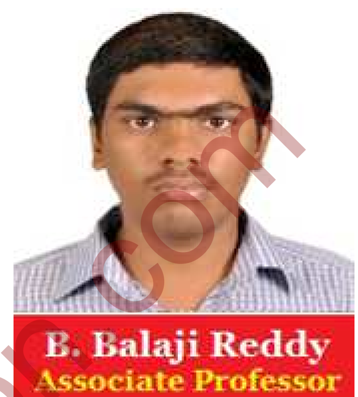
Basic Electrical Circuit Concepts

Network:



Interconnection of different elements together forms a network. If the network is formed with electrical elements then it is said to be electrical network.

The closed path inside the network forms a circuit. An electrical circuit generally consists of 1) source 2) Load 3) connecting wires

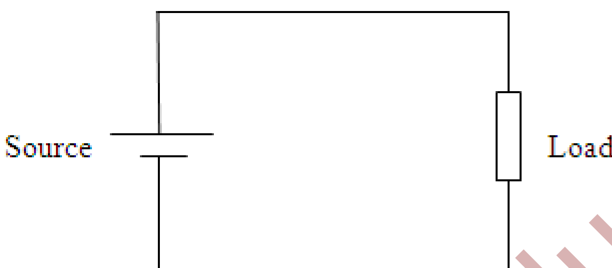
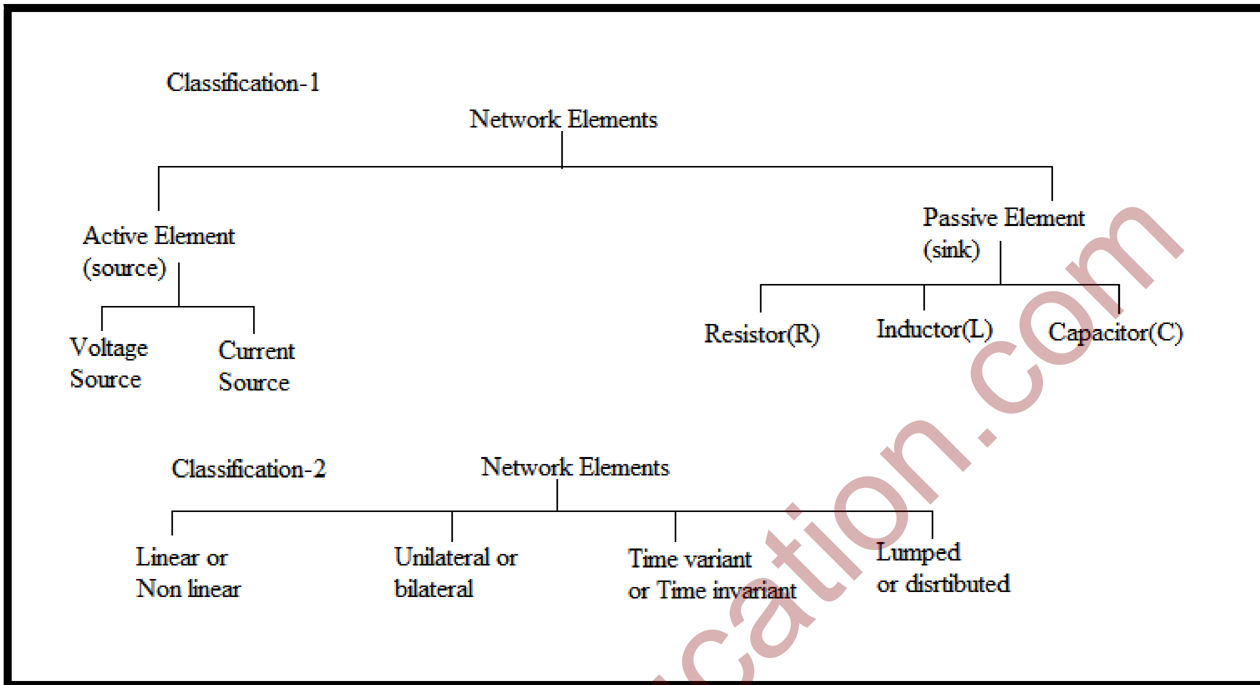


Fig: Circuit

- The element that delivers power in the circuit is called source like battery, generator etc..
- The element that consumes power in the network is said to be load like fan, light etc..,
- The source and load are interconnected with the help of wires.

