PPT ON

BASIC ELECTRICAL AND ELECTRONICS ENGINEERING

Course Objectives

- To introduce the concepts of electrical circuits and its components
- To understand magnetic circuits, DC circuits and AC single phase & three phase circuits
- To study and understand the different types of DC/AC machines and Transformers.
- To import the knowledge of various electrical installations.
- To introduce the concept of power, power factor and its improvement.

Course Outcomes

- To analyze and solve electrical circuits using network laws and theorems.
- To understand and analyze basic Electric and Magnetic circuits
- To study the working principles of Electrical Machines
- To introduce components of Low Voltage Electrical Installations

VOLTAGE

What is Voltage?

- Voltage (also known as electric potential difference, electromotive force emf, electric pressure, or electric tension) is defined as the electric potential difference per unit charge between two points in an electric field. Voltage is expressed mathematically (e.g. in formulas) using the symbol “V” or “E”.
- Voltage describes the “pressure” that pushes electricity. The amount of voltage is indicated by a unit known as the volt (V), and higher voltages cause more electricity to flow to an electronic device.

VOLTAGE

In a static electric field, the work required to move per unit of charge between two points is known as voltage. Mathematically, the voltage can be expressed as,

$$Voltage = \frac{Work\ Done\ (W)}{Charge\ (Q)}$$

Where, work done is in joules and charge is in coulombs.

$$Thus, Voltage = \frac{joule}{coulomb}$$

VOLTAGE

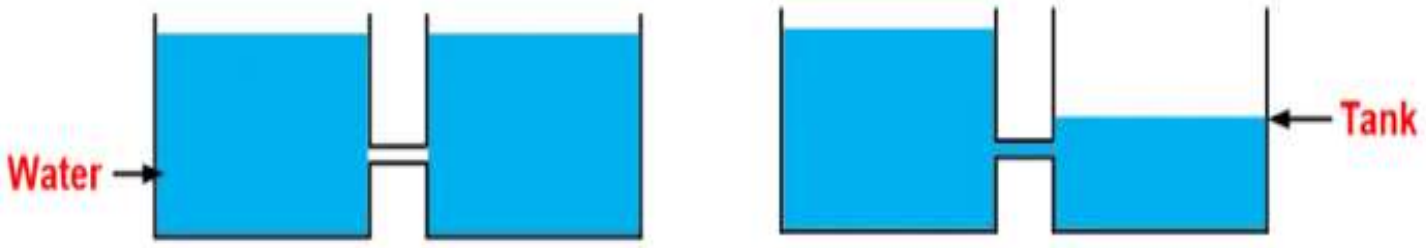
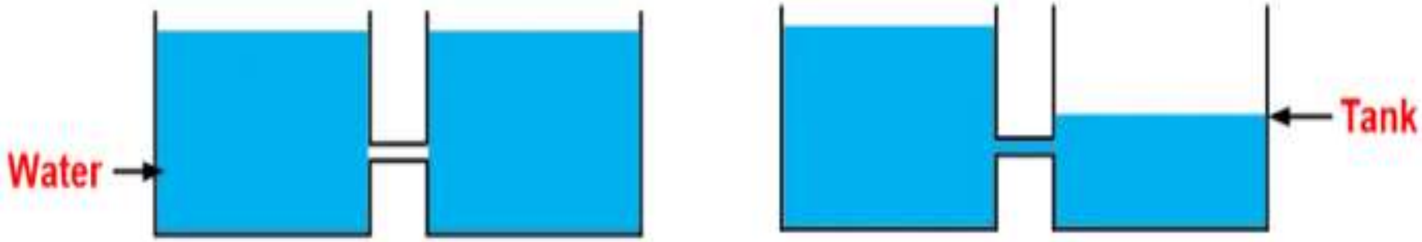


Fig.(a) Two Tanks with Same Water Level

Fig.(b) Two Tanks with Different Water Level

- if we connect two batteries through conducting wire with different voltage levels then charges can flow from the battery of higher potential to the battery of lower potential. Hence, the battery of lower potential gets charged till the potential of both the battery becomes the same.

VOLTAGE



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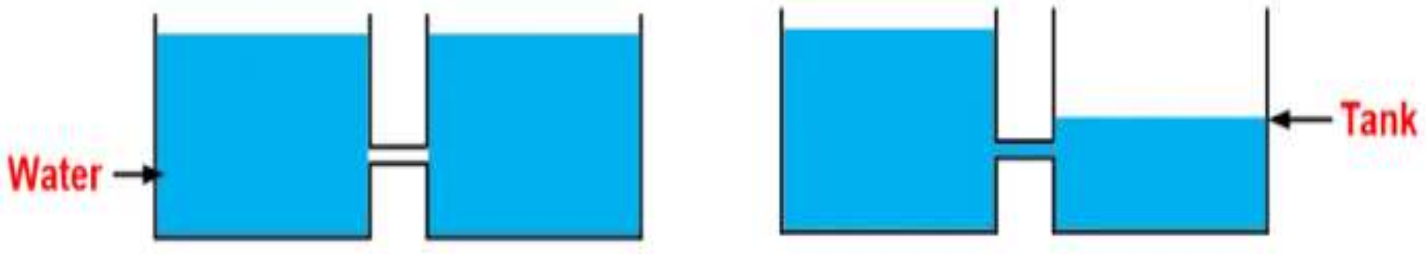
VOLTAGE



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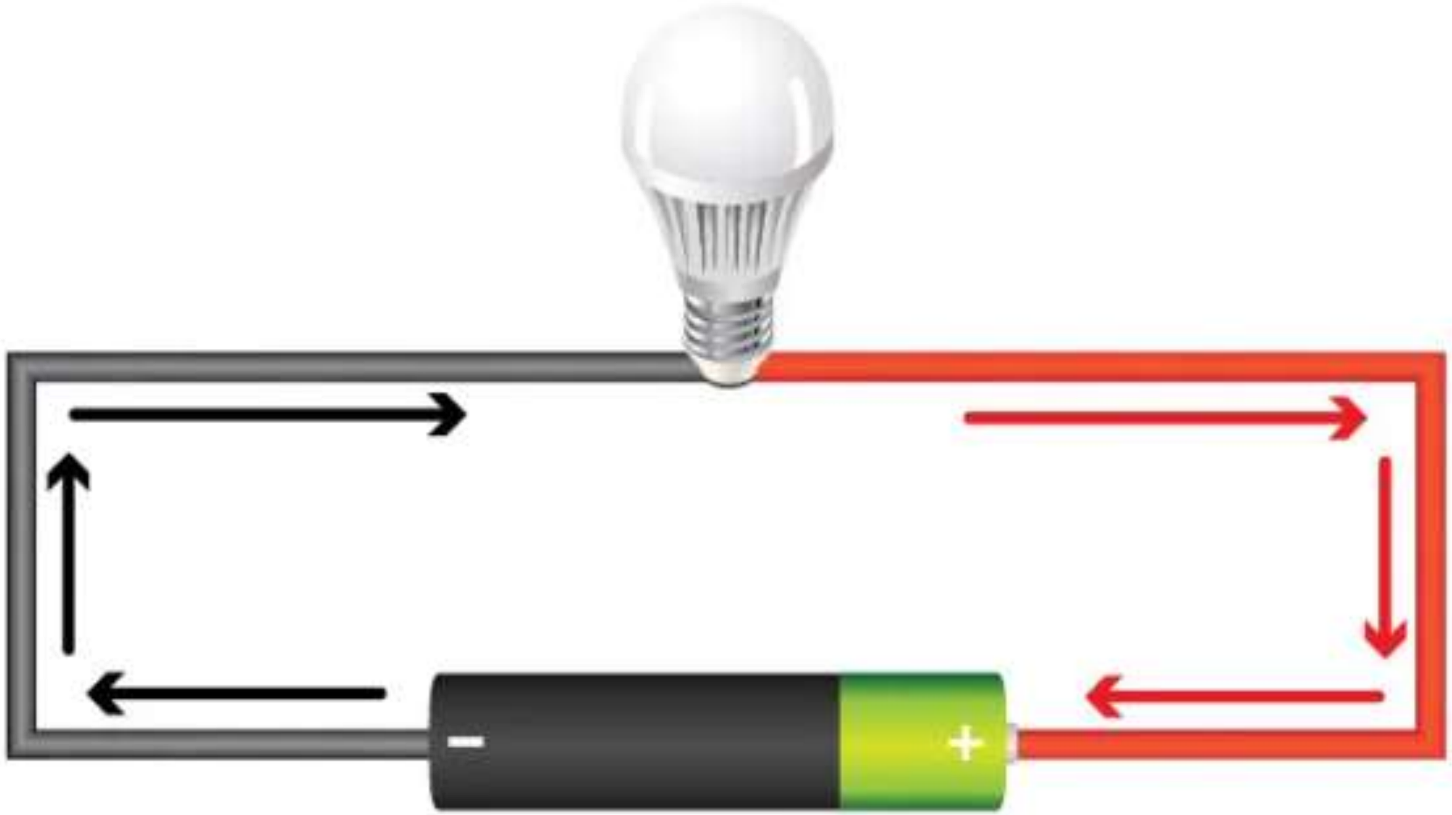
VOLTAGE



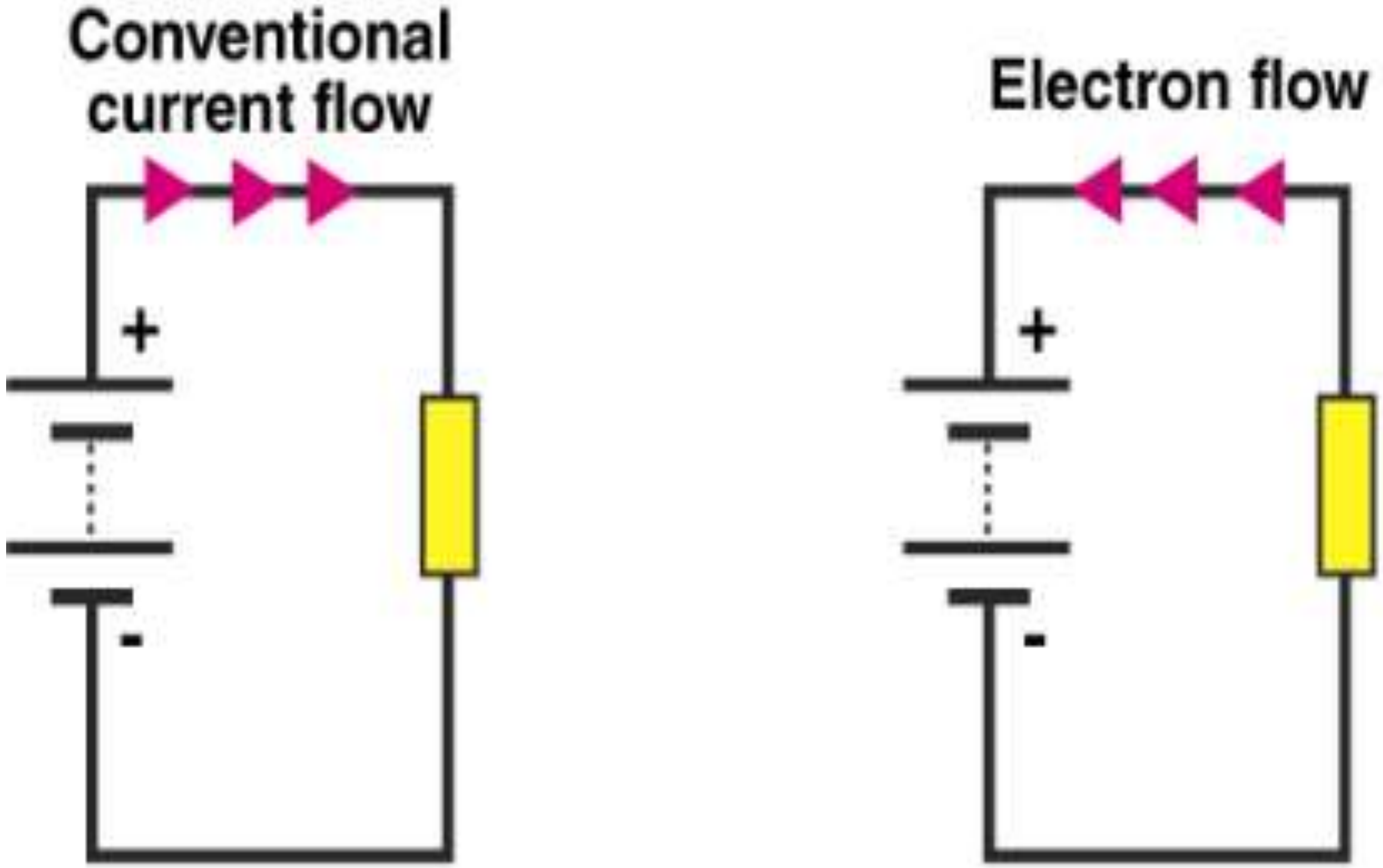
CURRENT

Current is just the rate of flow of electric charge. In simple words, the current is the rate at which electric charge flows in a circuit at a particular point.

The SI unit of current is Ampere (A).

Note: 1 Ampere = 1 coulomb/second.
Current is denoted by “I”.

ELECTRON AND CONVENTIONAL CURRENT FLOW



POWER

- The rate at which work is done, or energy expended, per unit time. Power is usually measured in watts (especially for electrical power) or horsepower (especially for mechanical power).
- For a path conducting electrical current, such as a component in an electric circuit, $P = VI$, where P is the power dissipated along the path, V is the voltage across the path, and I is the current through the path.

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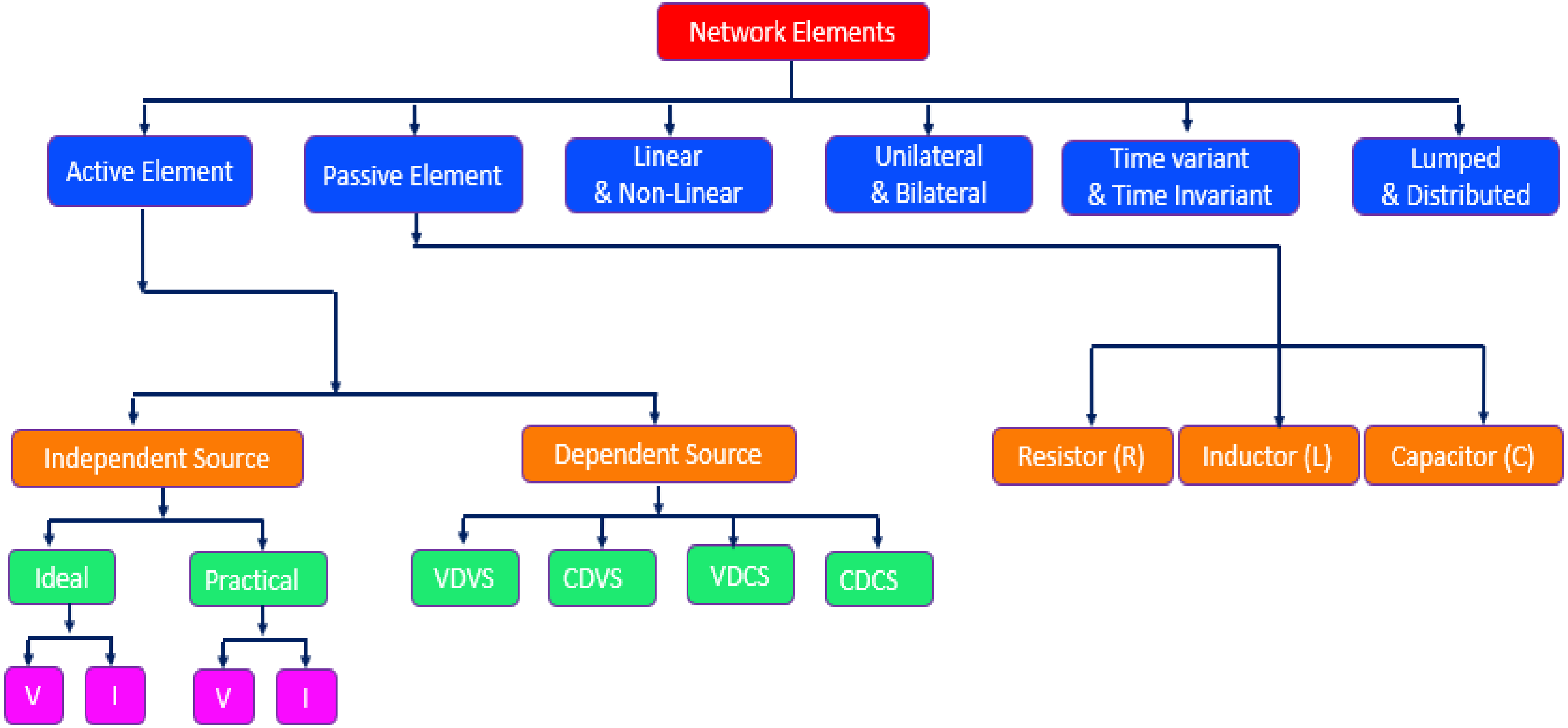
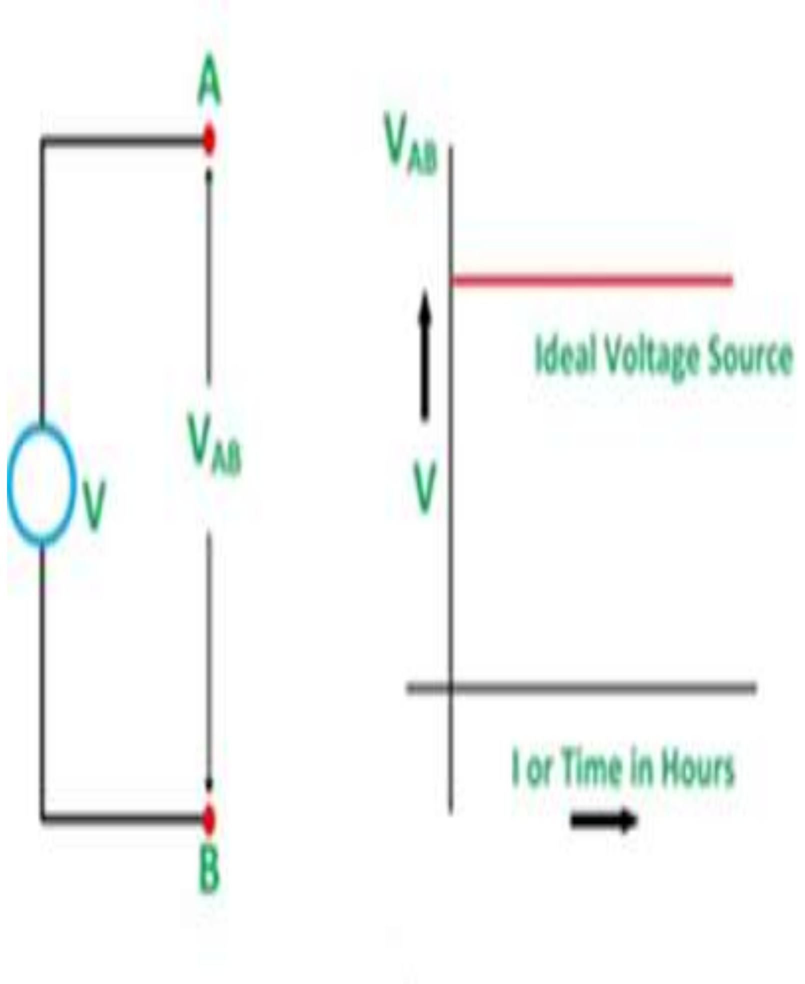
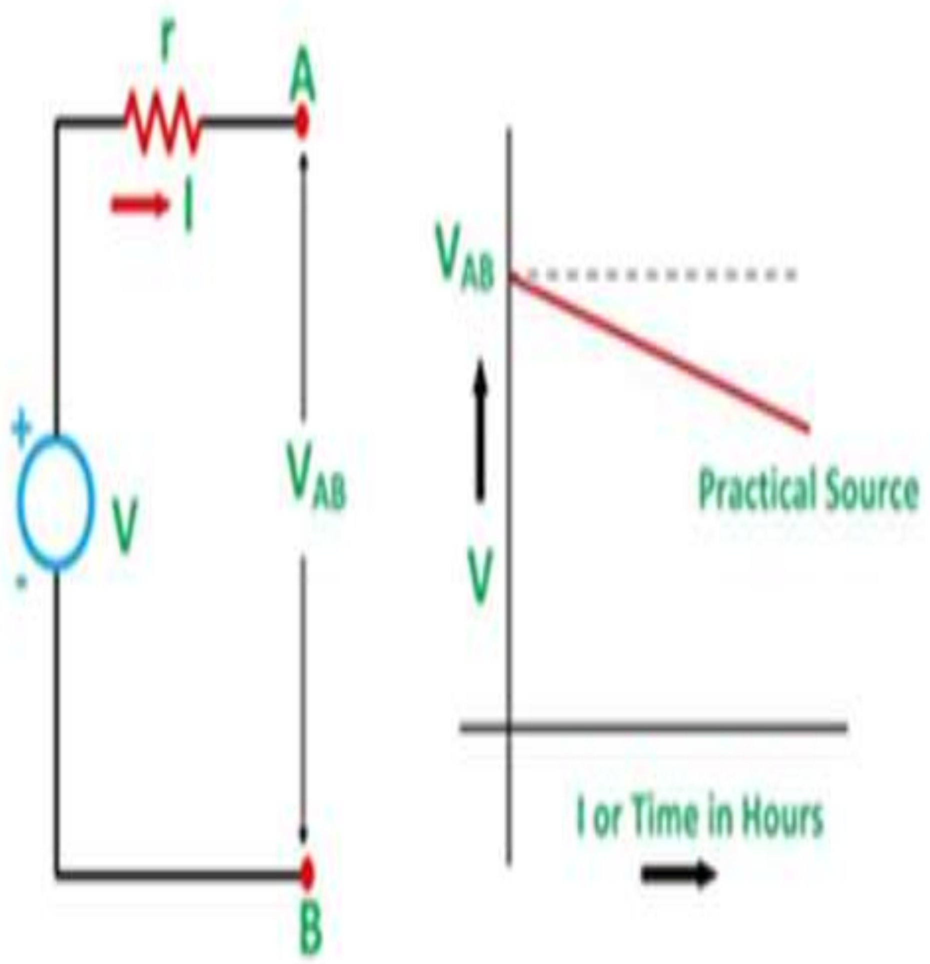
Classifications of Elements

