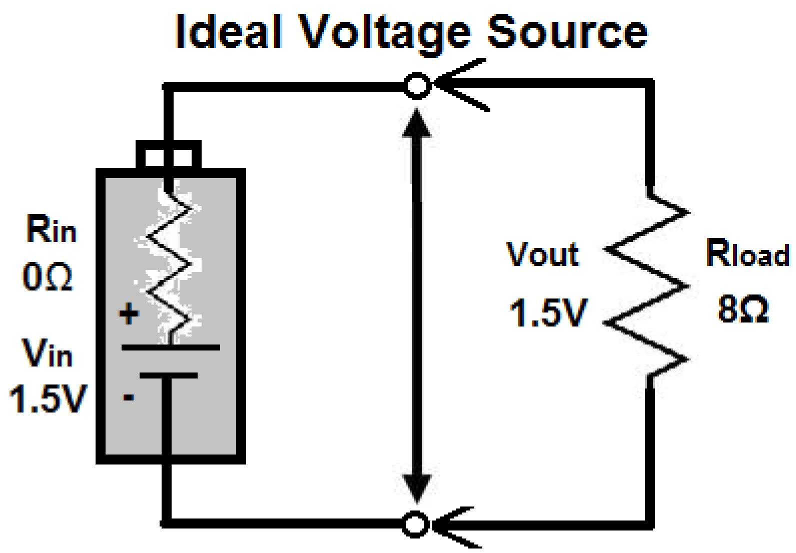
$V/R=V(1/R_1+1/R_2+1/R_3)$

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

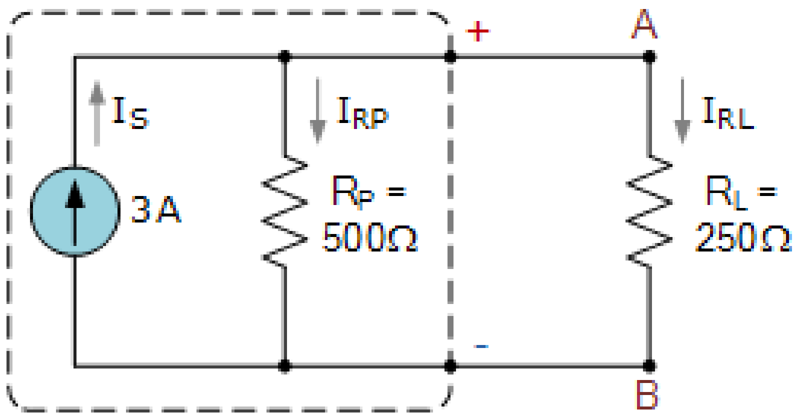
Reciprocal of total Resistance =Sum of Reciprocal of the individual, resistance