A conducting material consists of number of atoms. Each atom consist positive and negative charges. The negative charges revolve around the nucleus. Whenever additional energy is given to these negative charges some of the charges which are loosely bond with the nucleus will get excited and move from a new location to another location. Thus the transfer of charges occurs in a conducting material.

CLASSIFICATION OF NETWORK ELEMENTS:



Active elements: Supplies the energy to the circuit. Ex: voltage source, current source.

Passive elements: These may absorb or store energy. Ex: R, L, C

Linear or Non-linear:

A Linear element is one which is governed by a linear relationship between the excitation and response. Otherwise, it is a non linear. In case of a linear element the value of the parameter is independent of voltage or current through the element.

Ex: 1) R, Air cored inductor are linear elements.

2) Germanium diode, triode, Iron cored inductor are non linear elements.

Unilateral or Bilateral:

Unilateral elements offer low impedance for the flow of current in one direction and high impedance for the flow of current in opposite direction. The current flowing through the elements changes with the direction of current flow. Ex: vacuum diode, Semiconductor device etc.

Bilateral elements offer same impedance for the flow of current in either direction. The current flowing through the elements does not change with its direction. Ex: R, L, C.

Lumped and Distributed Elements:

Lumped element is on e whose size is small compared to the wave length corresponding to their normal frequency of operation; otherwise it is called a distributed element.

The Kirchoff's law is only applicable to only lumped elements.

Ex: R, L, C are lumped elements. And long transmission line is a distributed network.

Time variant and time invariant elements:

If the parameters of network elements do not vary with time, they are called time invariant elements, otherwise they are called time variant. Normally, we will consider networks whose elements are linear, time invariant and lumped.

Current:

The rate transfer of charge (e^-) in a circuit is said to be current.

$$I = \frac{Q}{T}$$

$$i = \frac{dq}{dt}$$

Units are columns/ second or amperes

Potential difference or voltage or E.M.F:

The difference in potential at two points is said to be potential difference.

Or

The work done per unit charge is called voltage

Or

The force that motivates electrons to move from one point to another point is known as EMF

$$V = \frac{W}{Q} \quad or\ v = \frac{dw}{dq}\ \frac{joules}{coloumbs}\ or\ volts$$

Power: The rate of work done is considered as power

$$P = \frac{W}{T} = \frac{W}{Q} * \frac{Q}{T} = V * I$$

dw/dt is the instantaneous power

Units: watts (or) J/S (or) VA (or) VAR

Energy: The capacity of doing work (i.e. moving charge) is known as energy.

W=P*T   Units: watt hour

—› Consumption of electrical energy is measured in units where one unit is equal to one kilowatt-hour (kwh)

1 unit = 1 kwh. i.e. if an electrical equipment consumes 1000 watts per hour then it is called one unit consumption of power

Ohms law: At constant temperature and pressure the current passing through the element is directly proportional to potential difference across the element.

$$I \propto V => I = \frac{V}{R}$$

$$V = IR$$

Basic Elements:

1) **Resistor:** The property that opposes the flow of current is known as resistance.

The element that exhibits this property is known as resistor. It is denoted as 

— Where ρ= resistivity of material; l= length of conductor; a= area of cross section

According to ohms law –

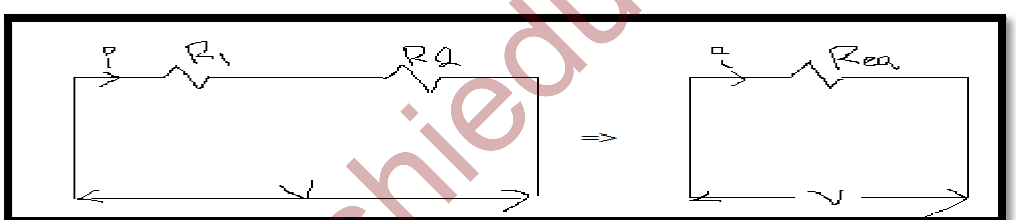
Potential difference across the resistor is

Current through the resistor is –

Power dissipated across the resistor – —

Resistances in series and parallel:

- If two resistances connected in series then they carry same current. The equivalent resistance can be calculated as fallows.