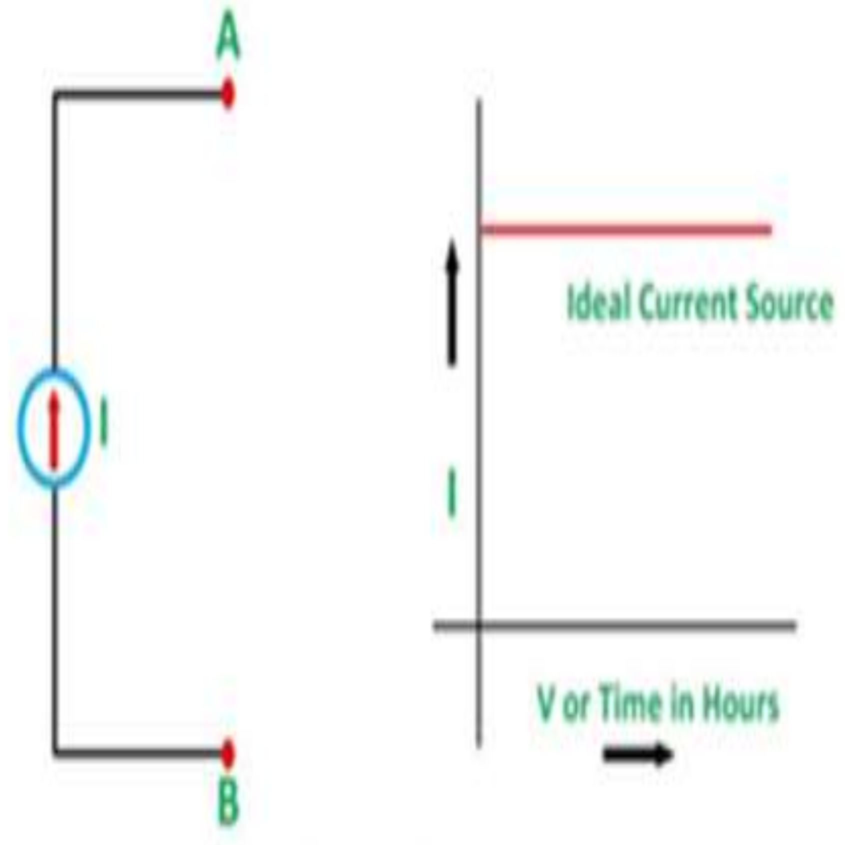


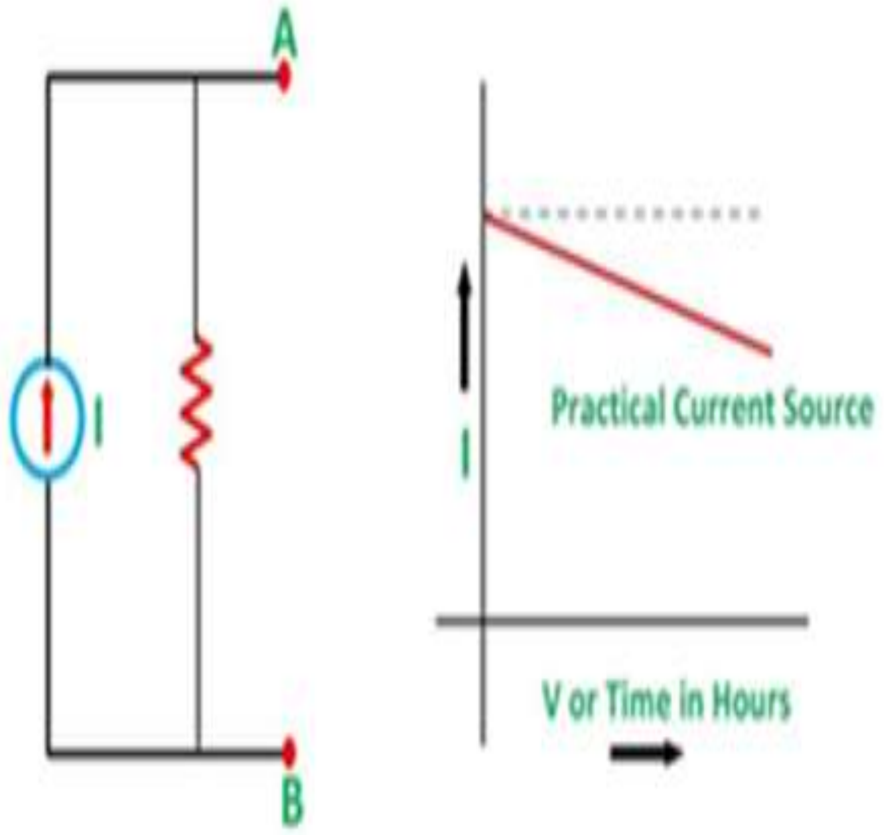
INDEPENDENT SOURCES





INDEPENDENT SOURCES





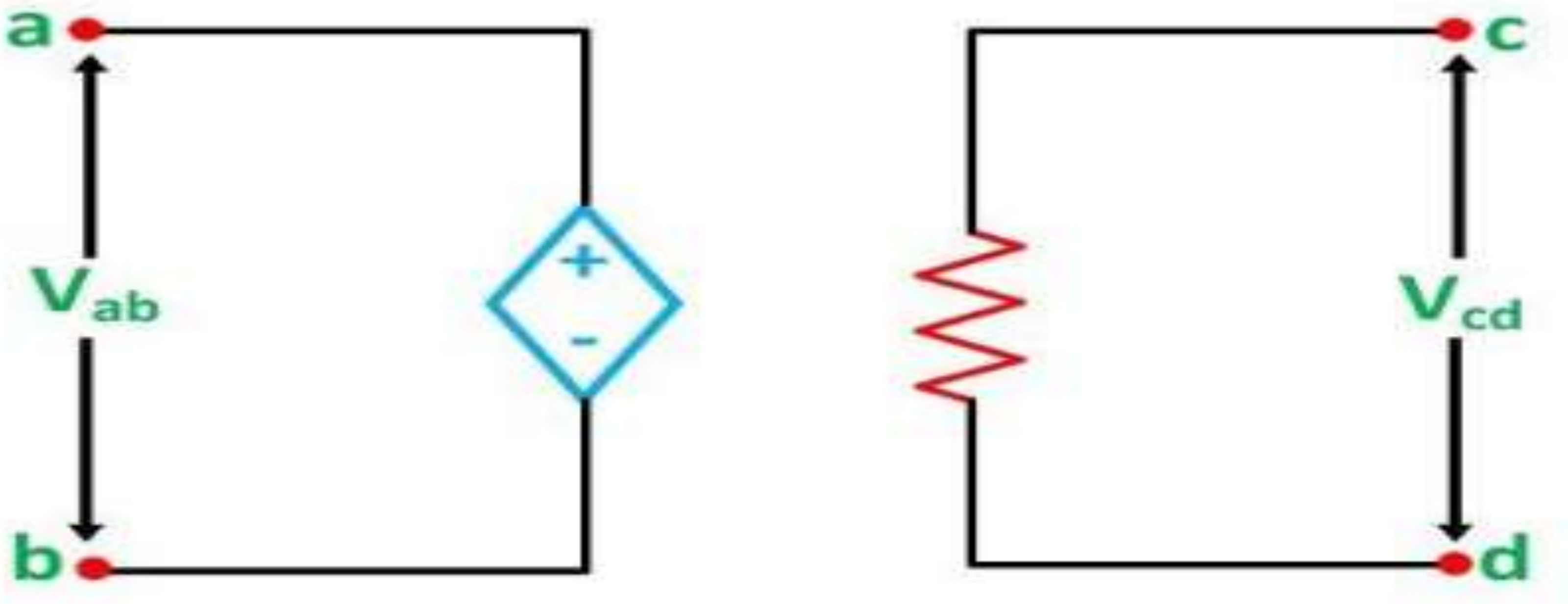
Classifications of Elements

Dependent Source : The sources whose output voltage or current is not fixed but depends on the voltage or current in another part of the circuit is called Dependent or Controlled source.

The dependent sources are further categorized as

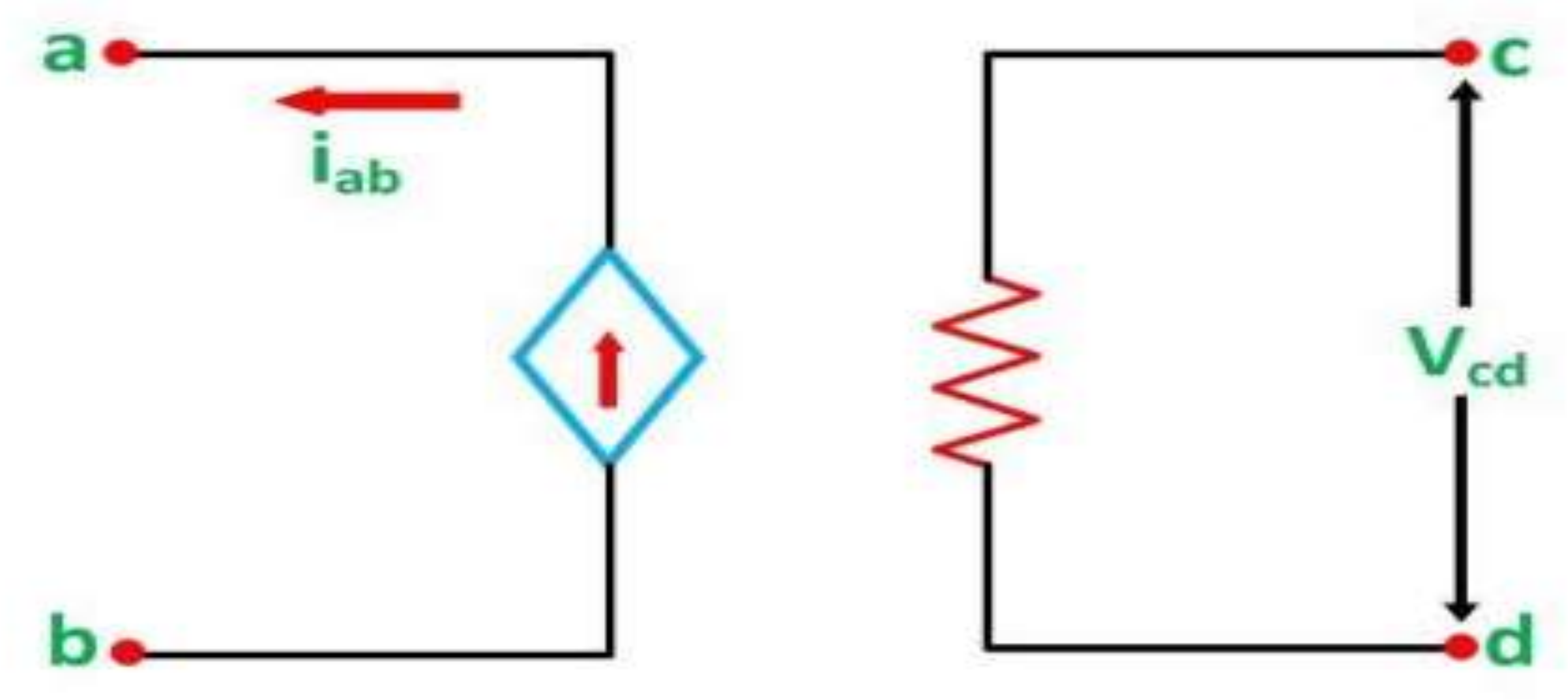
- Voltage Controlled Voltage Source (VCVS)
- Voltage Controlled Current Source (VCCS)
- Current Controlled Voltage Source (CCVS)
- Current Controlled Current Source (CCCS)