Current and Voltage source

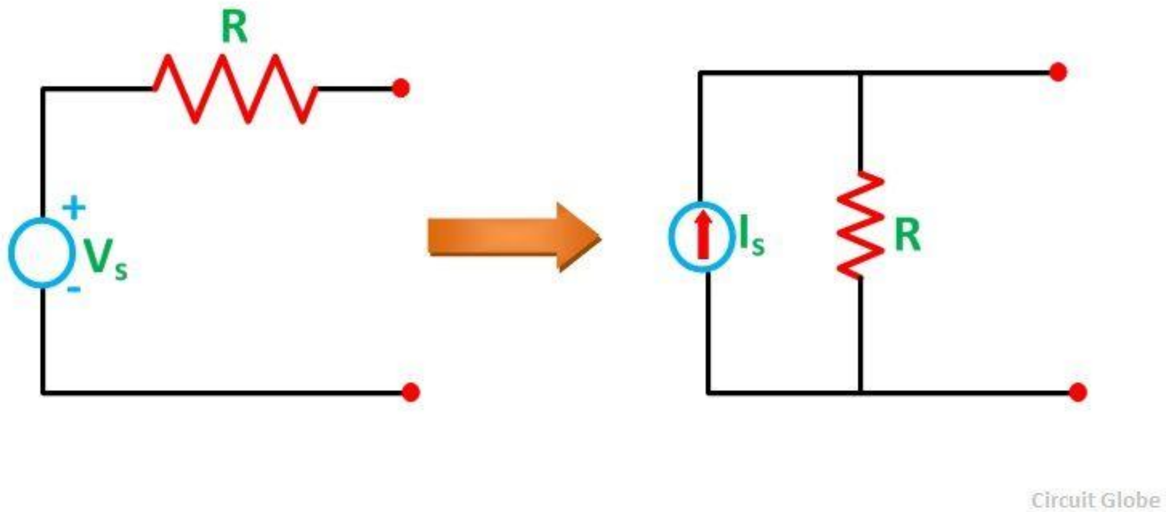
Voltage source

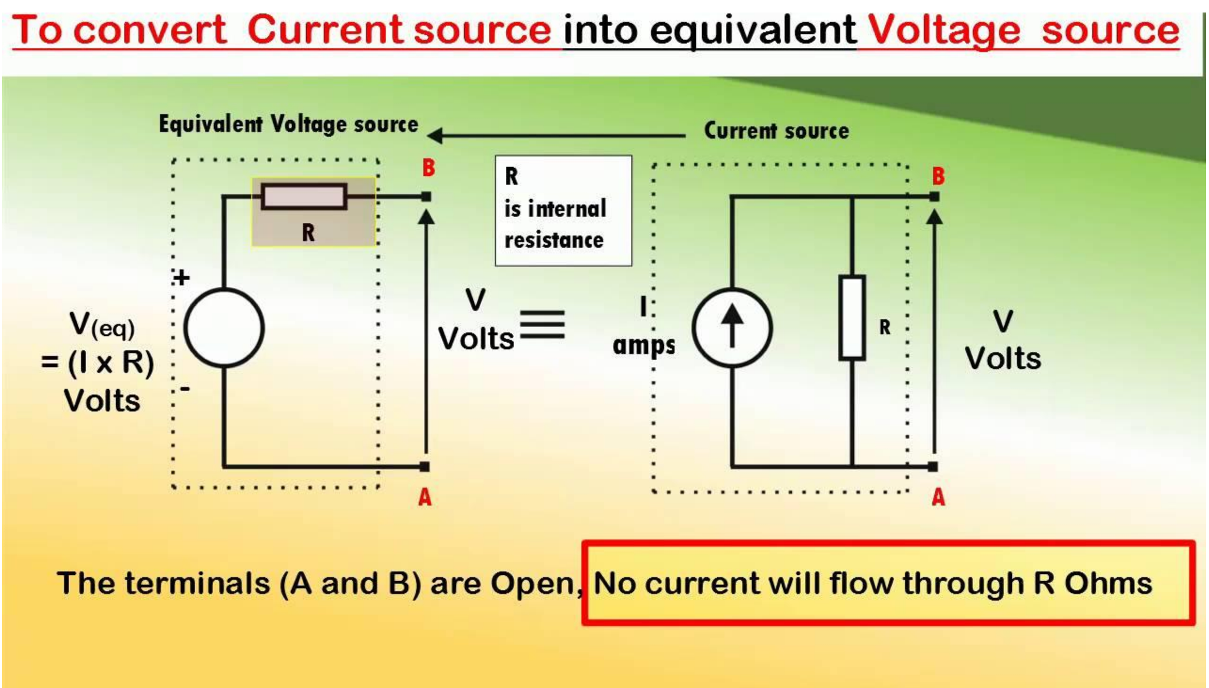


Current source



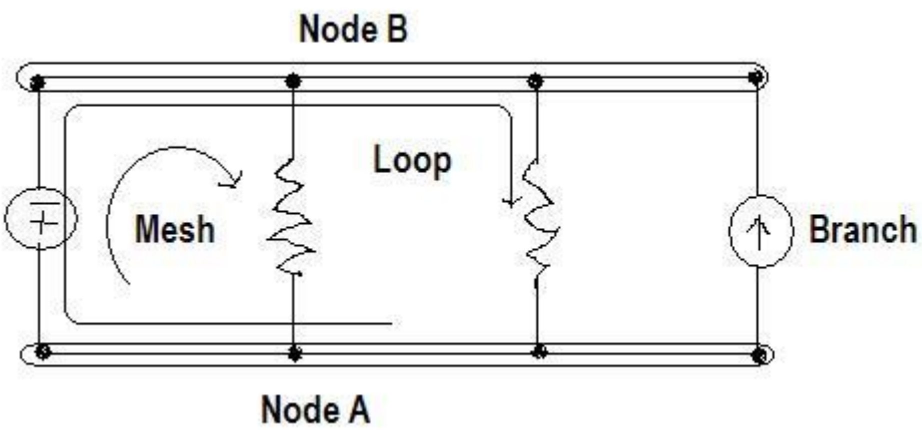
Conversion of current source into Voltage source





Network Terminology-

1. **Active element**- The element which supplies energy to the circuit is called active element. Battery is an active element
2. **Passive element**- The element which receive energy is called passive element. Eg- Resistor, Inductor& capacitor.
3. **Node**- A node is a point in the network where two or more circuit element are joined.