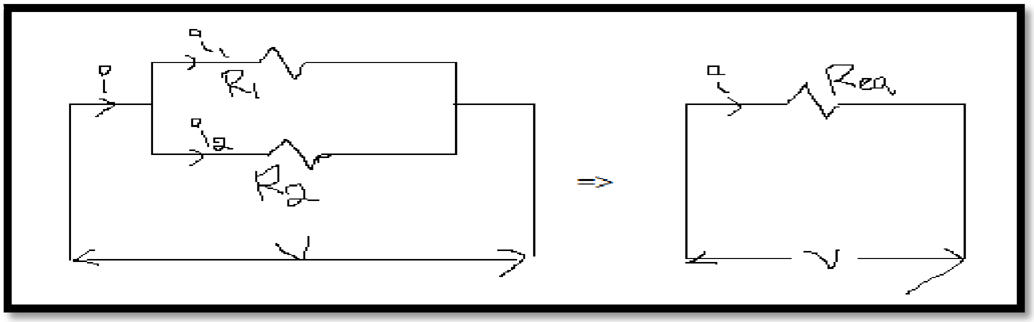


V = + = I + I = I +

Therefore = +

If n number of resistances than, = + + - - - - - +

- If two resistances connected in parallel then they have same voltage. The equivalent resistance can be calculated as fallows.



I = + = — + — = V (— +—)

Therefore = (— +—)

If n number of resistances than, = — + — + - - - - - + —

2) *Inductance :*

The property of element that opposes the sudden change in current is inductance (L). The element that exhibits inductance property is said to be an inductor.

A wire of certain length is twisted into a coil become a basic inductor. The unit of inductance is **Henry**. By definition 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 symbol for inductance is

– —

Where ψ= flux linkages or total flux

N= number of turns

Φ= flux

I= current through inductor

The current voltage relation is given by —

— –

Hence the current passing through the inductor is given by –

Power absorbed by inductor is —

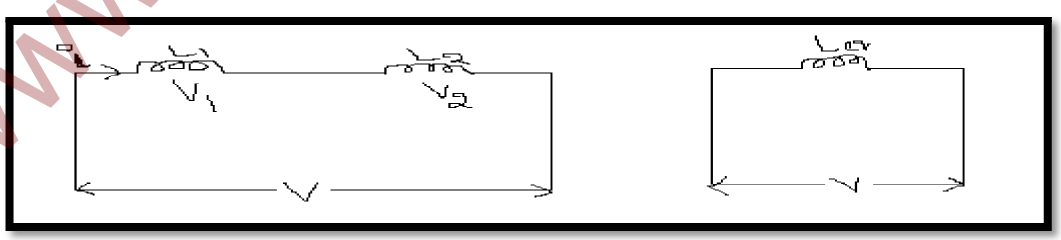
Energy stored by the inductor is — —

Properties of Inductor :

- ✓ The induced voltage across an inductor is zero if the current through it is constant, meaning that an inductor acts as short circuit to DC supply.
- ✓ A small change in current within zero time through an inductor gives an infinite voltage across the inductor , which is physically impossible . In a fixed inductor the current cannot change abruptly.
- ✓ The inductor can store finite amount of energy , even if the voltage across the inductor is zero
- ✓ A pure inductor never dissipates energy , only stores it. That is why it is also called a non dissipative passive element. However , physical inductors dissipate power due to internal resistance .

Inductances in Series and Parallel:

- If two inductances connected in series then they carry same current. The equivalent inductance can be calculated as fallows.

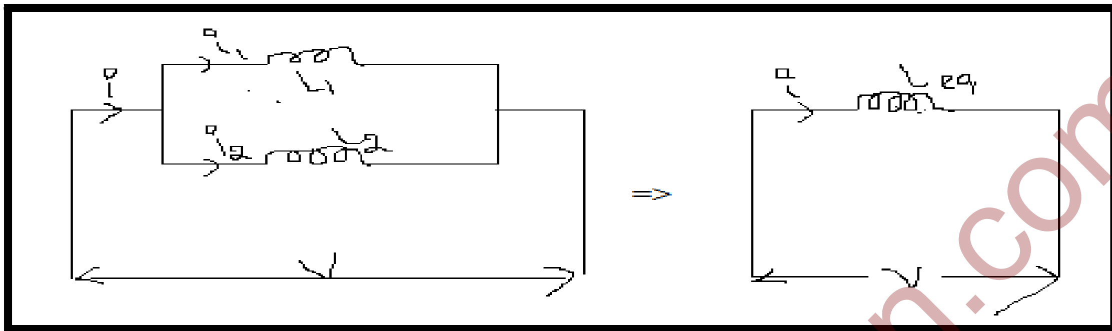


V = + = — + — = — +

Therefore = +

If n number of inductances than, = + + - - - - - - +

- If two inductances connected in parallel then they have same voltage. The equivalent inductance can be calculated as fallows.