Voltage Controlled Voltage Source (VCVS)



$$V_{ab} \propto V_{cd} \quad \text{or}$$
$$V_{ab} = kV_{cd}$$

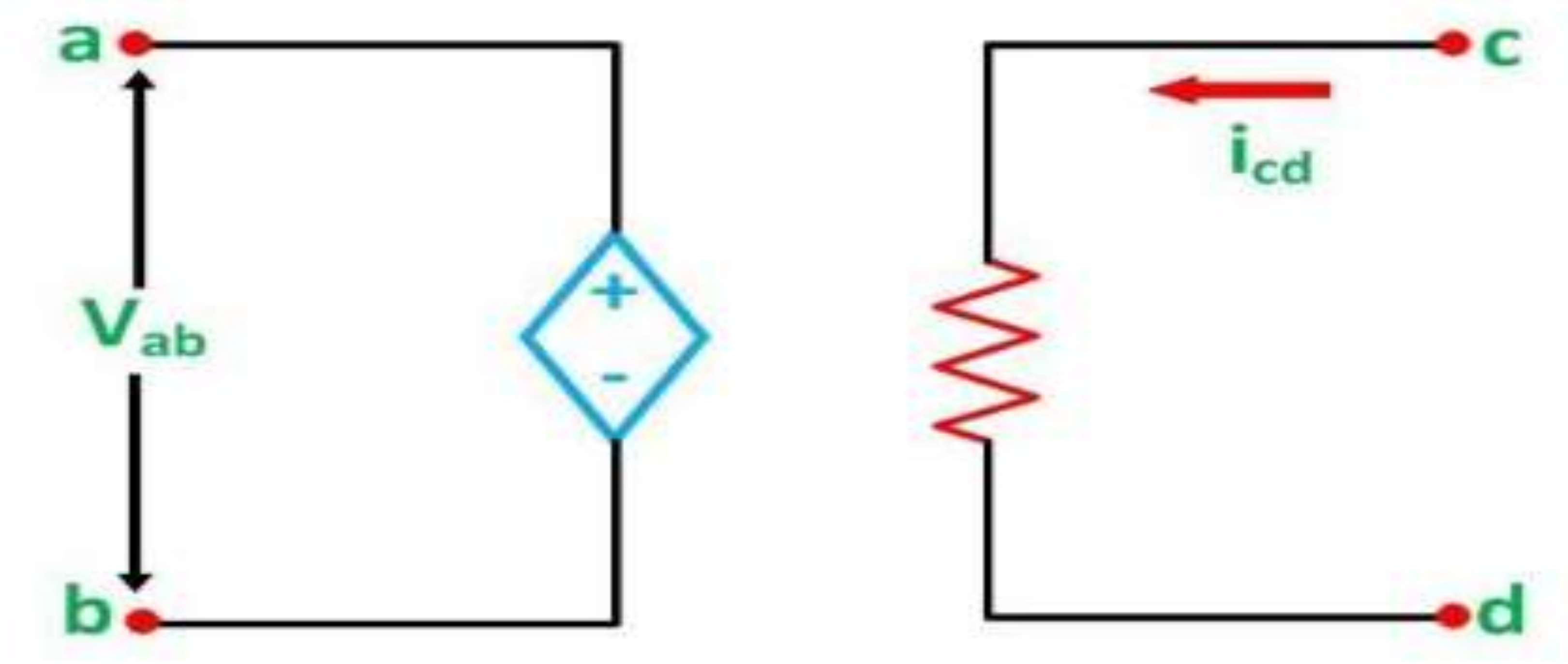
Voltage Controlled Current Source (VCCS)



$$i_{ab} \propto V_{cd}$$

$$i_{ab} = \eta V_{cd}$$

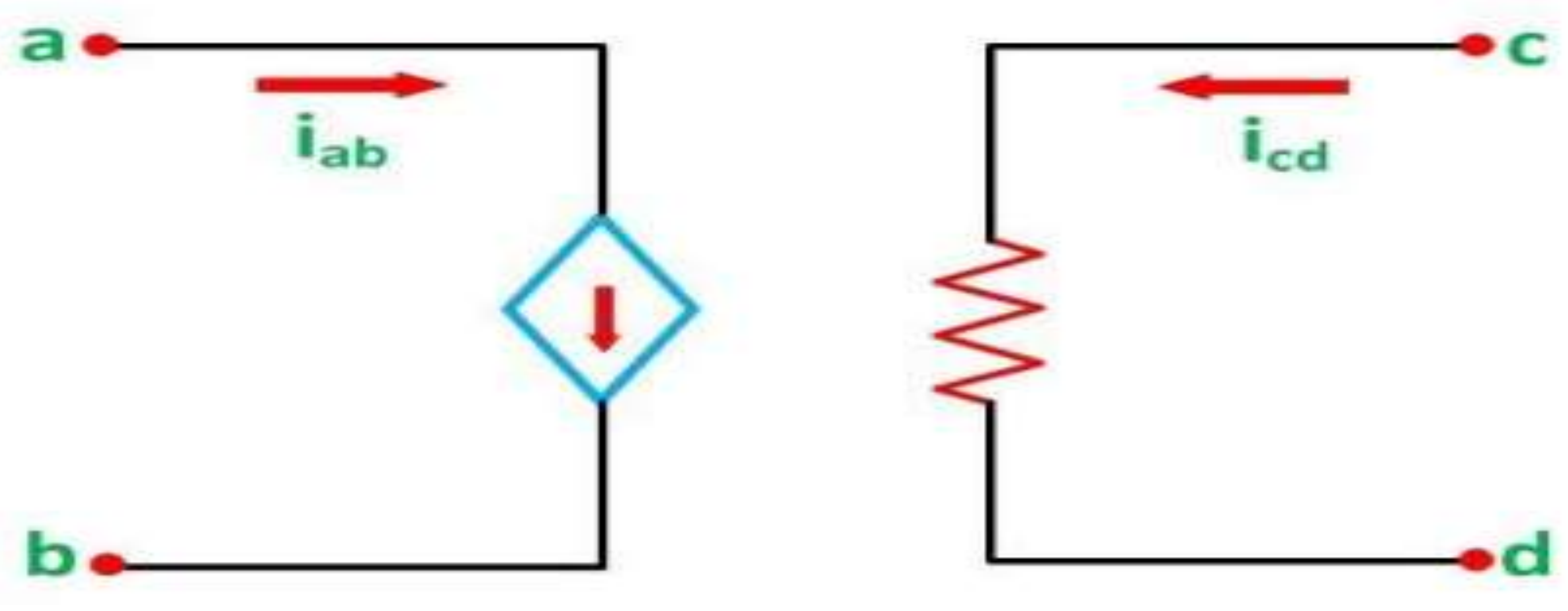
Current Controlled Voltage Source (CCVS)



$$V_{ab} \propto i_{cd}$$

$$V_{ab} = r\, i_{cd}$$

Current Controlled Current Source (CCCS)

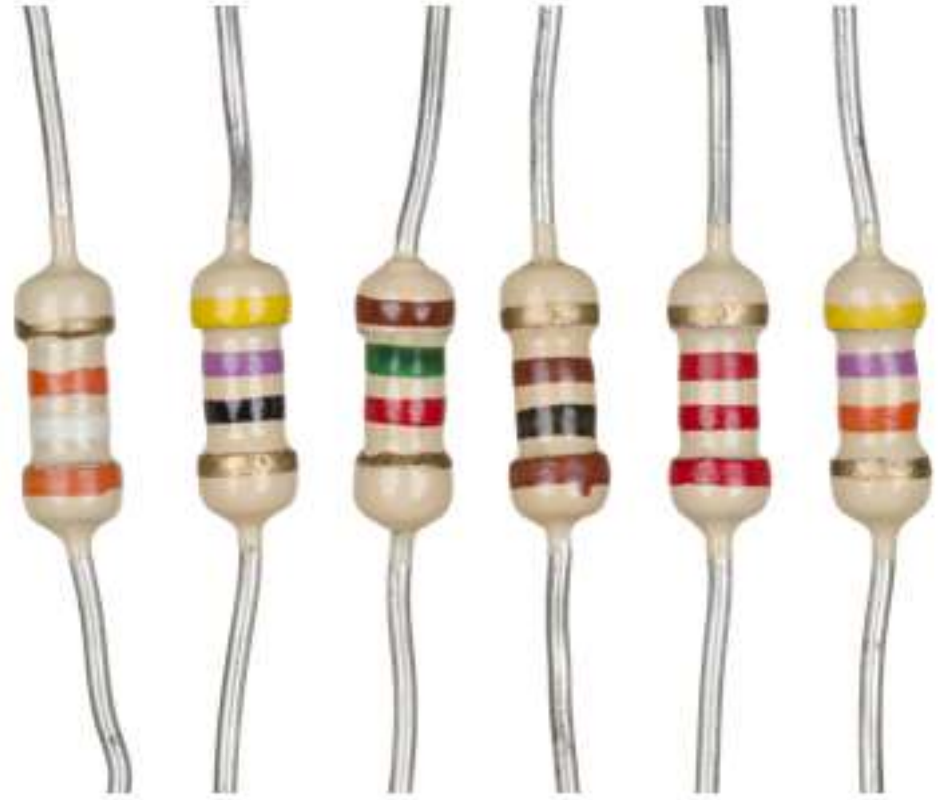


$$i_{ab} \propto i_{cd}$$

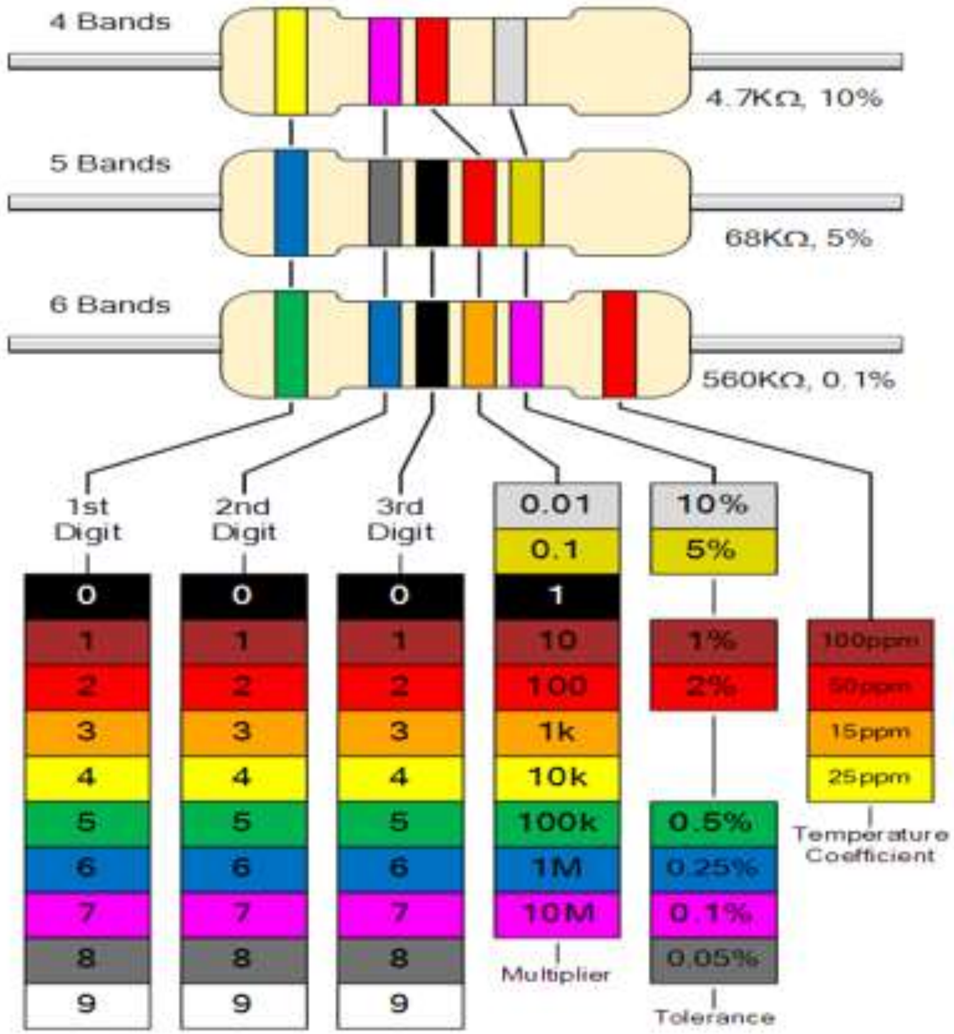
$$i_{ab} = \beta i_{cd}$$

Resistor Colour coding

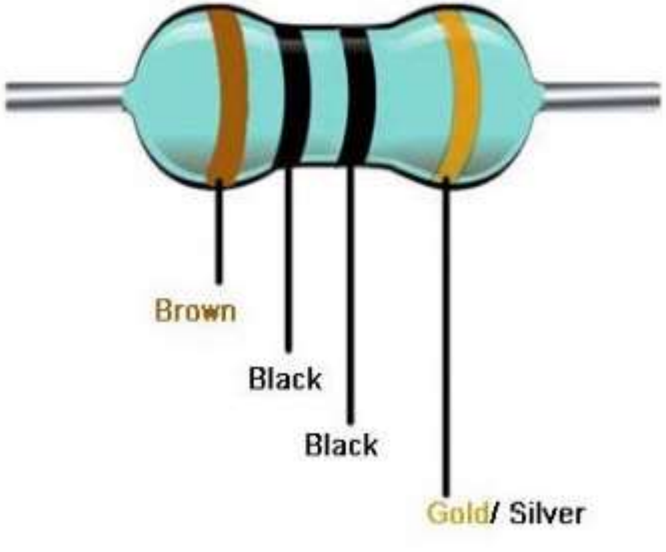
R, L, C Parameters



Color	Color	Value	Multiplier	Tolerance
	Black	0	X 1	N/A
	Brown	1	X 10	N/A
	Red	2	X 100	2%
	Orange	3	X 1000	N/A
	Yellow	4	X 10000	N/A
	Green	5	X 100000	N/A
	Blue	6	X 1000000	N/A
	Violet	7	X 10000000	N/A
	Gray	8	X 100000000	N/A
	White	9	X 1000000000	N/A
	Gold	N/A	X 0.1	5%
	Silver	N/A	X 0.01	10%


4 Bands
4.7KΩ, 10%
5 Bands
68KΩ, 5%
6 Bands
560KΩ, 0.1%
1st Digit
2nd Digit
3rd Digit
0 1 2 3 4 5 6 7 8 9
0.01
0.1
1
10
100
1k
10k
100k
1M
10M
Multiplier
10%
5%
1%
2%
0.5%
0.25%
0.1%
0.05%
Tolerance
100ppm
50ppm
15ppm
25ppm
Temperature Coefficient

Four quadrant operation



2.2k resistor color code

Resistance: The property of a material to restrict flow of electrons is called resistance

From Ohm's law, $I \propto V \text{ or } V \propto I \Rightarrow V = IR$

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

Where R = Resistance of the conductor

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

$$V = IR$$

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

Where V = Instantaneous Voltage in Volts

R = Resistance in Ohm's

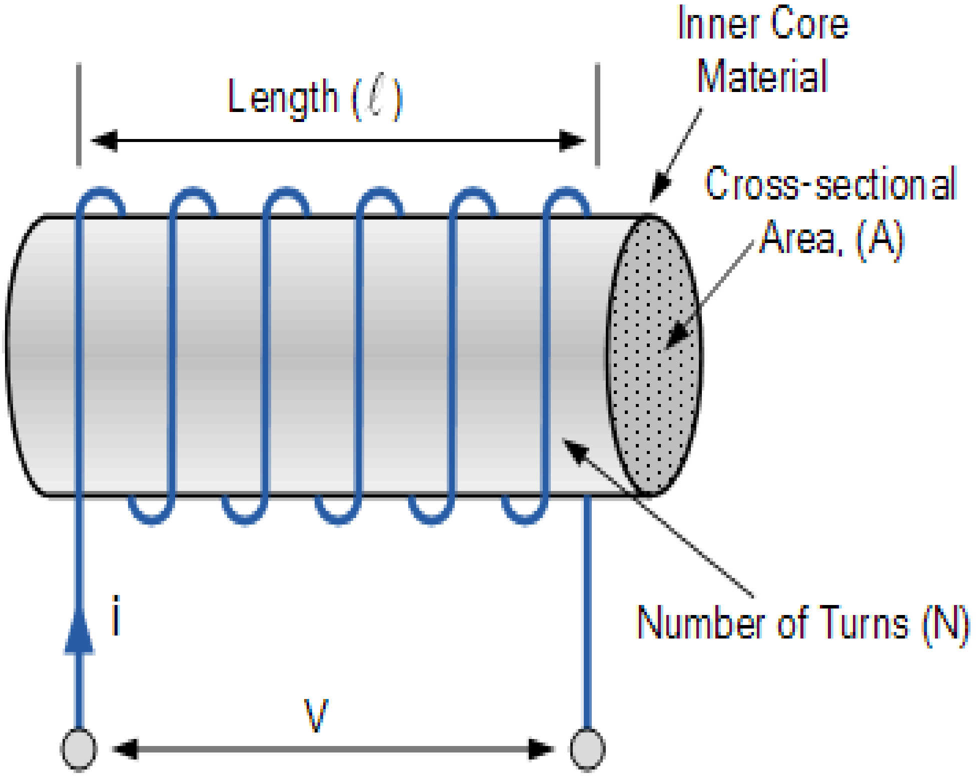
I = Instantaneous current in Amps

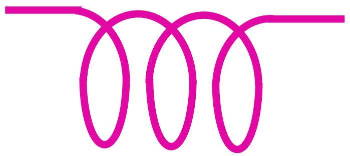
Inductor (L) : An inductor, also called a **coil, choke, or reactor**, is a passive two-terminal electrical component that stores energy in a magnetic field when electric current flows through it.

An inductor typically consists of an insulated wire wound into a coil around a core.

The inductance is directly proportional to the number of turns in the coil.

The units of Inductance is **Henry (H).**





Inductor

$$\mathbf{L} = \frac{\mu N^2 A}{l}$$

$$\text{Energy} = \frac{1}{2} L i^2$$

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

$$I = \frac{1}{L}\int v\,dt$$

Where V = Instantaneous Voltage across the Inductor

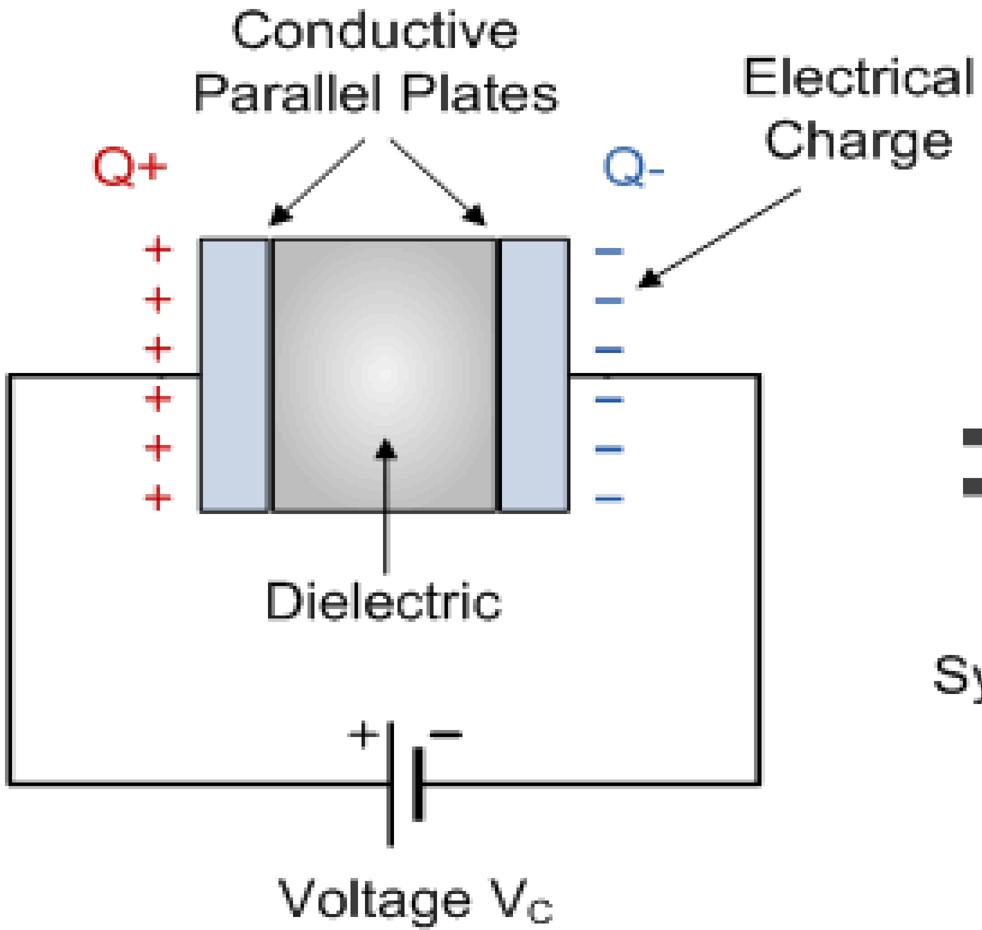
L = Inductance in Henrys

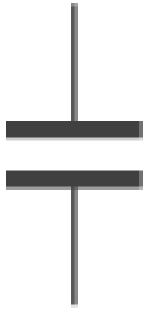
$\frac{di}{dt}$ = Instantaneous rate of current change (amps per second)

Applications: Filters, Sensors, Transformers, Motors, Energy Storage etc.