4. **Junction**- A junction is a point in the network where three or more circuit elements are joined.
5. **Branch** – The part of the network which lies b/w two junction points is called branch.
6. **Loop** – The closed path of a network is called a loop.
7. **Mesh**- The most elementary form of a loop which cannot be further divided is called a mesh.



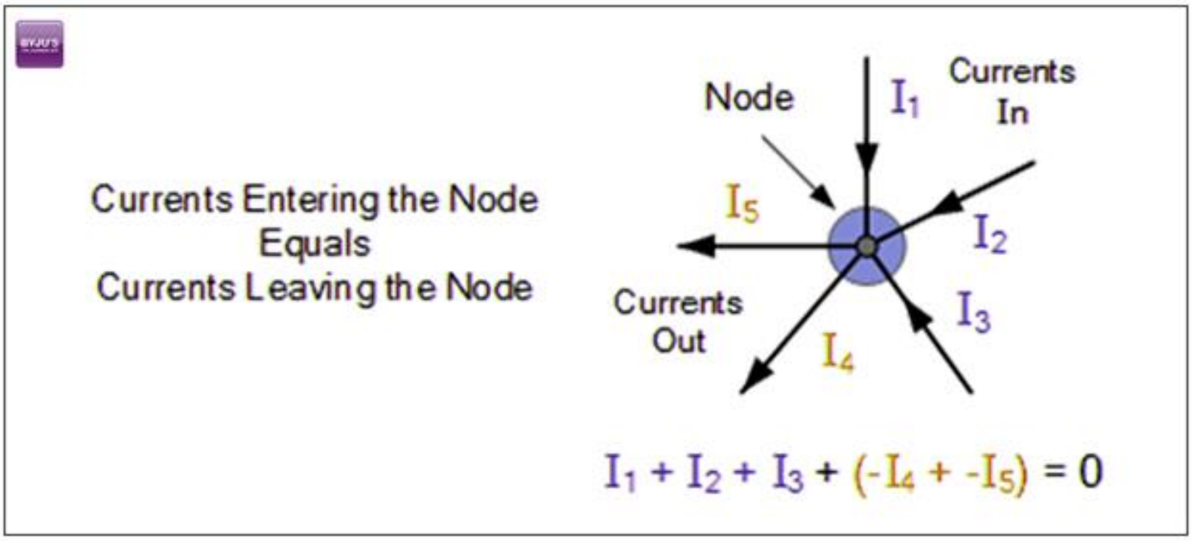
Kirchhoff's law- Gustav Kirchhoff, a German scientist summed up his finding in a set of two laws known as Kirchhoff's laws.