I = + = — + — = (— + —)

Therefore = (— + —)

If n number of inductances than, = — + — + - - - - - - + —

3) Capacitor:

The property of element that opposes the sudden change in voltages isa called capacitor (c) . The element that exhibits capacitance property is called capacitor.

Any two conducting surfaces separated by an insulating medium exhibit the property of capacitor. The conducting surfaces are called electrodes and the insulating medium is called dielectric.

—

Units : Faraday (F)

—

Current passing through the capacitor is —

For DC supply v is constant then dv/dt becomes zero then i=0 i.e capacitor acts as ashort circuit for d.c supply

– –

Voltage across capacitor –

Power (P) = V*I — —

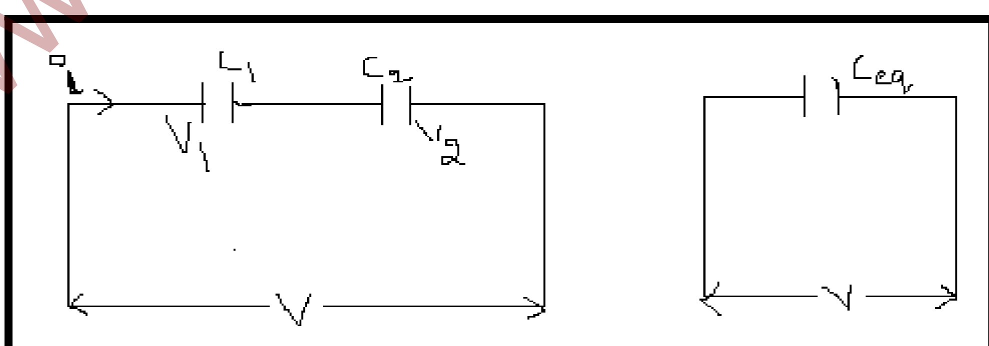
Energy stored —

Properties of capacitor:

- ✓ The current in a capacitor is zero if the voltage across it is constant : that means the capacitor acts as an open circuit to dc supply.
- ✓ A small change in voltage across capacitor within zero time gives an infinite current through the capacitor , which is physically impossible . In a fixed capacitance the voltage cannot change abruptly .
- ✓ The capacitor can store a finite amount of energy , even if the current through it is zero.
- ✓ A pure capacitor never dissipates energy , but it only stores it ; that is why it is called non dissipative passive element . However , physical capacitors dissipate power due to internal resistance.

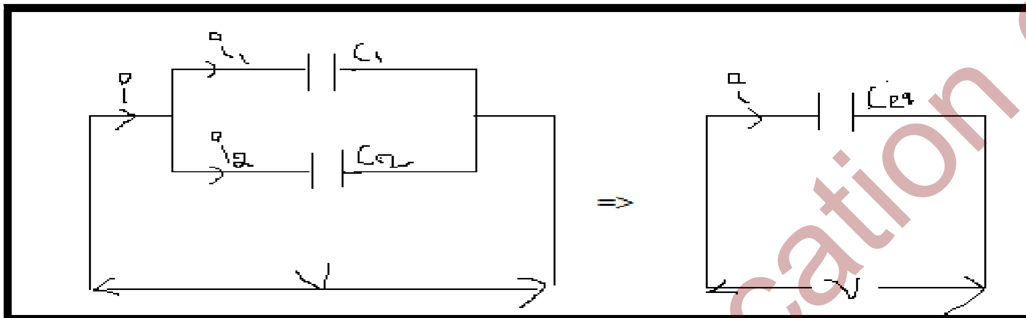
Capacitances in series and parallel:

- If two capacitances connected in series then they carry same current. The equivalent capacitance can be calculated as fallows.



V = + = — + — = (—+—)

- Therefore = (—+—)
- If n number of inductances than, = — + —+ - - - - - + —
- If two capacitances connected in parallel then they have same voltage. The equivalent capacitance can be calculated as fallows.