Capacitor (C) : The **capacitor** is made of 2 close conductors (usually plates) that are separated by a dielectric material. The plates accumulate electric charge when connected to power source. One plate accumulates positive charge and the other plate accumulates negative charge.

The property of a capacitor to store charge on its plates in the form of an electrostatic field is called the **Capacitance** of the capacitor. . The units of capacitance is **Farads (F)**.





Symbol

$$C = \frac{\varepsilon_0 A}{d}$$

$$\text{Energy} = \frac{1}{2} C v^2$$

$$I = C\frac{dv}{dt}$$

$$V = \frac{1}{C}\int i\,dt$$

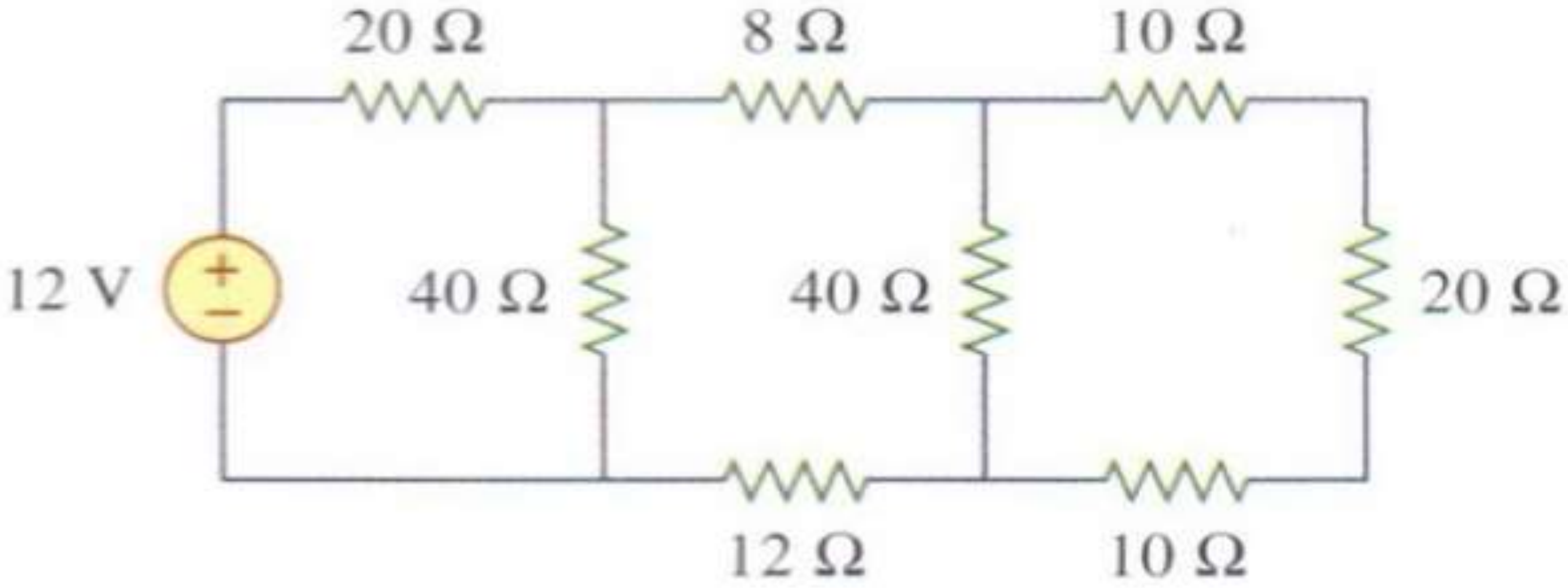
Where I = Instantaneous Current through the capacitor

L = Capacitance in Farads

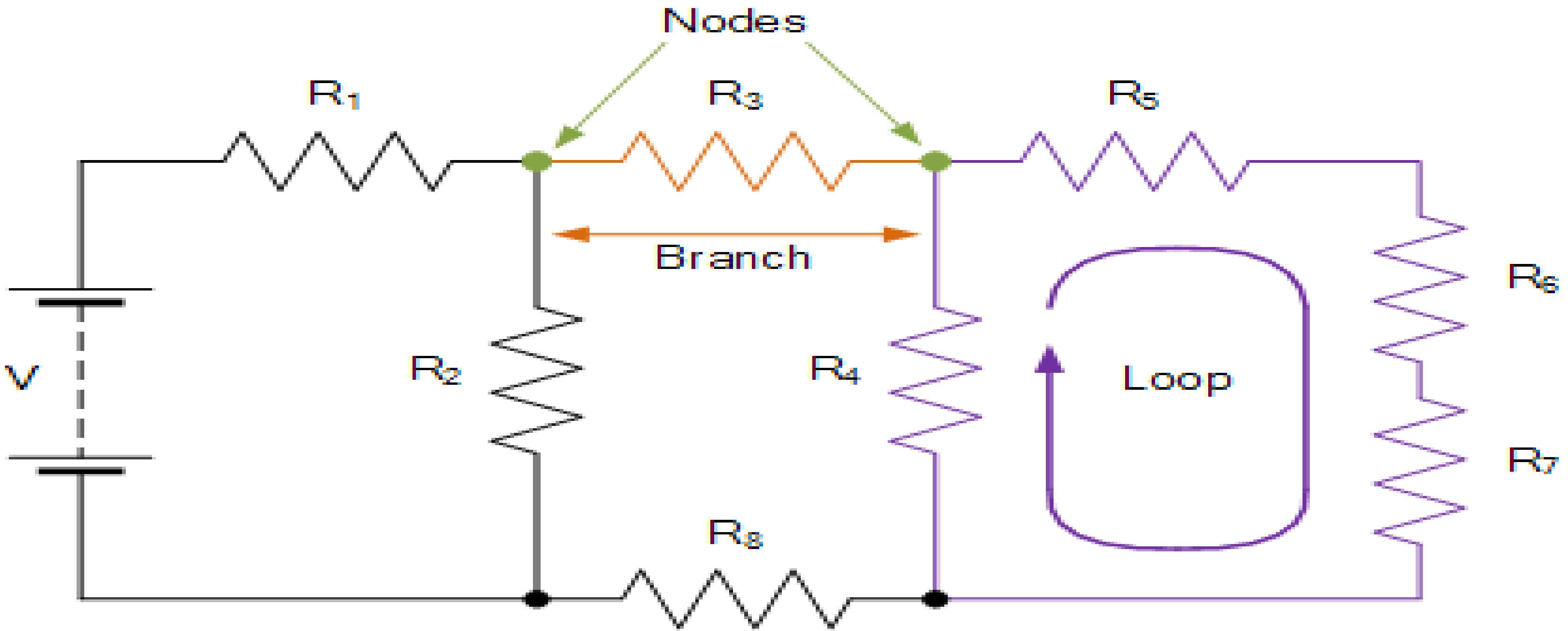
$\frac{dv}{dt}$ = Instantaneous rate of Voltage change (Volts per second)

Applications: Filters, Sensors, Energy Storage etc.

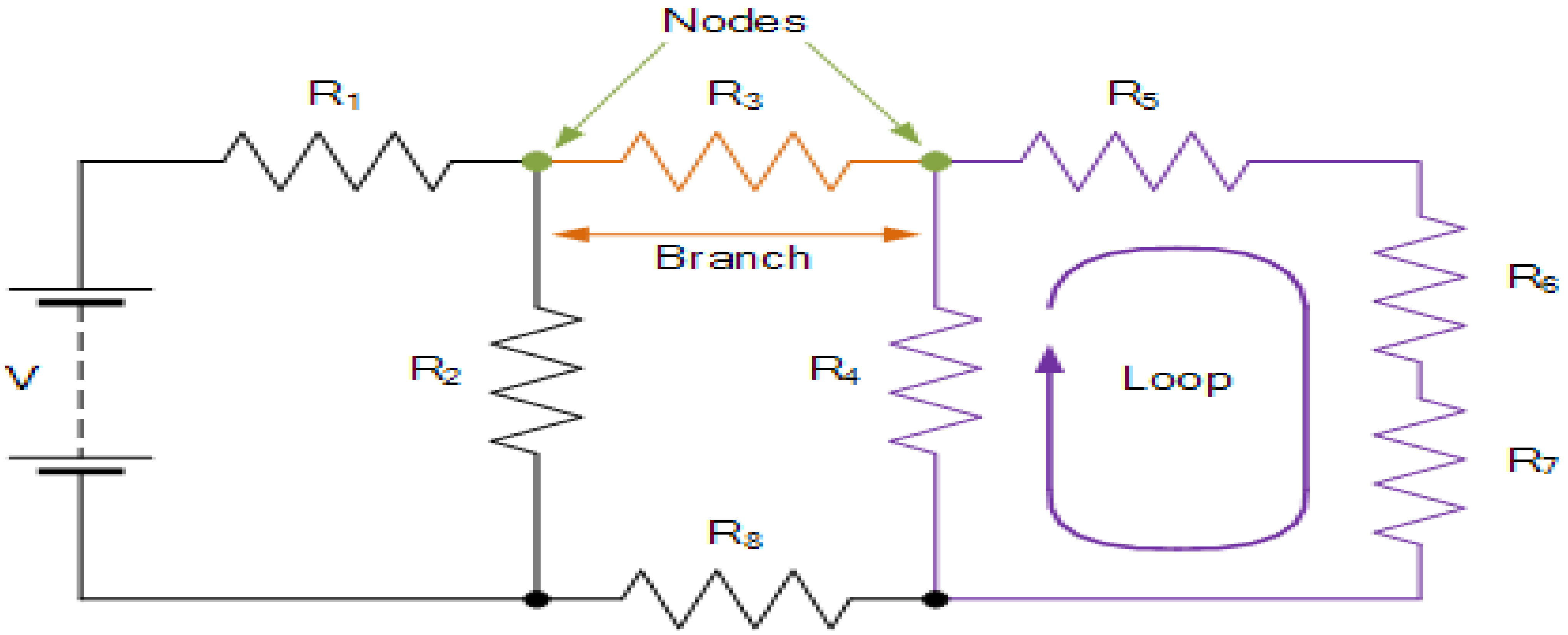
- Find R_{eq} by combining the resistors.



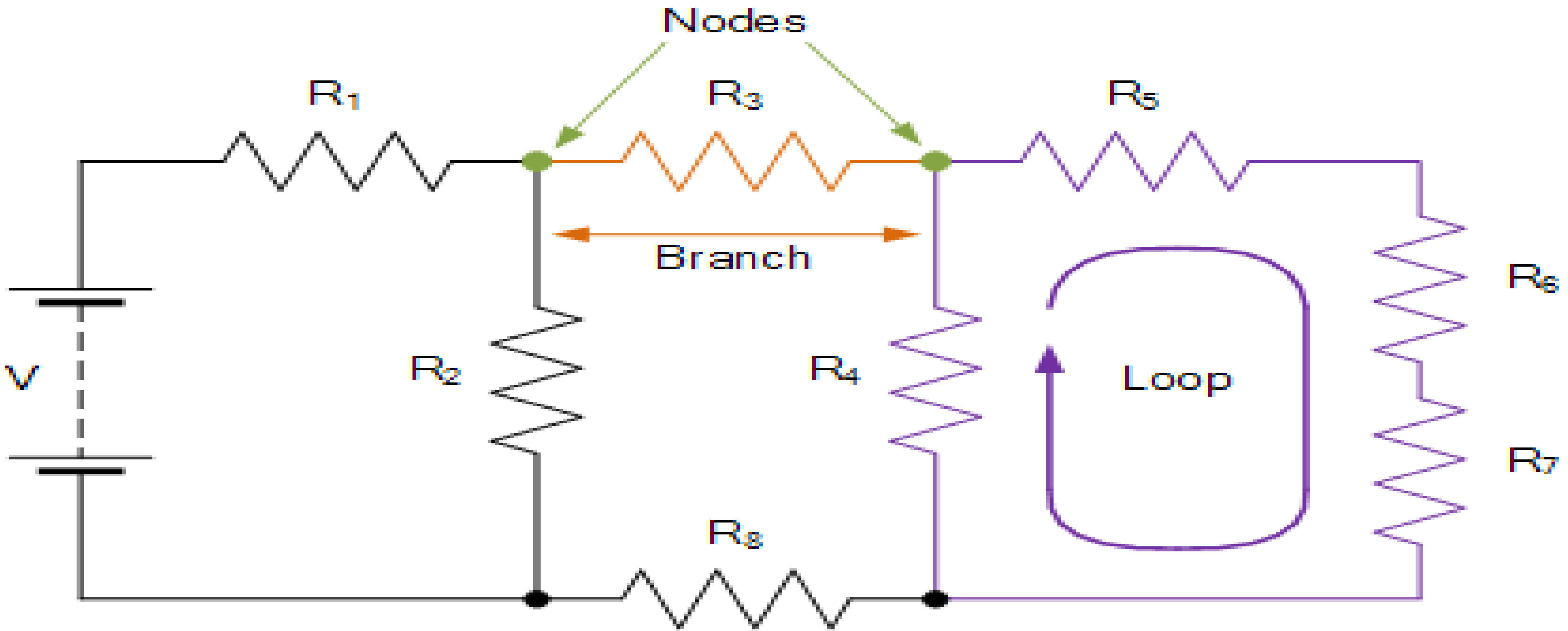
Node : A terminal of any branch of a network or an interconnection common to two or more branches of network is called a Node. If more than two elements meet at a node, then it is called principal node.



Branch : A direct path joining two nodes of a network or graph is called branch. A branch may have one or more elements connected in series. $b = l + n - 1$



Closed path : A closed path is a path which starts at node and travels through some branches of circuit and arrives at the same node without crossing the node more than once.



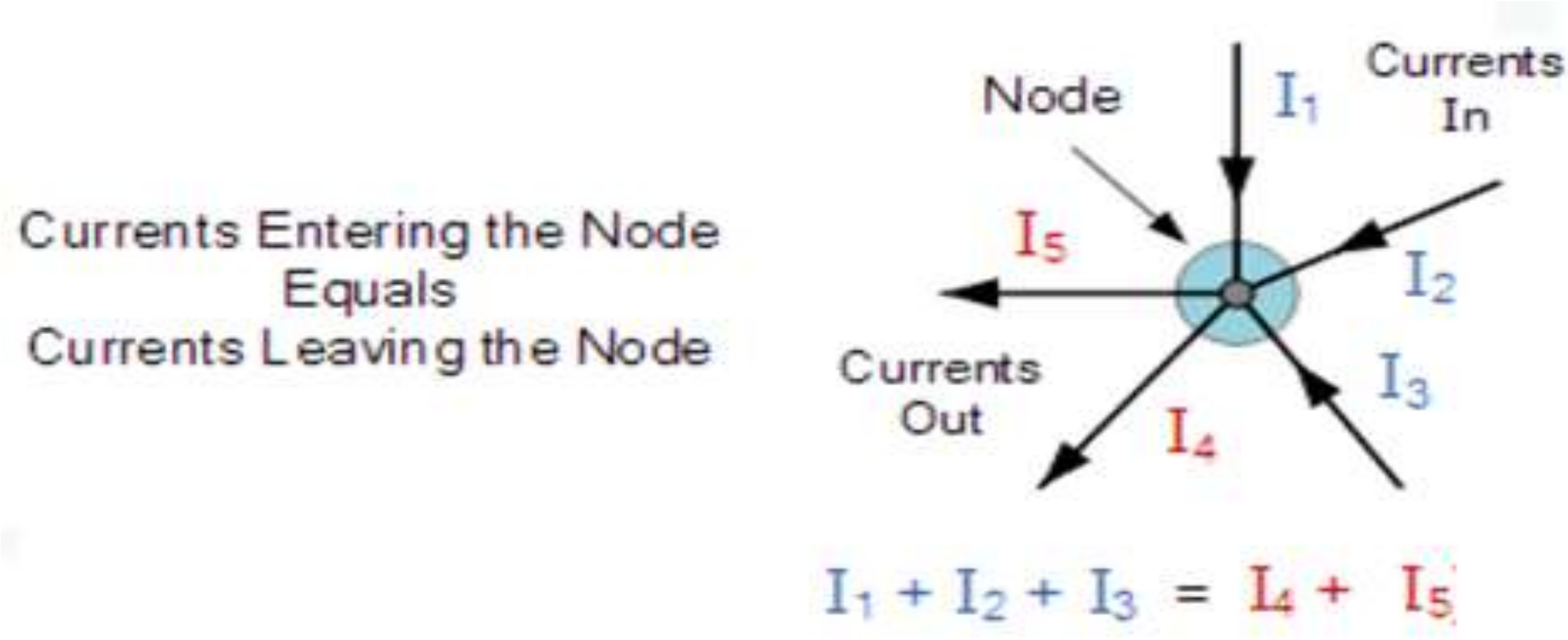
Kirchhoffs First Law – The Current Law, (KCL)

Kirchhoffs Current Law states that the “total current or charge entering a junction or node is exactly equal to the charge leaving the node.