Kirchhoff's first law- This law relates the current flowing through the circuit, it is also known as Kirchhoff's Current law(KCL)

This law states that,

The algebraic sum of all the currents meeting at a point or junction is zero.

Mathematically $\Sigma I=0$



Sign convention-

Incoming current=+ve

Outgoing current=-ve

Applying Kirchhoff's current law to junction 'O'

$$I_1+I_2+I_3-I_4-I_5=0$$

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

Sum of incoming current=Sum of outgoing current

Hence, Kirchhoff's Current law can also be stated as

The sum of incoming current are equal to the sum of outgoing current at a point or junction in an electrical network.

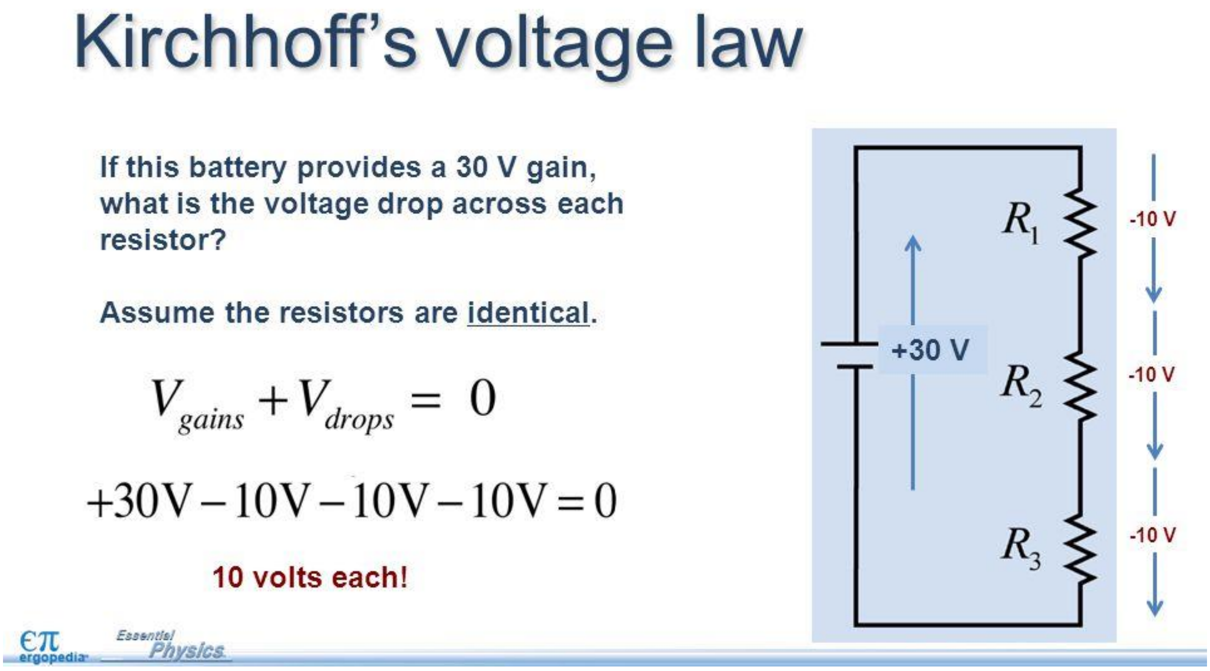
Kirchhoff's Second law- Since this law relates to the voltage in a closed circuit of an electrical network, it also known as Kirchhoff's voltage law or Kirchhoff's Mesh law.