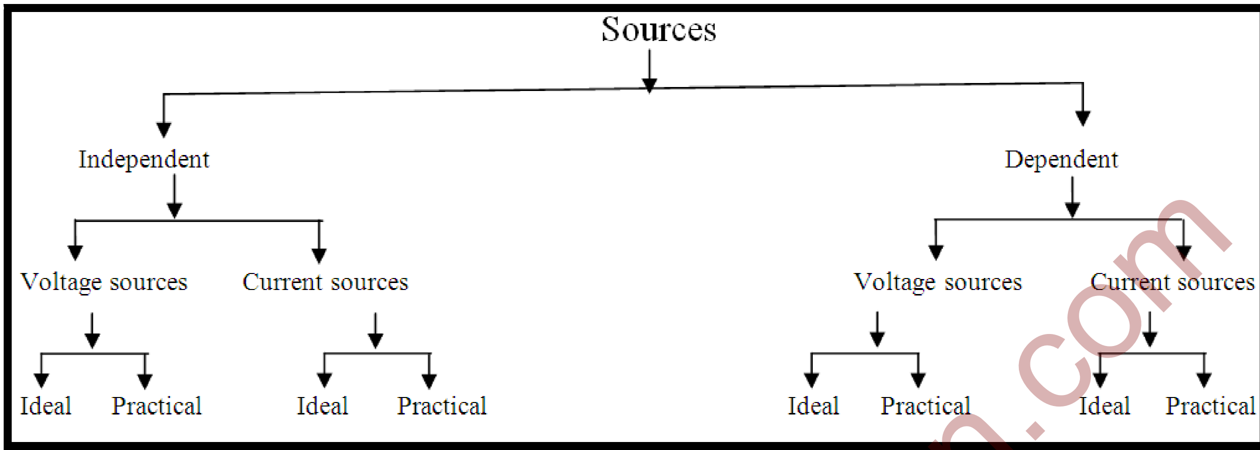
I = + = — + — = — +

Therefore = +

If n number of capacitances than, = + + - - - - - +

Element	Basic relation	Voltage across, if current known	Current through, if voltage known	Energy
R	$R = \frac{V}{I}$	$v_R(t) = R\, i_R(t)$	$i_R(t) = \frac{1}{R} v_R(t)$	$w = \int_{-\infty}^{t} i_R(t)\, v_R(t)\, dt$
L	$L = \frac{N\phi}{I}$	$v_L(t) = L \frac{di_L(t)}{dt}$	$i_L(t) = \frac{1}{L} \int_{-\infty}^{t} v_L(t)\, dt$	$w = \frac{1}{2} L\, i^2(t)$
C	$C = \frac{q}{V}$	$v_C(t) = \frac{1}{C} \int_{-\infty}^{t} i_C(t)\, dt$	$i_C(t) = C \frac{dv_C(t)}{dt}$	$w = \frac{1}{2} C\, v^2(t)$

Source Classification:



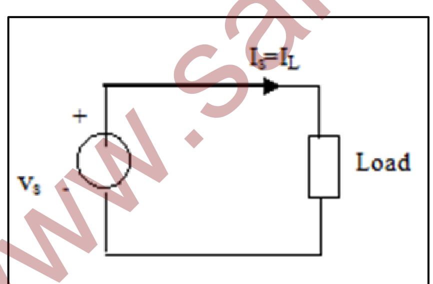
Independent Sources:

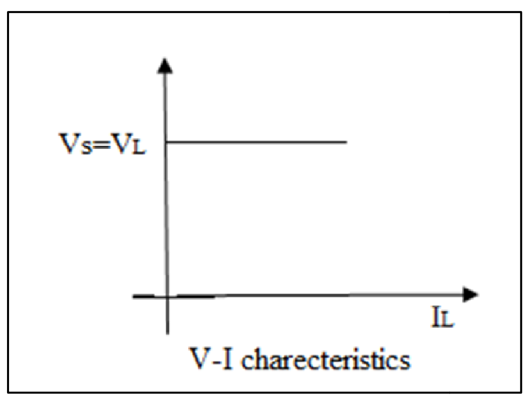
These sources doesn't depend on any other parameters of the circuit.

Voltage sources:

- ***Ideal voltage source*:** Ideal voltagre source delivers constant voltage irrespective of the load current drawn from the supply.