In other words the algebraic sum of ALL the currents entering and leaving a node must be equal to zero. This idea by Kirchhoff is commonly known as the Conservation of Charge.

$$I_{(exiting)} + I_{(entering)} = 0.$$

KIRCHOFF LAWS



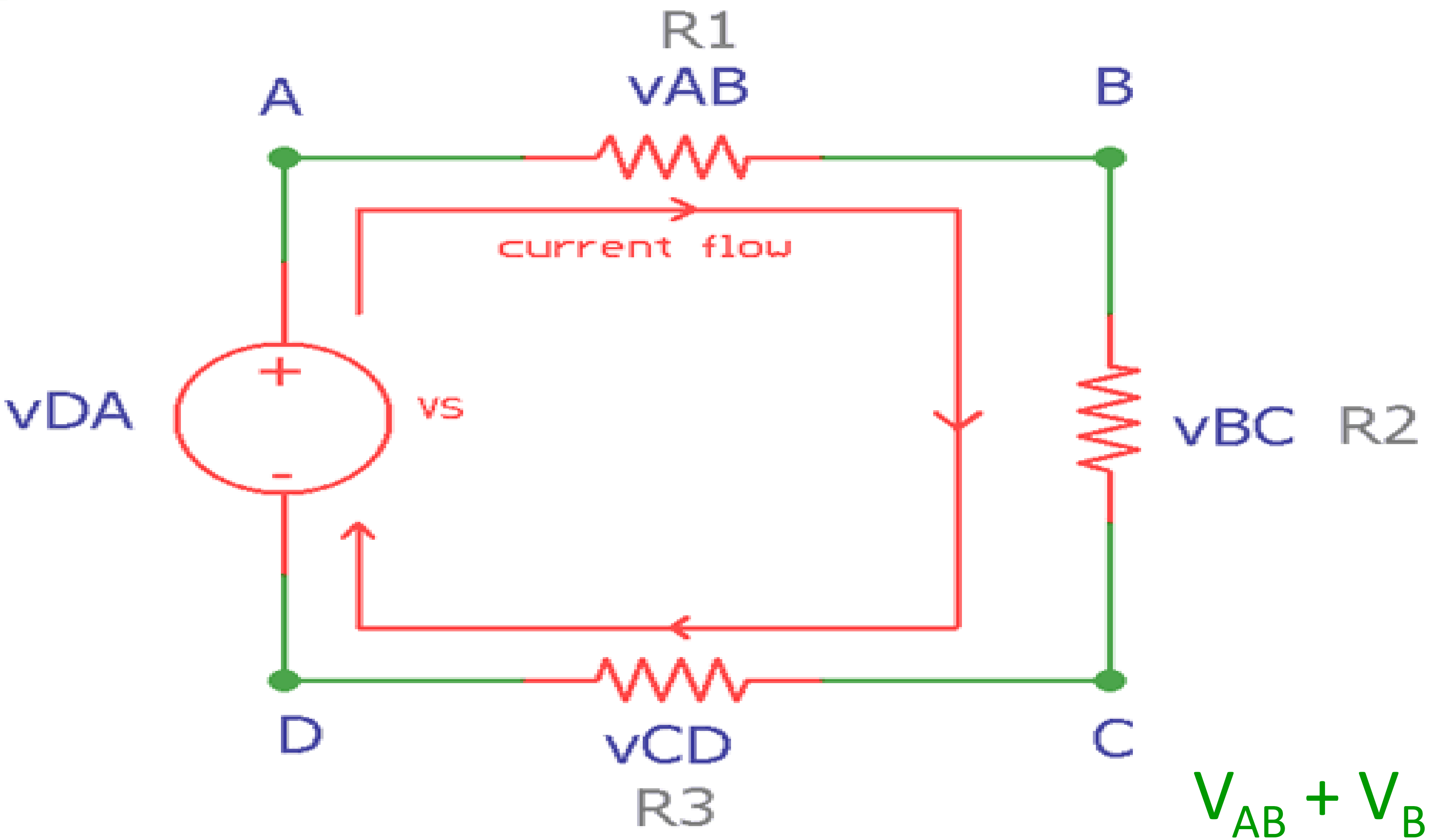
$$I_1 + I_2 + I_3 - I_4 - I_5 = 0$$

Kirchhoffs Second Law – The Voltage Law, (KVL)

Kirchhoffs Voltage Law, states that “in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop” which is also equal to zero.

In other words the algebraic sum of all voltages within the loop must be equal to zero. This idea by Kirchhoff is known as the Conservation of Energy.

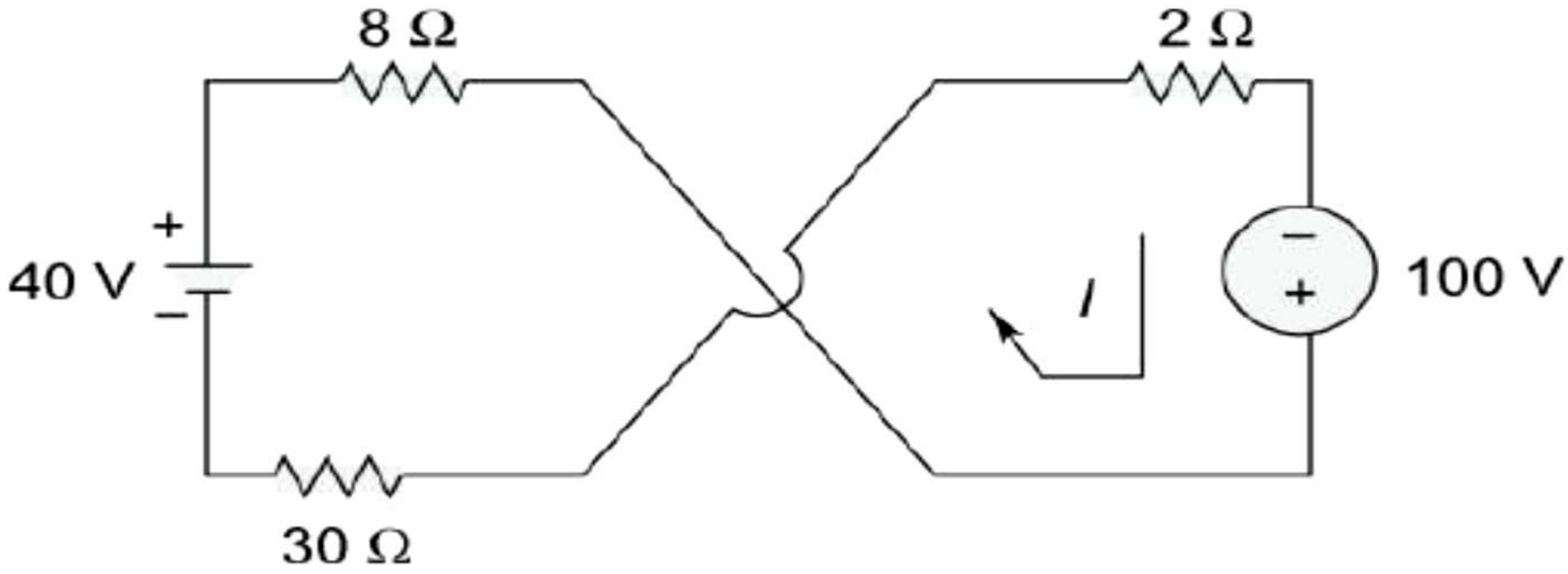
KIRCHOFF LAWS



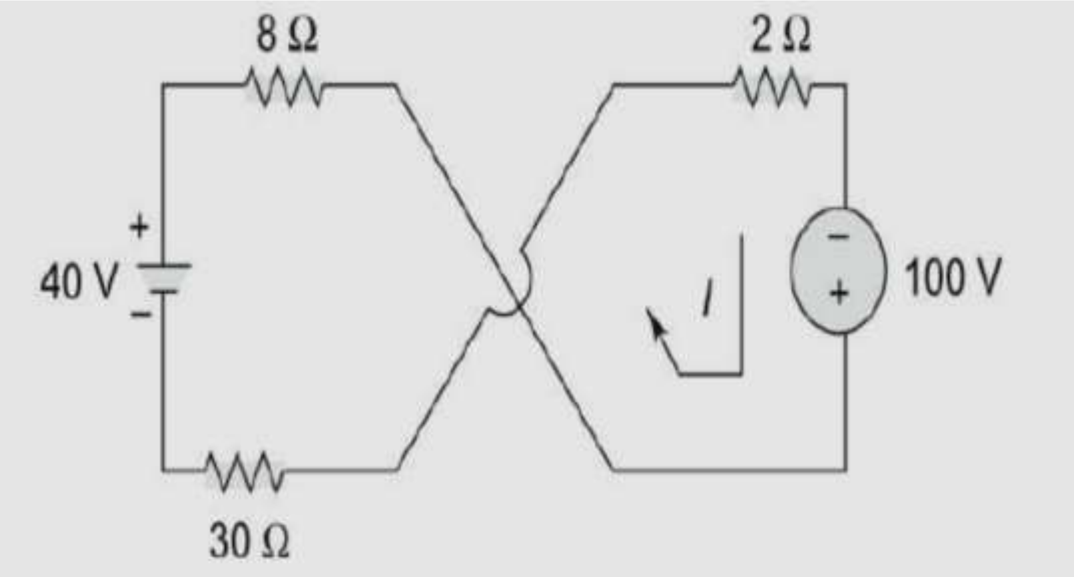
$$V_{AB} + V_{BC} + V_{CD} - V_{DA} = 0$$

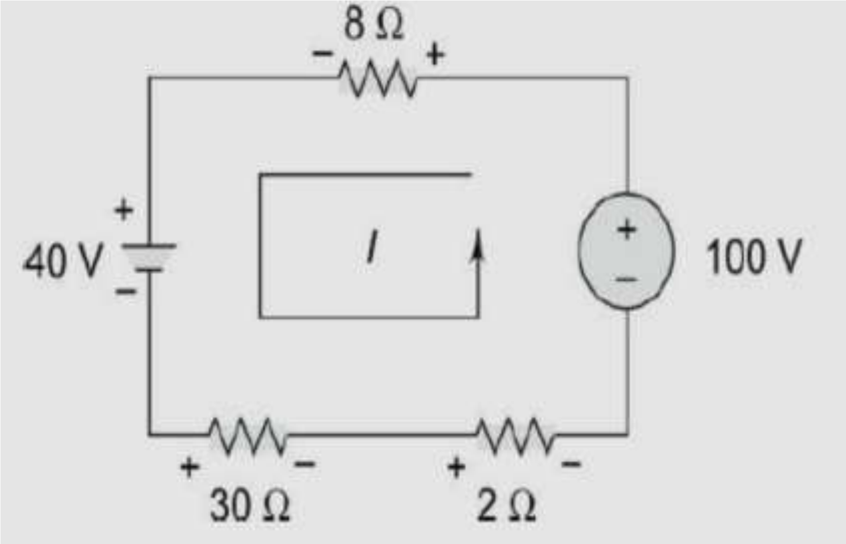
KIRCHOFF LAWS

Q : in the circuit given below, find (a) the current I, and (b) the voltage across 30 ohm resistor.