In a closed circuit or mesh, the algebraic sum of all the emf's plus the algebric sum of all the voltage drops (i.e. product of current & resistance) is zero.

i.e. algebraic sum of all the emf's + algebraic sum of all the voltage drops=0

Mathematically,

$$\Sigma E+\Sigma V=0$$



Sign Convention

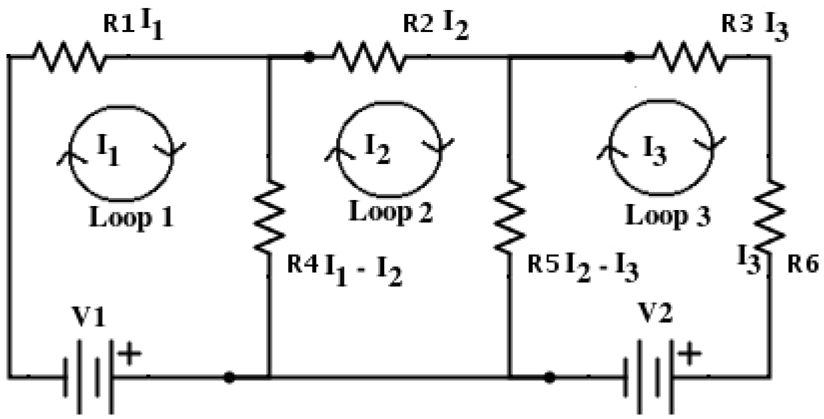
A fall in potential as- ve

A rise in potential as +ve

Tracing branch, A to B, E is negative [i.e.(-E)]

Tracing branch B to A, E is positive [i.e.(+E)]

Mesh Analysis –In this method, mesh currents are taken instead of branch currents.

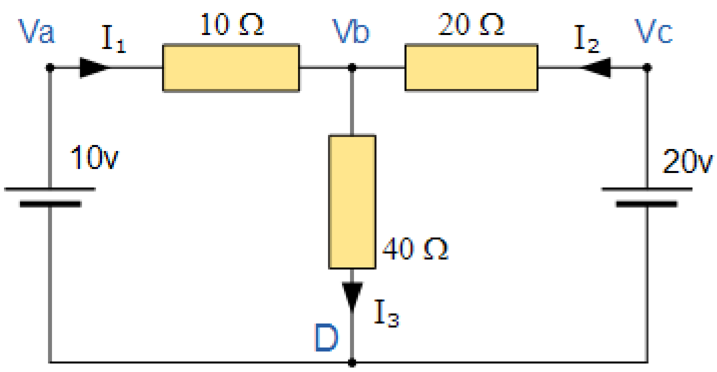


The following steps are taken while solving network by the method.

a) The whole n/w is divided into a number of meshes. Each mesh is, assigned a current having continuous path. These mesh currents are preferably drawn in clockwise direction
b) Write Kirchhoff's voltage law equation for each mesh using the same signs as applied to Kirchhoff's law.
c) No. of equations must be equal to the number of unknown quantities. Solve the equations& determine the mesh currents.
d) From mesh currents, determine the branch currents.

Nodal Analysis

In this method, one of the nodes is taken as the reference node and the other as independent nodes. The voltage at different independent nodes are assumed and equations, are written for each node as per KCL.



After solving those equations, the node voltage are determined.

Consider a circuit shown in fig where D&B are the two independent nodes. Let D be the reference node and the voltage of node B be V_B.

According to Kirchhoff's current law

$$I_1+I_2=I_3$$

In mesh ABDA, the p.d across R_1 is E_1-V_B

$$I_1=(E_1-V_B)/R1$$

In mesh BCDB, the p. d across R_2 is E_2-V_B

$$I_2=(E_2-V_B)/R2$$

Also current, $I_3=V_B/R_3$

Substituting the value of I_1, I_2&I_3 in Equation 1

$(E_1-V_B)/R_1+(E_2-V_B)/R_2=V_B/R_3$

Rearranging the terms

$V_B(1/R1+1/R2+1/R3)-E_1/R_1-E_2/R_2=0$

This method is faster as the results are obtained by solving lesser number of equation.