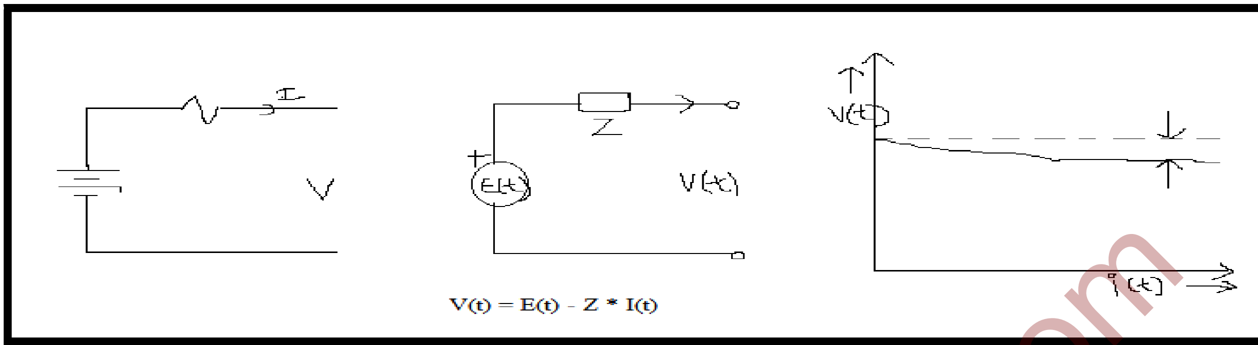
  I_S=source current ; I_L=Load current





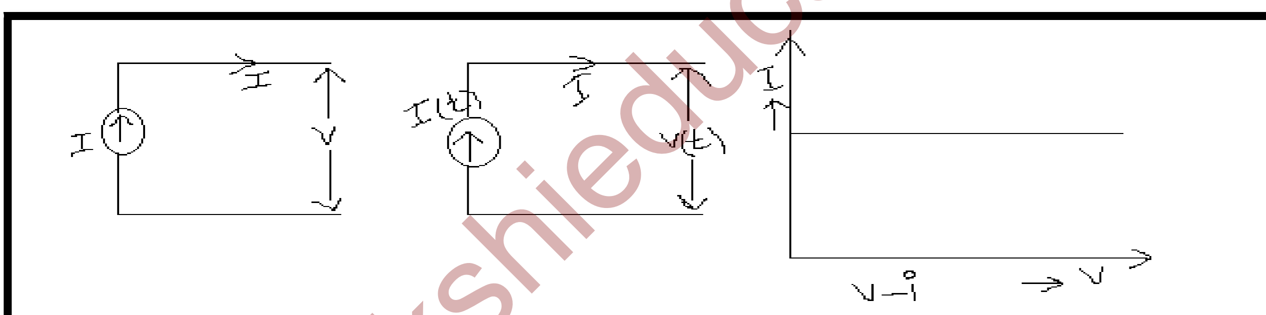
- ***Practical voltage source*:**

  It is represented with ideal volage source in series with its internal resistance or impedance.

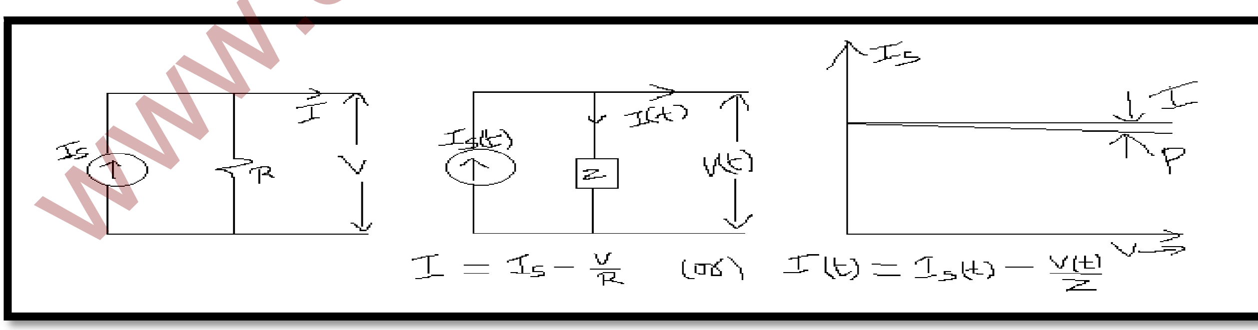


Current source:

- Ideal current source: A current source which maintains a constant specified current for all voltages is called an ideal current source. The internal admittance of a ideal current source is zero.



- ***Prctical current source:*** A practical current source represented with internal impedance across it.