KIRCHOFF LAWS





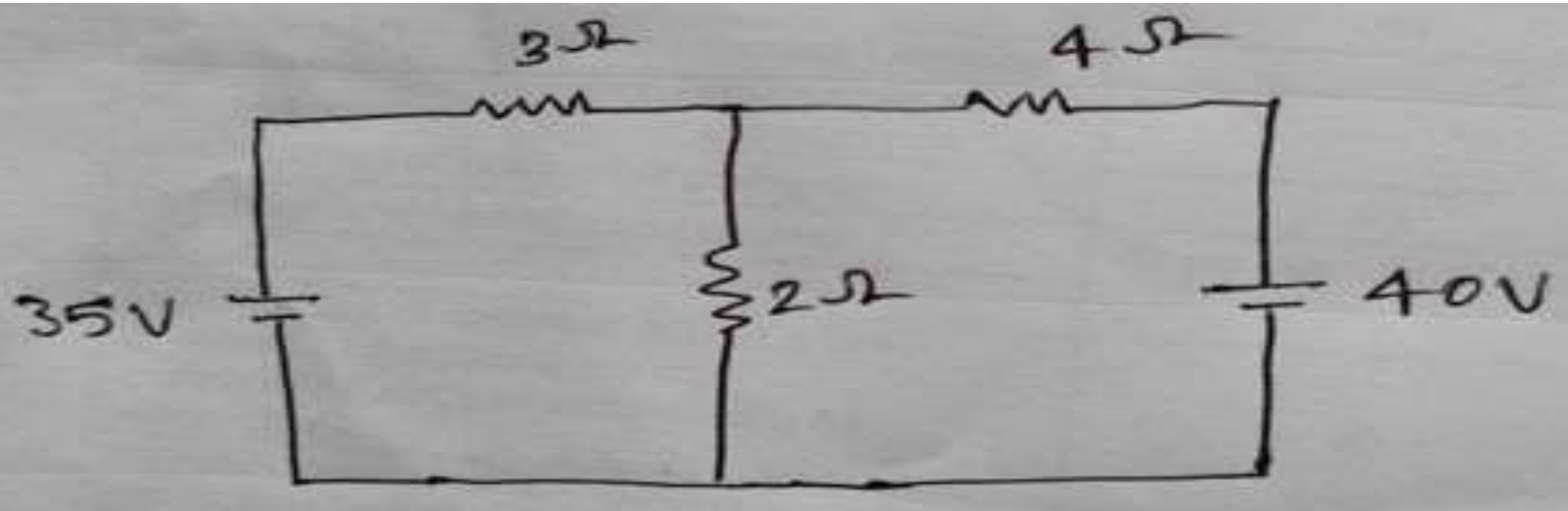
By applying Kirchhoff's law, we get

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

$$40I = 60 \quad \text{or} \quad I = \frac{60}{40} = 1.5\,\text{A}$$

$\therefore$ voltage drop across 30 Ω $= V_{30} = 30 \times 1.5 = 45$ V

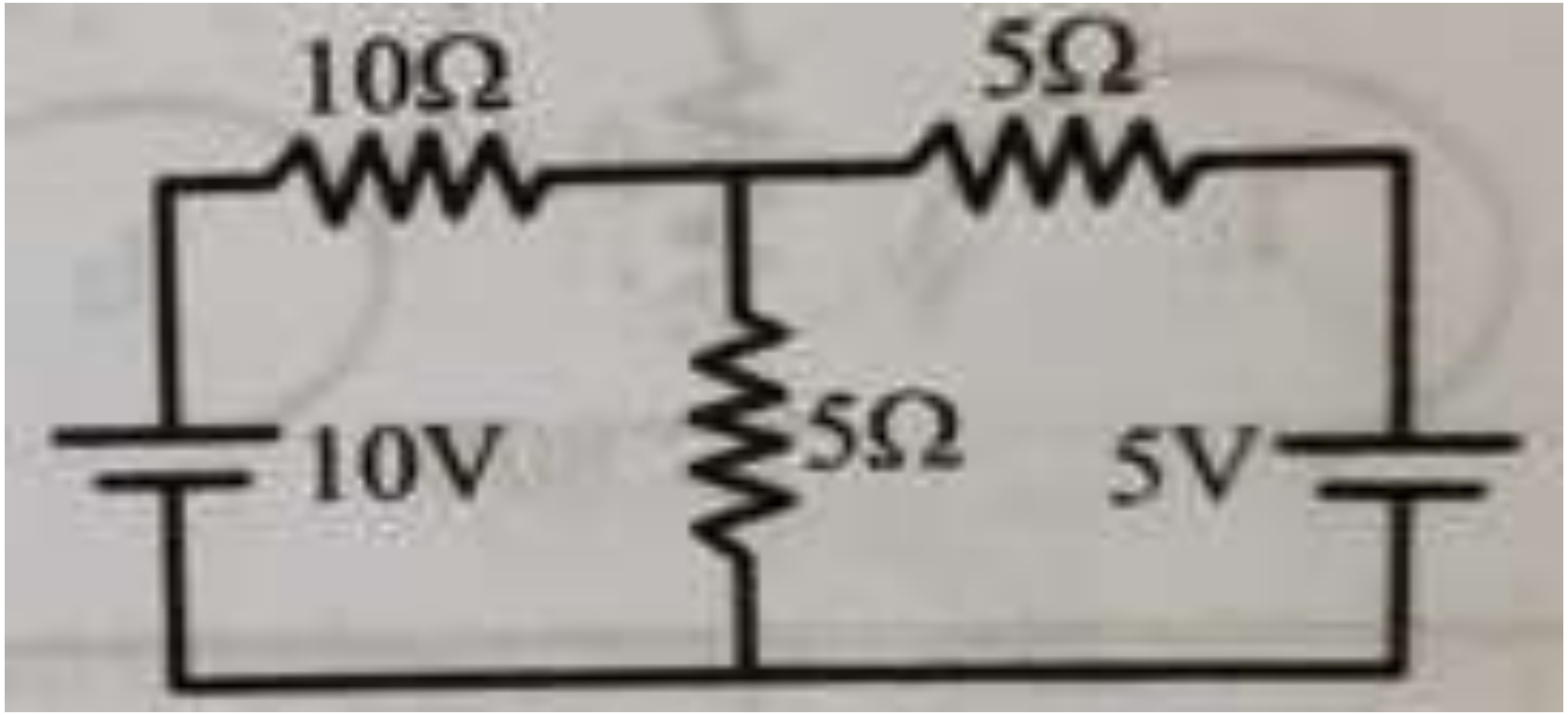
Mesh Analysis



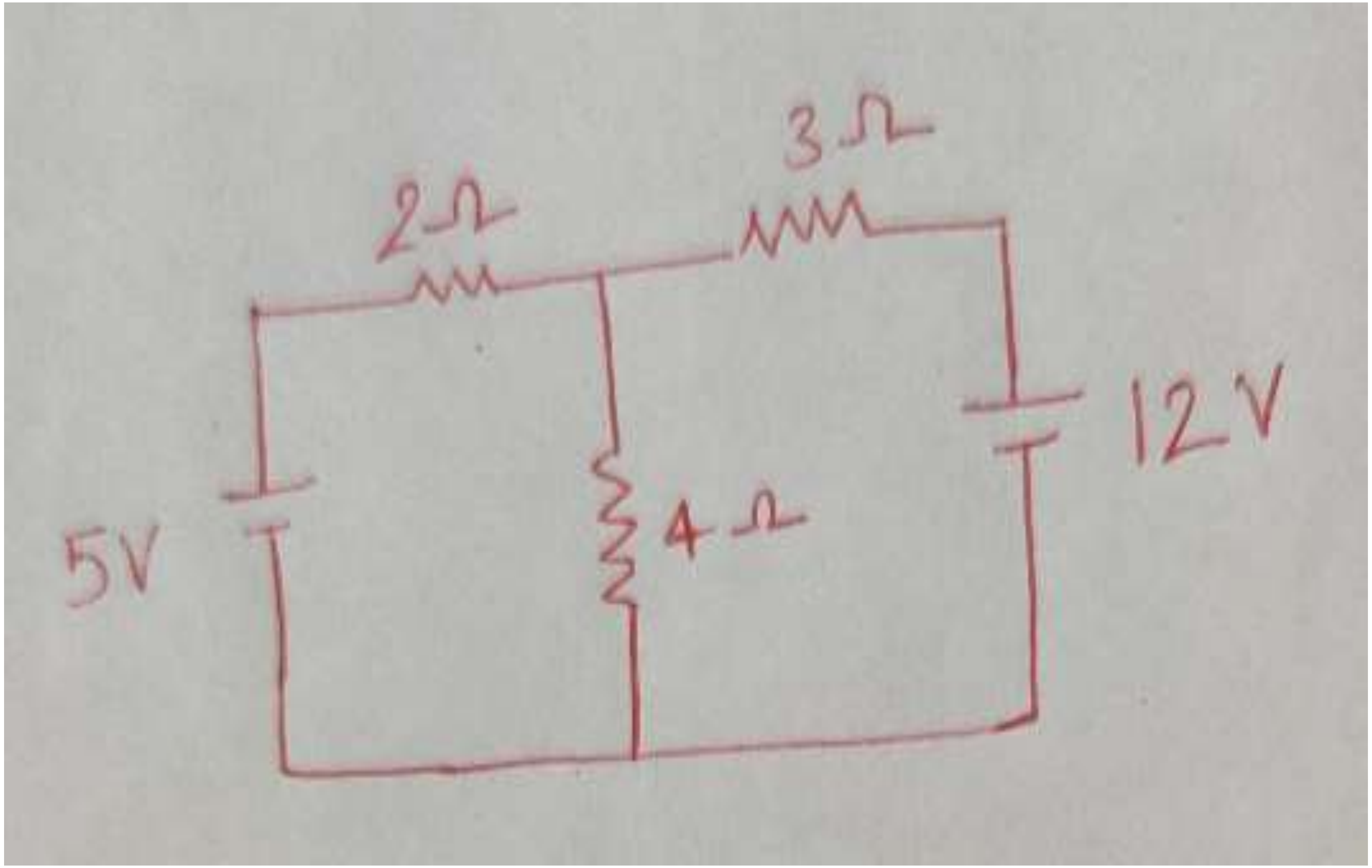
$I_1 = 5A$

$I_2 = 5A$

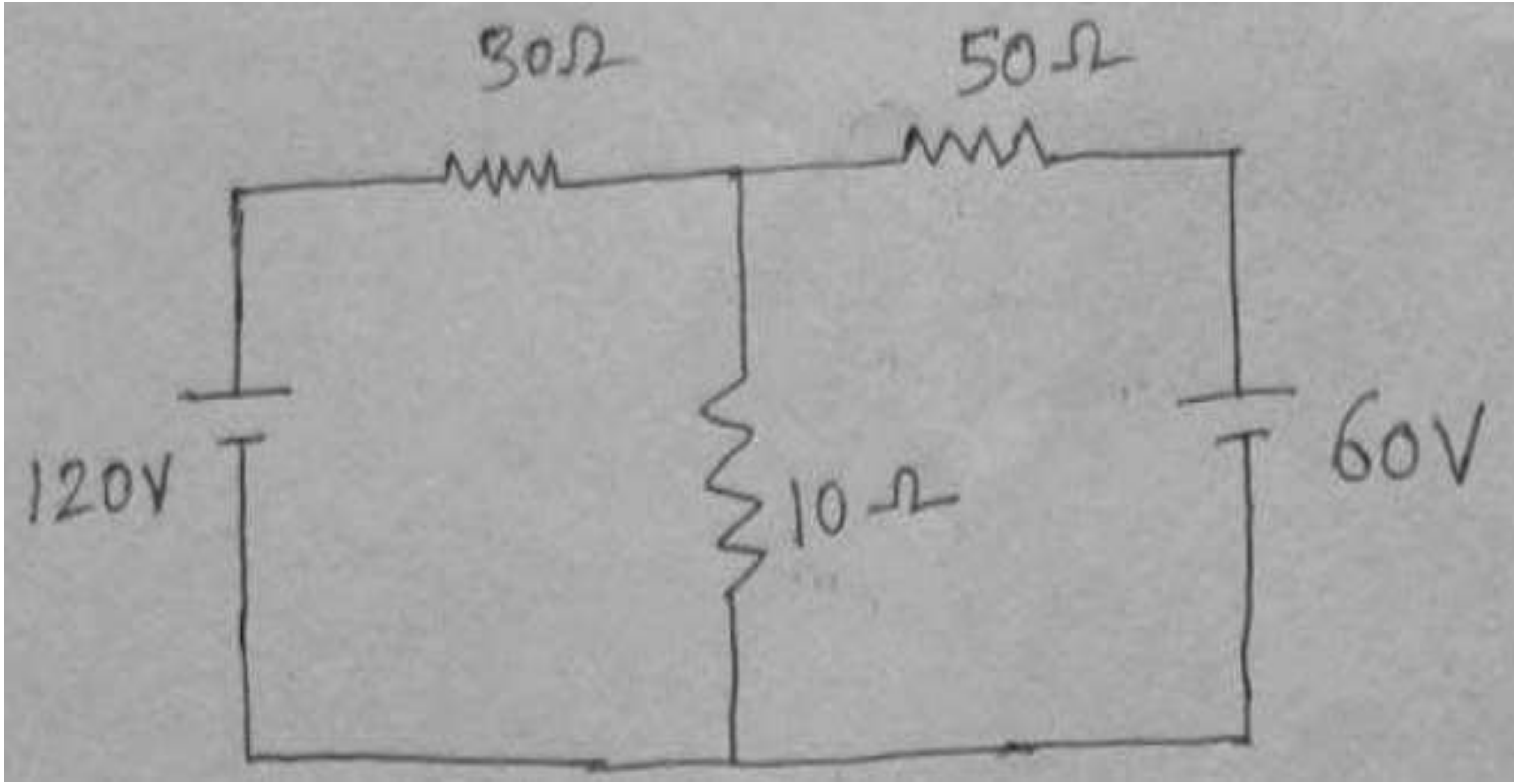
Mesh Analysis



Nodal Analysis



Nodal Analysis

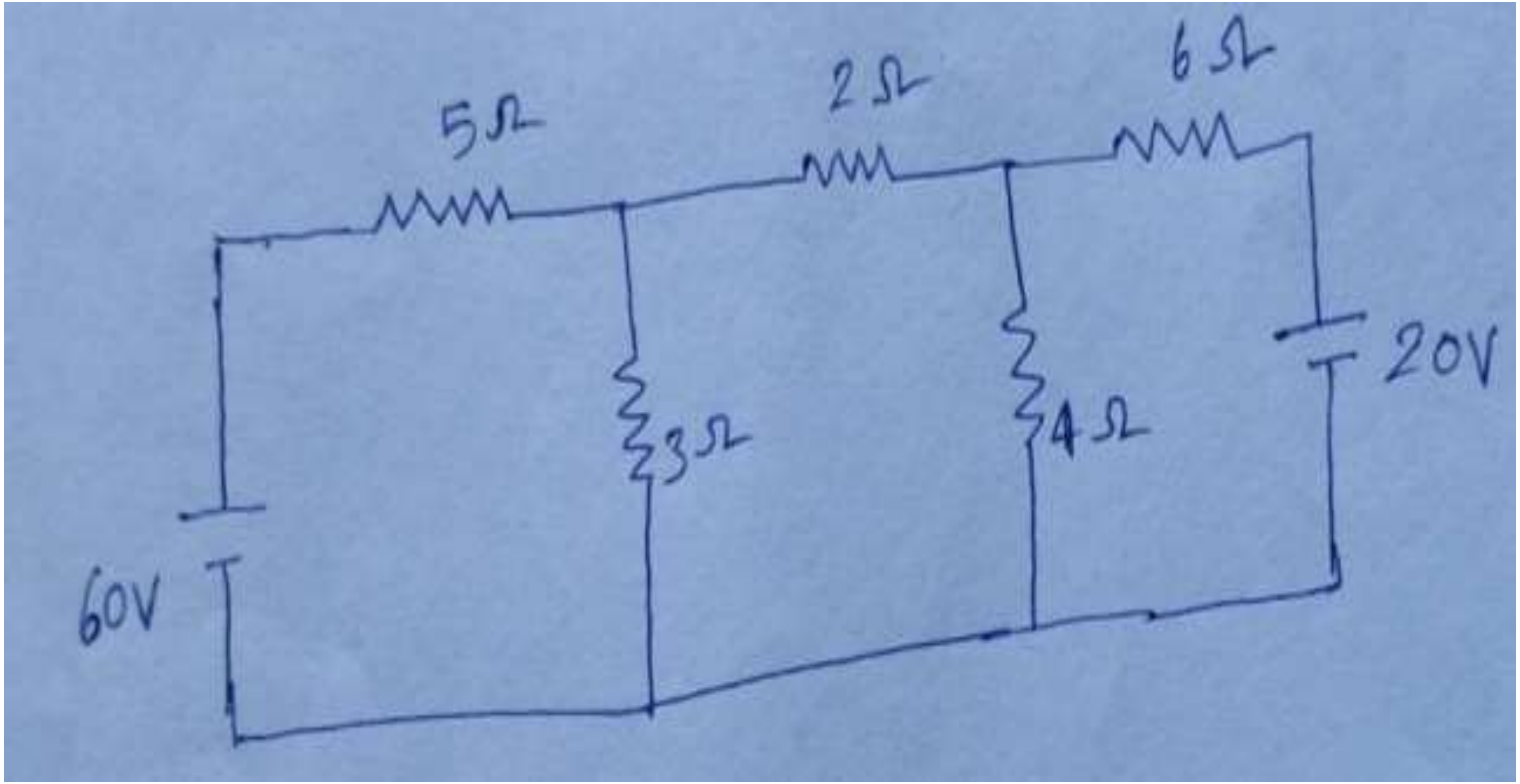


Mesh Analysis

$I1 = 2.86A$

$I2 = -0.521A$

Nodal Analysis



Mesh Analysis

$I2 = 2.31A$

$I3 = -1.07A$

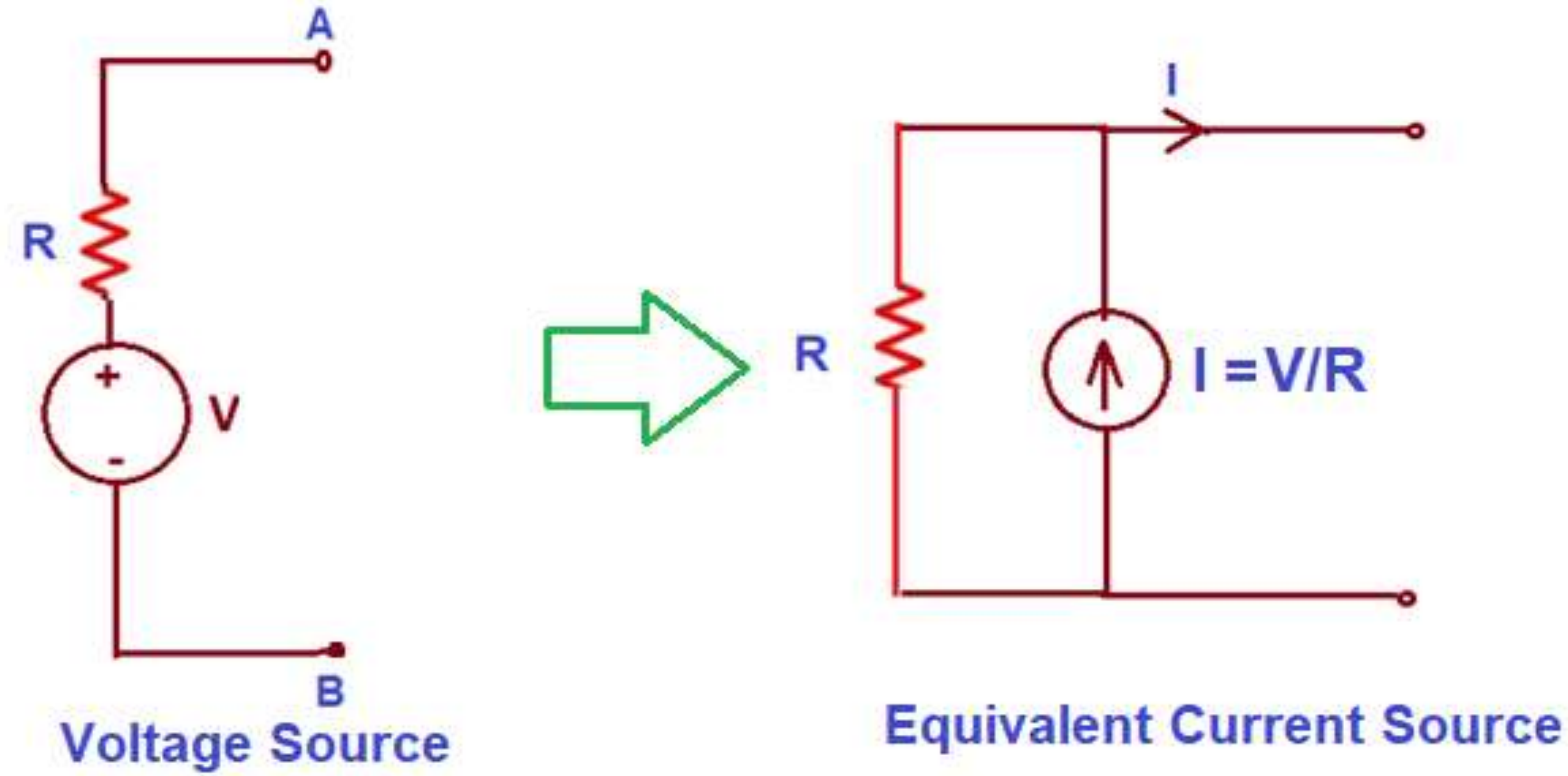
SOURCE TRANSFORMATION

Source Transformation is a technique to convert one kind of source into other.

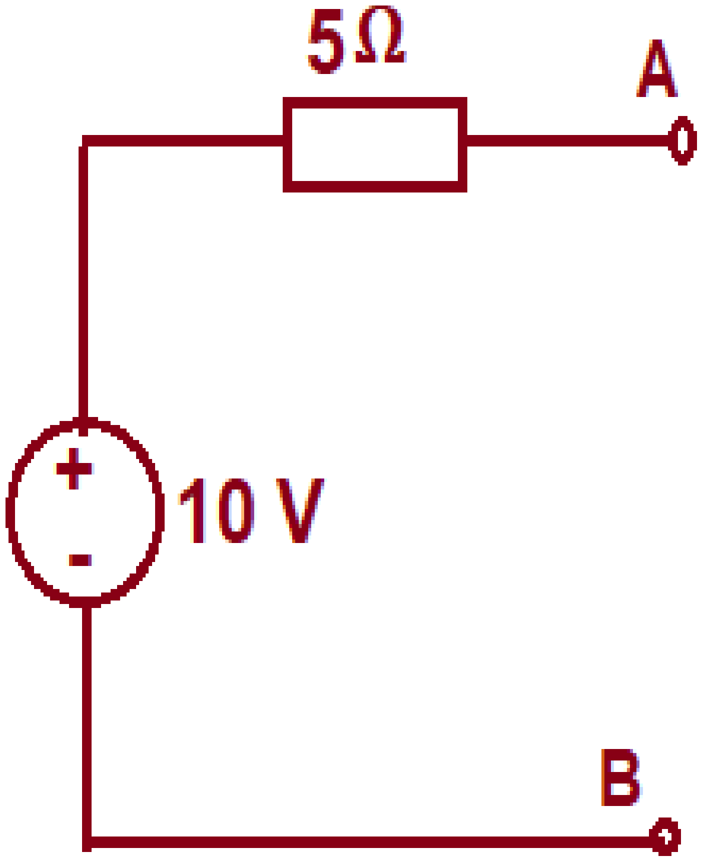
There are two types of sources:

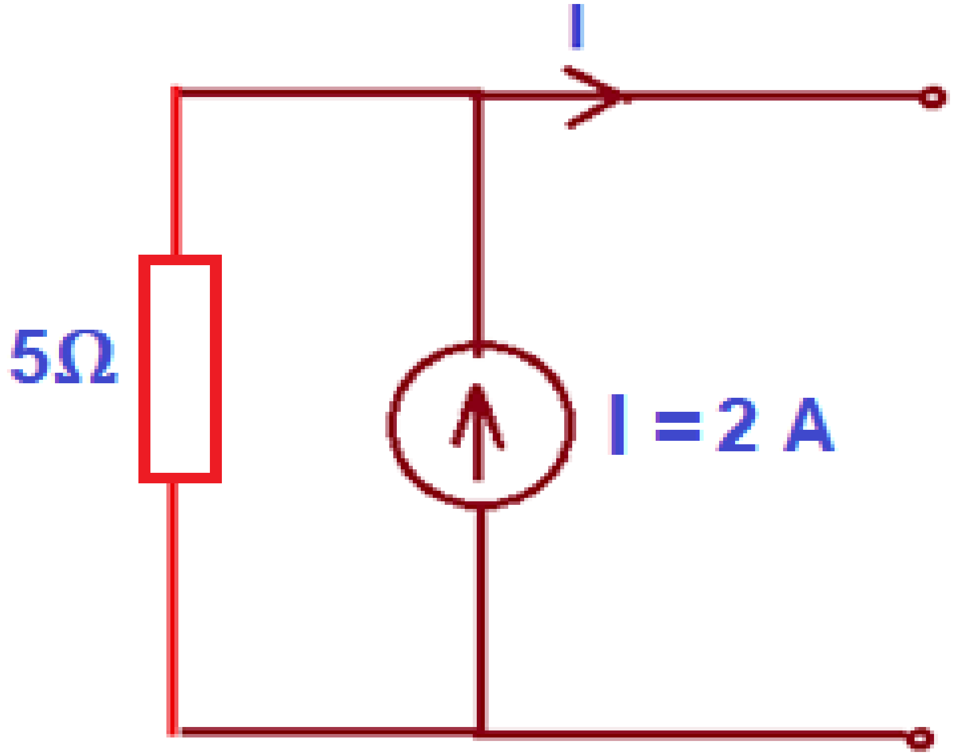
1. ***Voltage source***
2. ***Current Source***