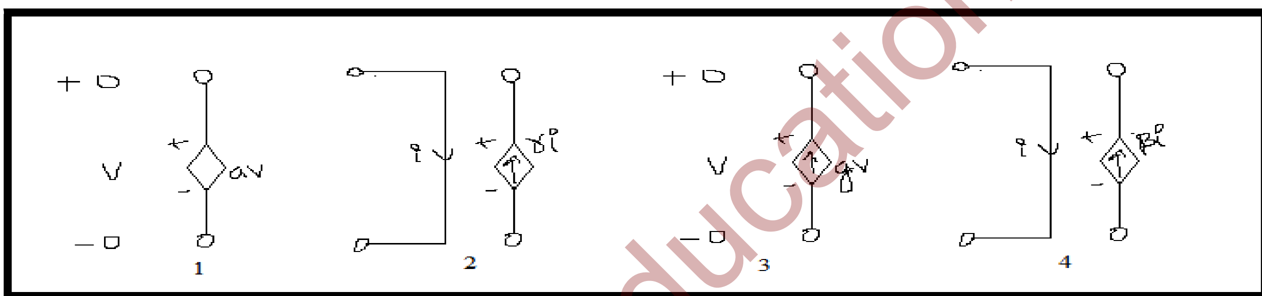


Dependent Sources:

An dependent voltage or current source one which depends on some other quantity in the circuit which may be either a volage or current . there are four possible dependent sources

1) Voltage dependent voltage source
2) Current dependent voltage source
3) Voltage dependent current source
4) Current dependent current source

Such sources can also be either constant sources or time varying sources.



KIRCHOFF'S LAW:

KCL: For any lumped electric circuit, for any of its nodes, at any time, the alzebraic sum of the currents is equal to zero.

KVL: For any lumped electric circuit, for any of its loops, and at any time the alzebric sum of the branch voltages around the loop is zero.

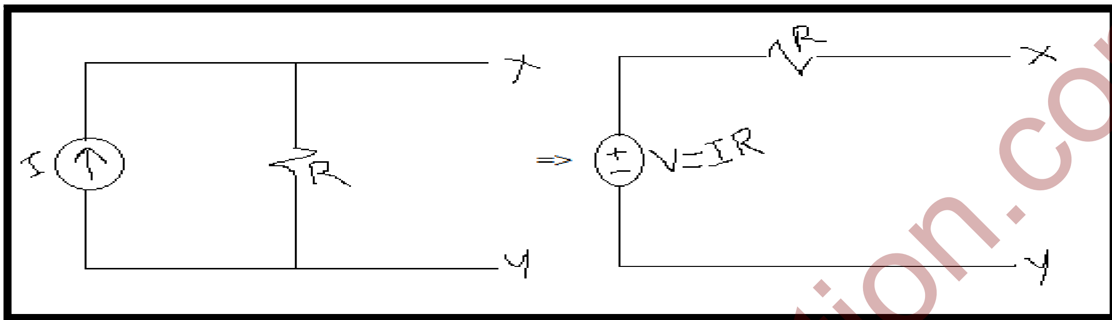
Source Transformation :

Electrical circuit consists of several components. Source transformation is simplifying a circuit solution, especially with mixed sources, by transforming a voltage into a current source, and vice versa. Finding a solution to a circuit can be difficult without using methods such as this to make the circuit appear simpler.

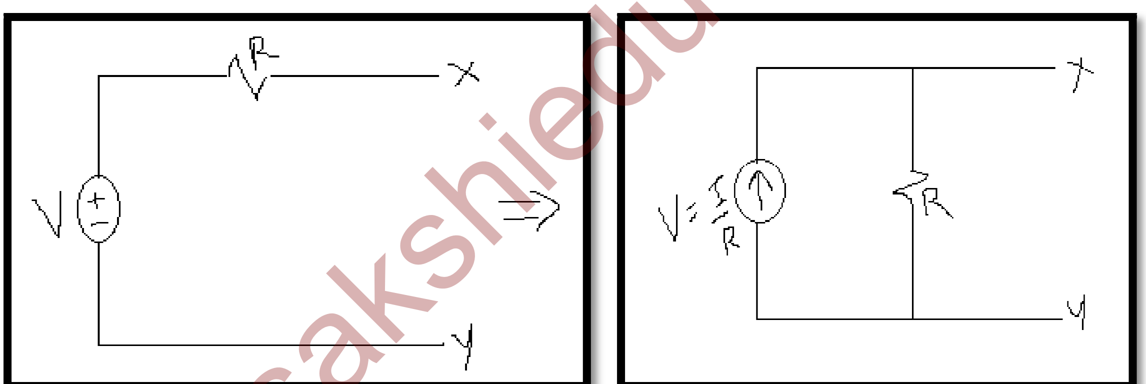
Performing a source transformation consists of using Ohm's law to take an existing voltage source in series with a resistance, and replace it with a current source in parallel with the same resistance. We know that Ohm's law states that

V=IR. Since source transformations are bilateral, one can be derived from the other and also Source transformations are not limited to resistive circuits. For capacitors and inductors also it is applicable.

Current Source to Voltage Source: We can replace I parallel with a resistor R by a voltage source V in series with the SAME resistor R.



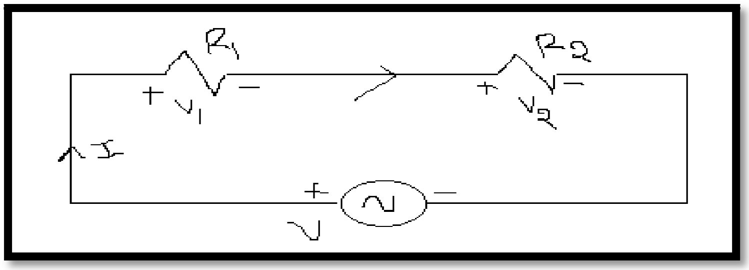
Voltage Source to Current Source: We can replace V in series with s resistor R by a current source in parallel with R



Voltage Divider Rule:

The voltage divider rule is a simple rule which can be used in solving circuits to simplify the solution. Applying the voltage division rule can also solve simple circuits thoroughly.

Lets analyze the below circuit,



= I ------ (1)

= I ------ (1)

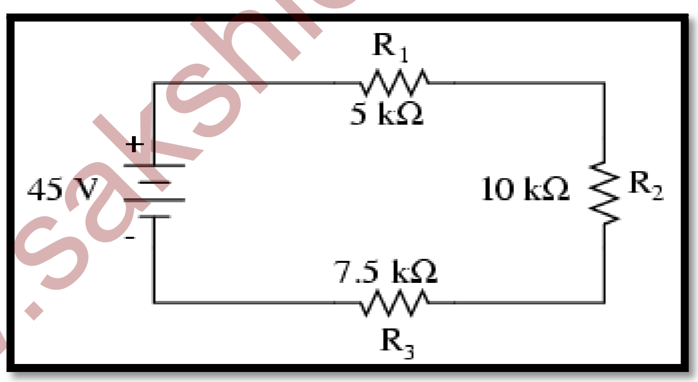
But V = I (+) from the circuit. => I = ——— ----------- (3)

Sustitite (1) & (3) we get,

= ———

= ———

Example: Analyze a simple series circuit, determining the voltage drops across individual resistors.



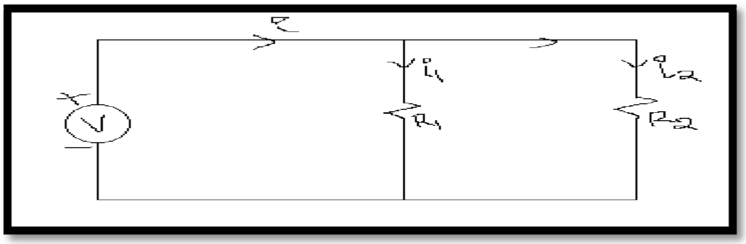
= ——— = ——— * 5 =10v

= ——— = ——— * 10 =20v

= ——— = ——— * 7.5 =15v

Current Divider Rule:

The current divider rule is a simple rule which can be used in solving circuits to simplify the solution. Lets analyze the below circuit,



From the fig, V = = ------------ (1)

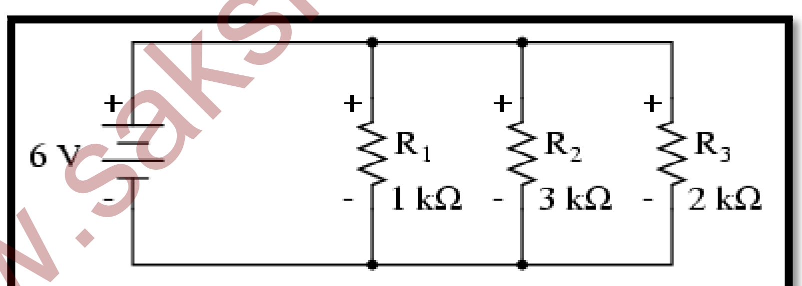
From KCL, I = + = — + — = v —— -------- (2)

From (1) & (2) we get,

= I ——

= I ——

Example: analyze the below example.



I = + + = (6/1) + (6/3) + (6/2) = 6 + 2 + 3 = 11mA

= I ———————— = 11 * — = 6mA

= I ———————— = 11 * — = 2mA

= I ———————— = 11 * — = 3mA