Transformation of Voltage Source into Current Source



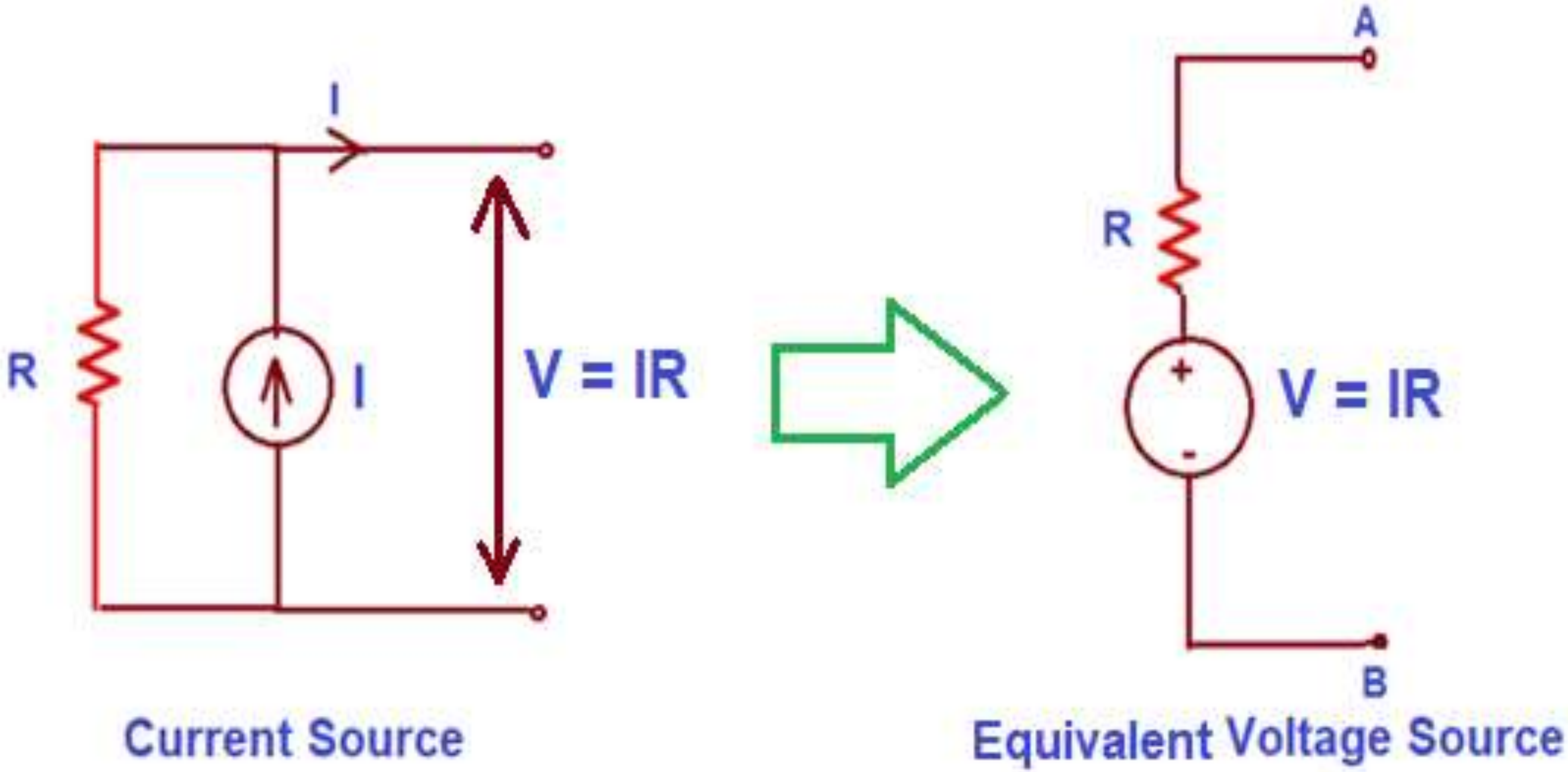
Transformation of Voltage Source into Current Source



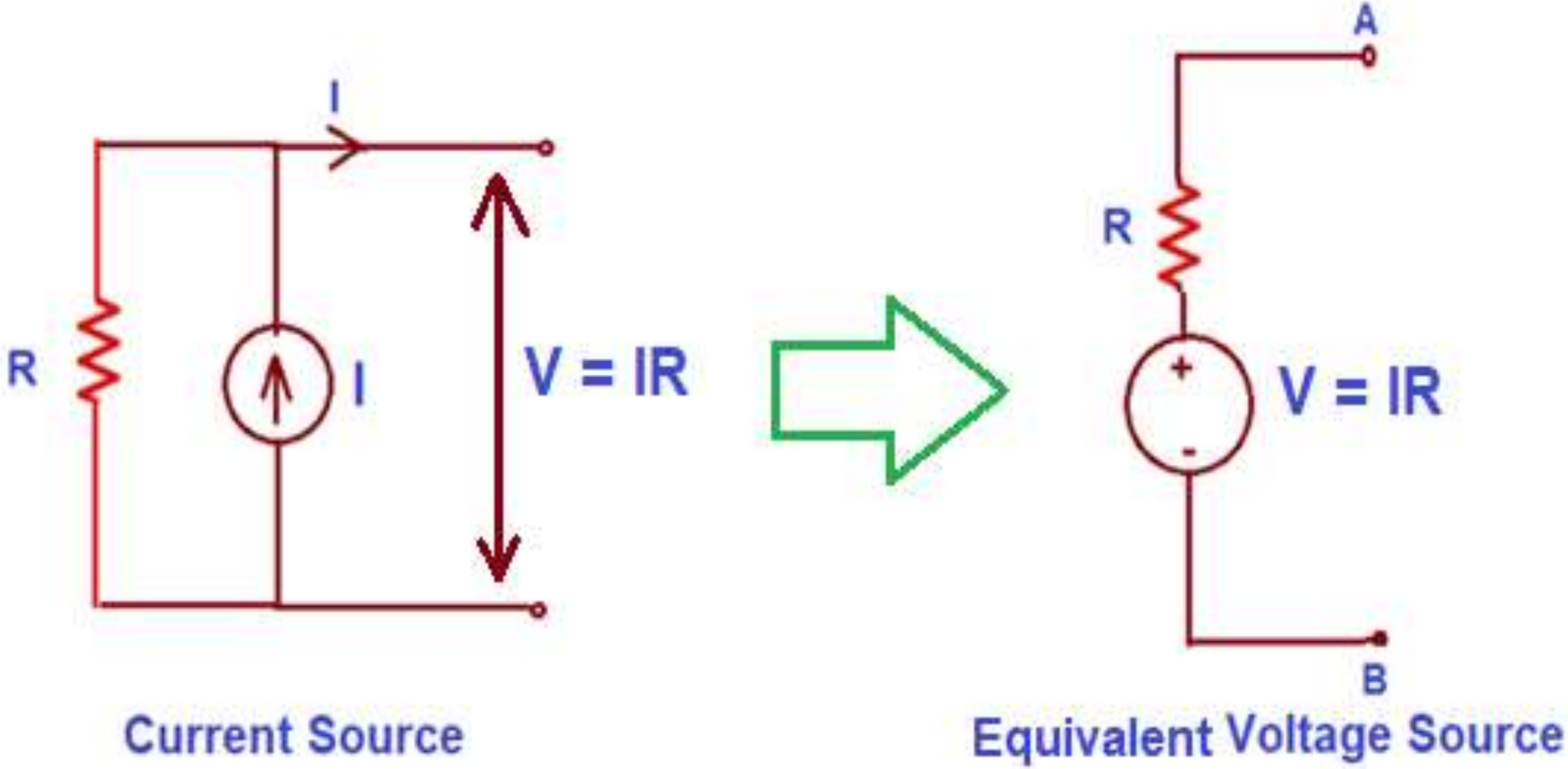


Equivalent Current Source

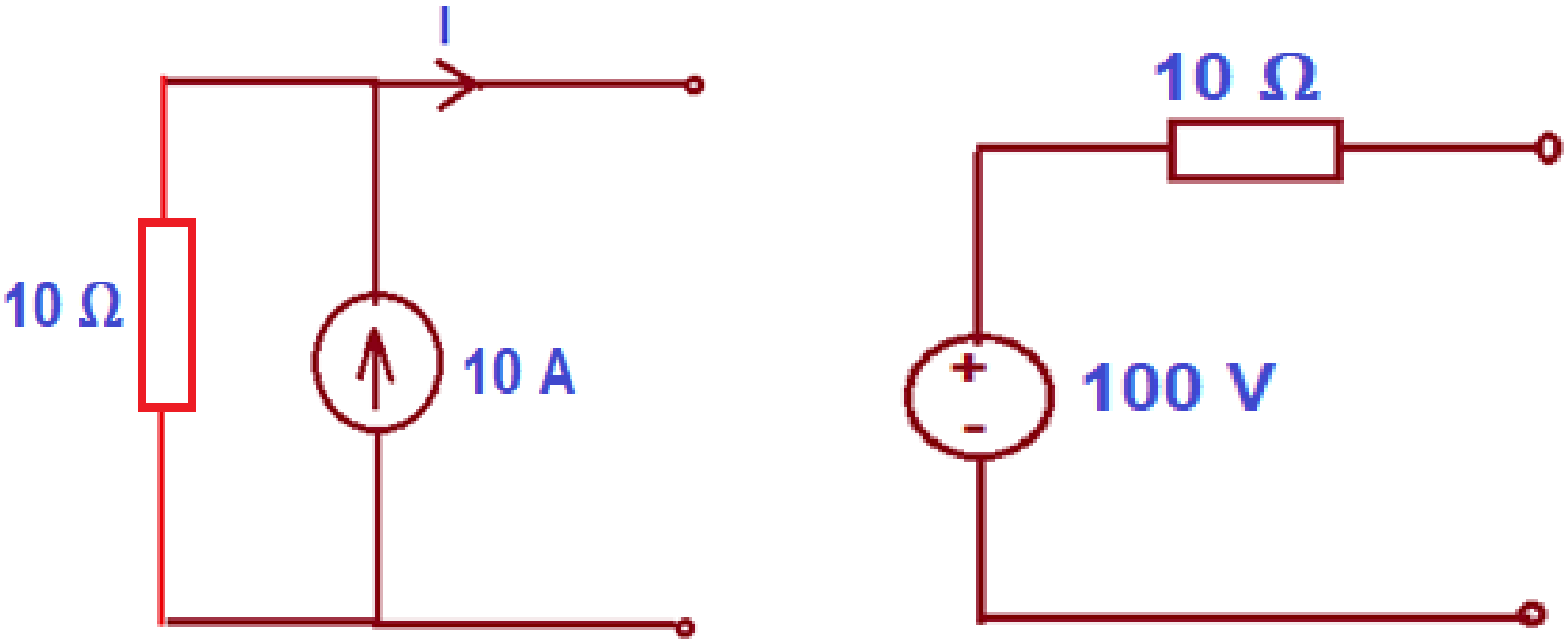
Conversion of Current Source into Voltage Source



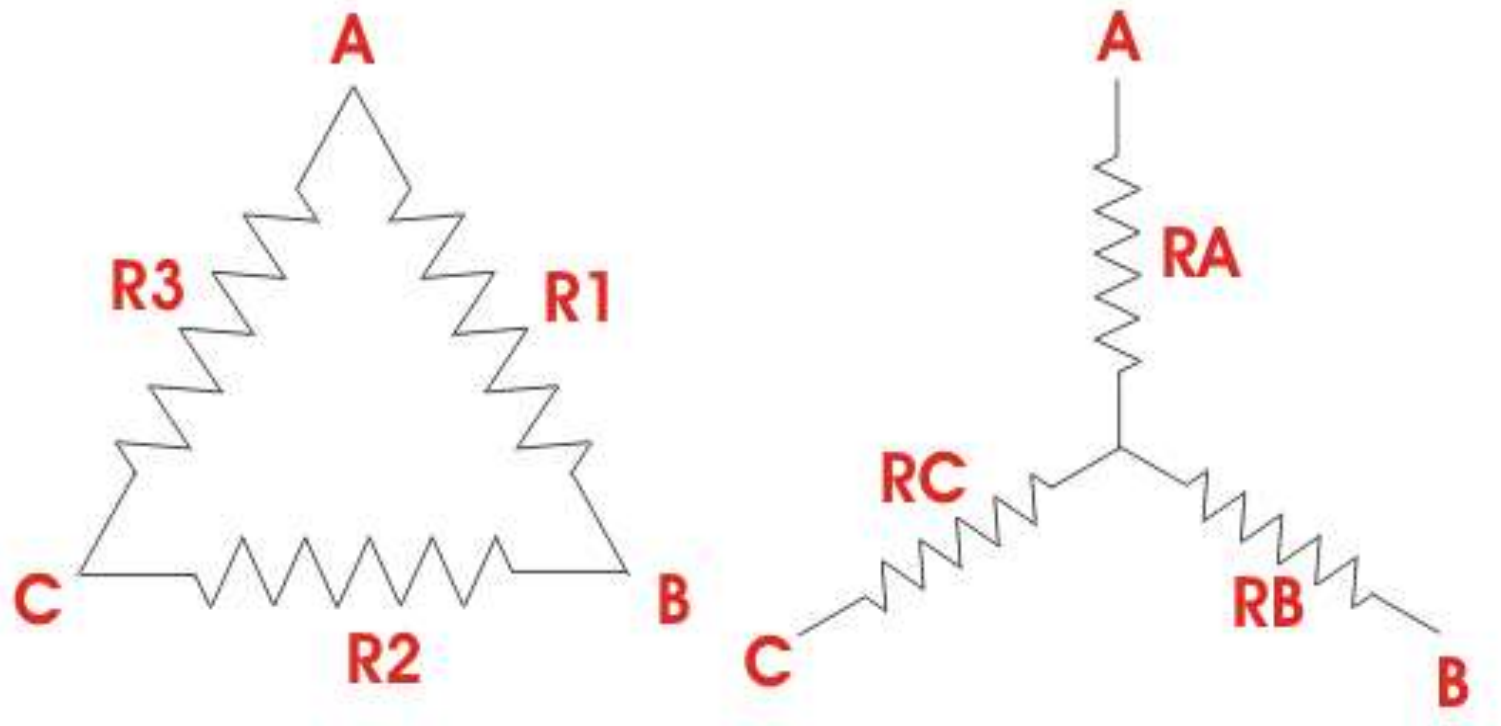
Conversion of Current Source into Voltage Source



Conversion of Current Source into Voltage Source



DELTA TO STAR TRANSFORMATION



Consider a delta system that's three corner points are A, B and C as shown in the figure. Electrical resistance of the branch between points A and B, B and C and C and A are R_1, R_2 and R_3 respectively.

DELTA TO STAR TRANSFORMATION

❖ The resistance between the points A and B will be,

$$R_{AB} = R_1 || (R_2 + R_3) = \frac{R_1.(R_2 + R_3)}{R_1 + R_2 + R_3}$$

❖ Now, one star system is connected to these points A, B, and C as shown in the figure. Three arms R_A, R_B and R_C of the star system are connected with A, B and C respectively. Now if we measure the resistance value between points A and B, we will get,

$$R_{AB} = R_A + R_B$$

DELTA TO STAR TRANSFORMATION

❖ Since the two systems are identical, resistance measured between terminals A and B in both systems must be equal.

$$R_A + R_B = \frac{R_1.(R_2 + R_3)}{R_1 + R_2 + R_3} \cdots\cdots\cdots\cdots (i)$$

❖ Similarly, resistance between points B and C being equal in the two systems,

$$R_B + R_C = \frac{R_2.(R_3 + R_1)}{R_1 + R_2 + R_3} \cdots\cdots\cdots\cdots (ii)$$

DELTA TO STAR TRANSFORMATION

- And resistance between points C and A being equal in the two systems,

$$R_C + R_A = \frac{R_3.(R_1 + R_2)}{R_1 + R_2 + R_3} \cdots\cdots\cdots\cdots (iii)$$

- Adding equations (I), (II) and (III) we get,

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

$$R_A + R_B + R_C = \frac{R_1.R_2 + R_2.R_3 + R_3.R_1}{R_1 + R_2 + R_3} \ldots\ldots\ldots (iv)$$

DELTA TO STAR TRANSFORMATION

❖ Subtracting equations (I), (II) and (III) from equation (IV) we get,

$$R_A = \frac{R_3.R_1}{R_1 + R_2 + R_3} \ldots\ldots\ldots\ldots\ldots\ldots(v)$$

$$R_B = \frac{R_1.R_2}{R_1 + R_2 + R_3} \ldots\ldots\ldots\ldots\ldots\ldots(vi)$$

$$R_C = \frac{R_2.R_3}{R_1 + R_2 + R_3} \ldots\ldots\ldots\ldots\ldots\ldots(vii)$$

STAR TO DELTA TRANSFORMATION

- For star – delta transformation we just multiply equations (v), (VI) and (VI), (VII) and (VII), (V) that is by doing (v) × (VI) + (VI) × (VII) + (VII) × (V) we get,

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

$$= \frac{R_1.R_2.R_3(R_1 + R_2 + R_3)}{(R_1 + R_2 + R_3)^2}$$

$$= \frac{R_1.R_2.R_3}{R_1 + R_2 + R_3} \ldots\ldots\ldots\ldots\ldots\ldots(viii)$$

STAR TO DELTA TRANSFORMATION

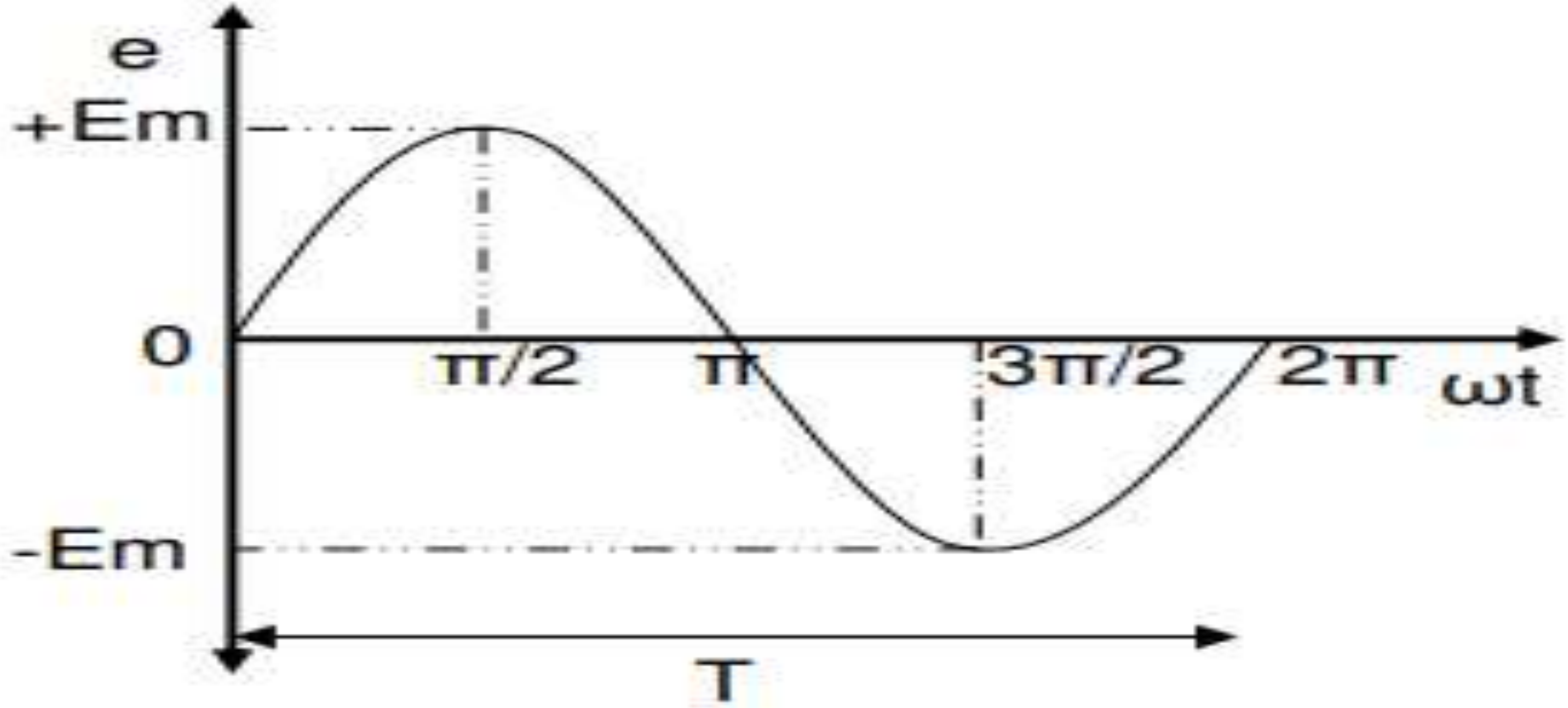
- Now dividing equation (VIII) by equations (V), (VI) and equations (VII) separately we get,

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

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

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

Alternating Quantity



An alternating quantity changes continuously in magnitude and alternates in direction at regular intervals of time

Terms of Alternating quantity

1. Amplitude

It is the maximum value attained by an alternating quantity. Also called as maximum or peak value

2. Time Period (T)

It is the Time Taken in seconds to complete one cycle of an alternating quantity

3. Instantaneous Value

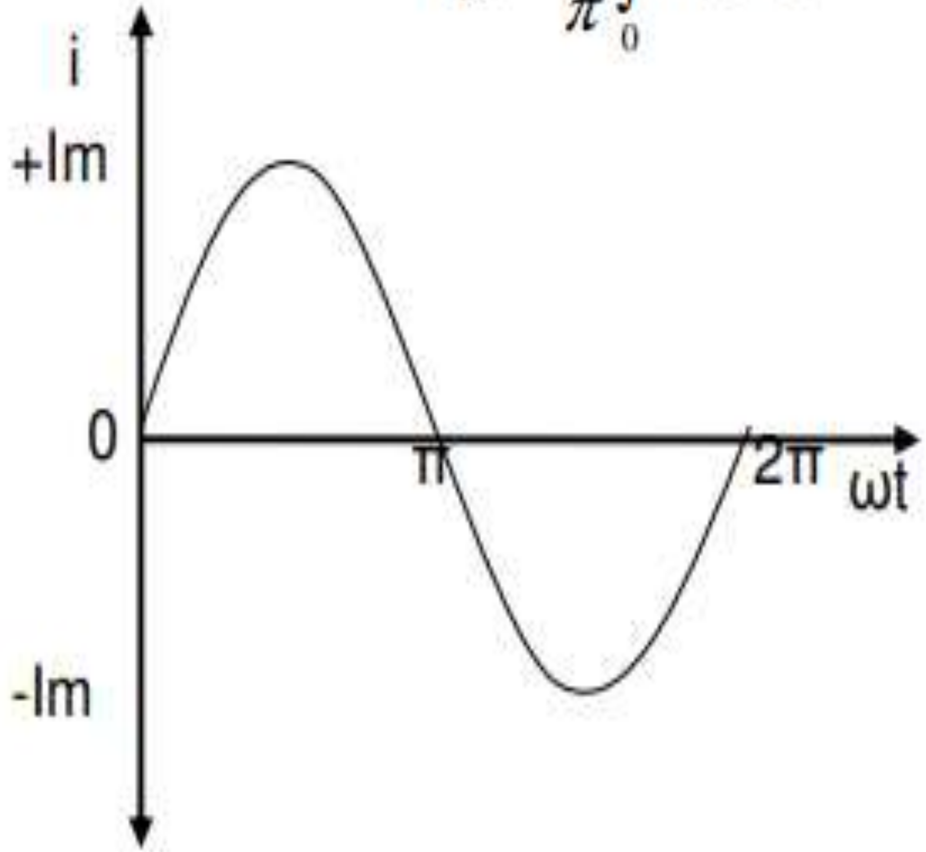
It is the value of the quantity at any instant

4. Frequency (f)

- It is the number of cycles that occur in one second. The unit for frequency is Hz or cycles/sec.
- The relationship between frequency and time period can be derived as follows.
- Time taken to complete f cycles = 1 second
- Time taken to complete 1 cycle = 1/f second
- $T = 1/f$

Average value of a sinusoidal current

$$V_{av} = \frac{1}{\pi}\int_0^{\pi} v\,d(\omega t)$$



$$i = I_m \sin \omega t$$

$$I_{av} = \frac{1}{\pi}\int_0^{\pi} i\,d(\omega t)$$

$$I_{av} = \frac{1}{\pi}\int_0^{\pi} I_m \sin \omega t\,d(\omega t)$$

$$I_{av} = \frac{2I_m}{\pi} = 0.637 I_m$$

RMS value of a sinusoidal current

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^T I_m^2 \sin^2\theta \, d\theta}$$

$$= \sqrt{\frac{I_m^2}{T}\int_0^T \sin^2\theta \, d\theta}$$

$$= \sqrt{\frac{I_m^2}{T}\int_0^T \left(\frac{1-\cos 2\theta}{2}\right) d\theta}$$

$$= \sqrt{\frac{I_m^2}{T} \times \frac{1}{2}\left(\int_0^T d\theta - \int_0^T \cos 2\theta\right) d\theta}$$

$$= \sqrt{\frac{I_m^2}{T} \times \frac{1}{2}\left(\theta - \frac{\sin 2\theta}{2}\right)_0^T}$$

$$= \sqrt{\frac{I_m^2}{2T}\left(T - \frac{\sin 2(0)}{2}\right)}$$

$$= \sqrt{\frac{I_m^2}{2T}(T - 0)}$$

$$I_{rms} = \sqrt{\frac{I_m^2}{2}} = \frac{I_m}{\sqrt{2}}$$

FORM FACTOR

Form Factor is defined as the ratio of RMS value to the average value of the wave.

For a sinusoidal signal,

$$Form\ factor = \frac{V_{rms}}{V_{av}}$$

$$Form\ factor = \frac{V_{rms}}{V_{av}} = \frac{0.707\ V_m}{0.637\ V_m} = 1.11$$

PEAK FACTOR

Peak or crest Factor is defined as the ratio of Peak value to the RMS value of the wave.

For a sinusoidal signal,

$$Peak\ factor = \frac{V_m}{V_{rms}}$$

$$Peak\ factor = \frac{V_m}{V_{rms}} = \frac{V_m}{0.707\ V_m} = 1.414$$

PEAK FACTOR

Q: A sine wave has a peak value of 25V.Determine the following values a) rms b)peak to peak c)average.

Sol: Given, $V_m = 25V$

$$a)\ RMS\ value, V_{rms} = \frac{V_m}{\sqrt{2}} = 0.707V_m = 0.707 \times 25 = 17.675V$$

$$b)\ Peak\ to\ Peak\ value = 2V_m = 2 \times 25 = 50V$$

$$c)\ Average\ value, V_{av} = \frac{2V_m}{\pi} = 0.637V_m = 0.637 \times 25 = 15.9V$$

Q: A sine wave has a frequency of 50KHZ.How many cycles does it complete in 20ms?

Sol: Given T = 20ms

$$\text{Frequency}, f = \frac{1}{T}$$

$$= \frac{1}{20 \times 10^{-3}} = 50\ hz\ (or)\ cycles/sec$$

Q: The period of a sine wave is 20 milliseconds. What is the frequency.

Sol: Given, Time period T=20 ms

$$Frequency, f = \frac{1}{T} = \frac{1}{20 \times 10^{-3}} = 50\,Hz$$

Q: The frequency of a sine wave is 30HZ .what is the period.

Sol: Given, frequency f=30 Hz

$$Time\,period, T = \frac{1}{f} = \frac{1}{30} = 0.0333 = 33.3\,ms$$

Q: A wire is carrying a direct current of 20A and a sinusoidal alternating current of peak value 20A. Find the RMS value of the resultant current in the wire.

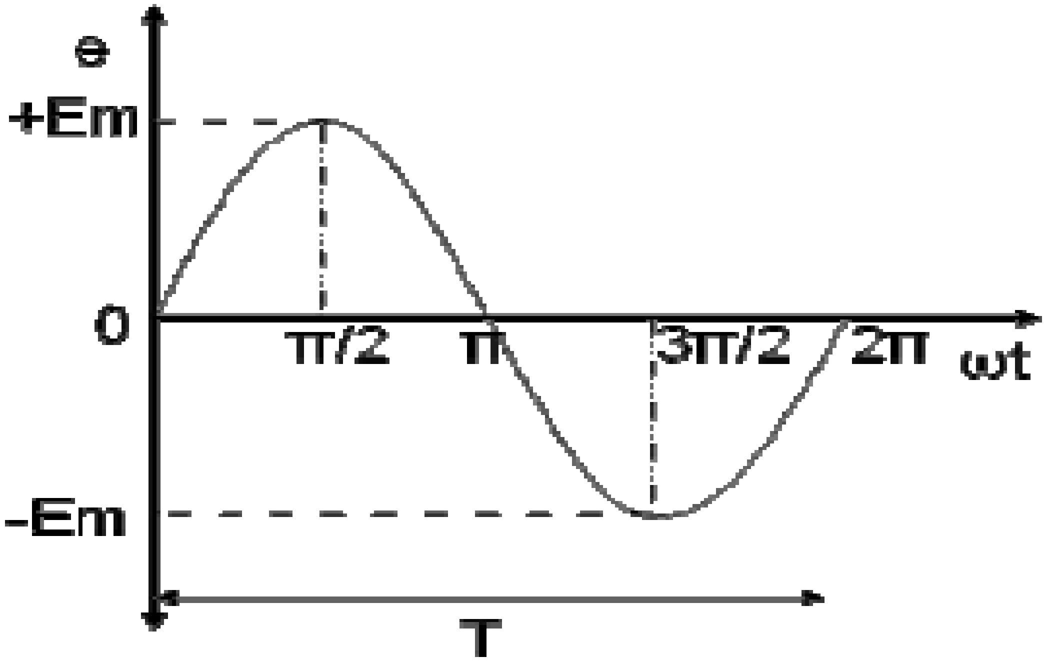
Sol: Given Idc=20A, Im=20A

$$Now, the\ RMS\ value\ of\ the\ resultant\ current\ in\ the\ wire, I_{rms} = \sqrt{{I_{dc}}^2 + \left(\frac{I_m}{\sqrt{2}}\right)^2}$$

$$= \sqrt{20^2 + \left(\frac{20}{\sqrt{2}}\right)^2}$$

= 24.5 amp

PHASE

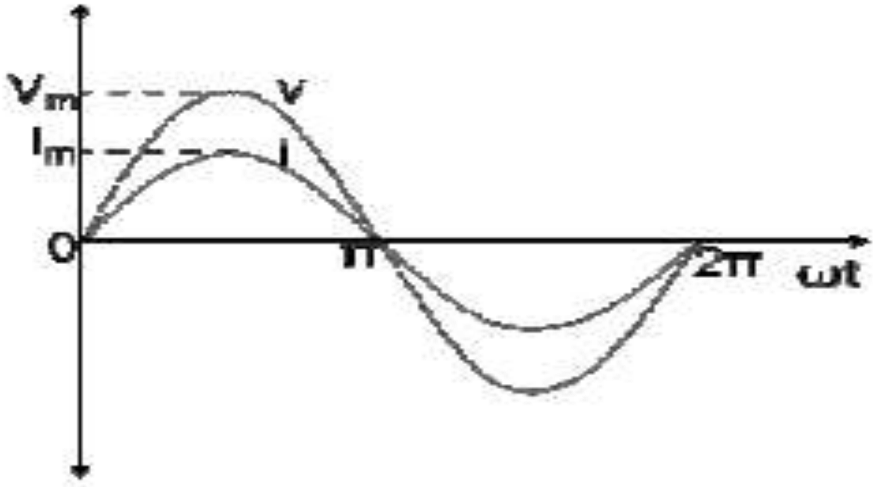


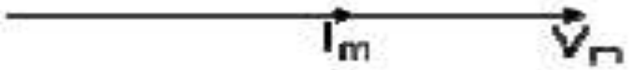
Phase is defined as the fractional part of time period or cycle through which the quantity has advanced from the selected zero position of reference

Phase of +Em is π/2 rad or T/4 sec

Phase of -Em is 3π/2 rad or 3T/4 sec

IN PHASE



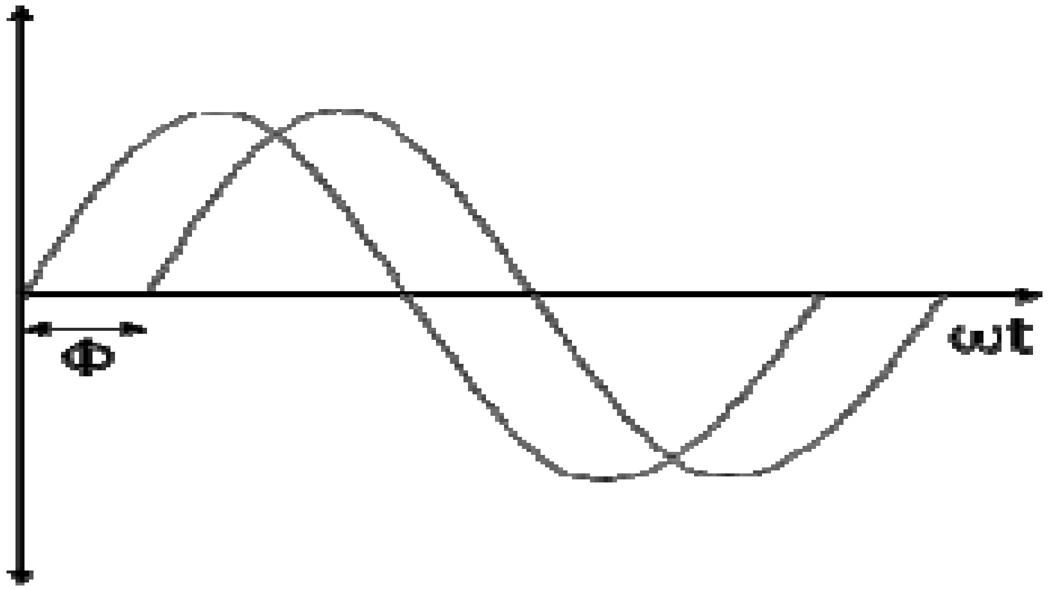


$$v = V_m \sin \omega t$$

$$i = I_m \sin \omega t$$

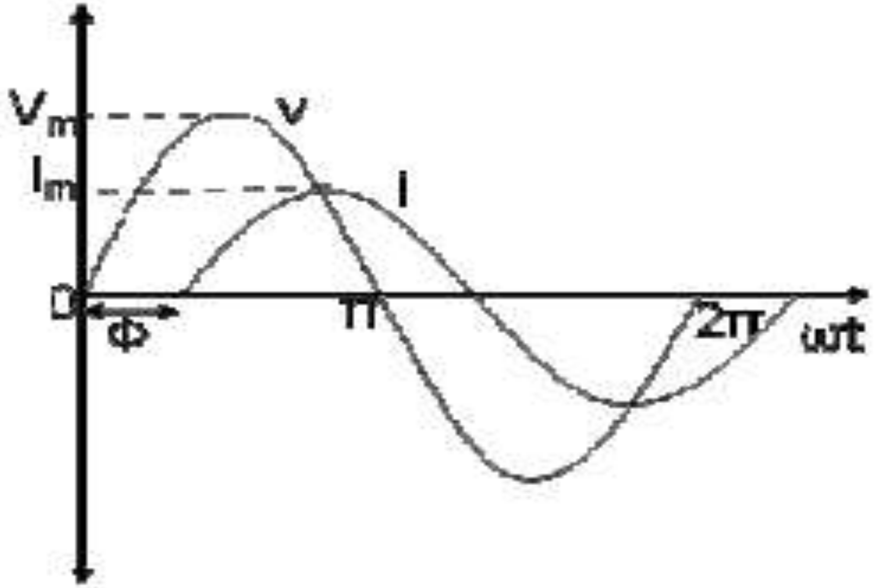
Two waveforms are said to be in phase, when the phase difference between them is zero

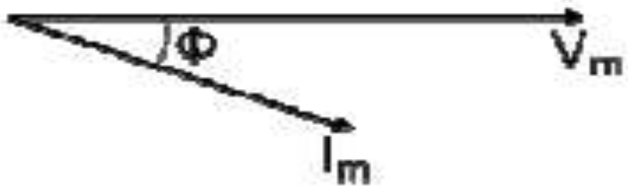
Phase Difference



- When two alternating quantities of the same frequency have different zero points, they are said to have a phase difference.
- The angle between the zero points is the angle of phase difference.

LAGGING

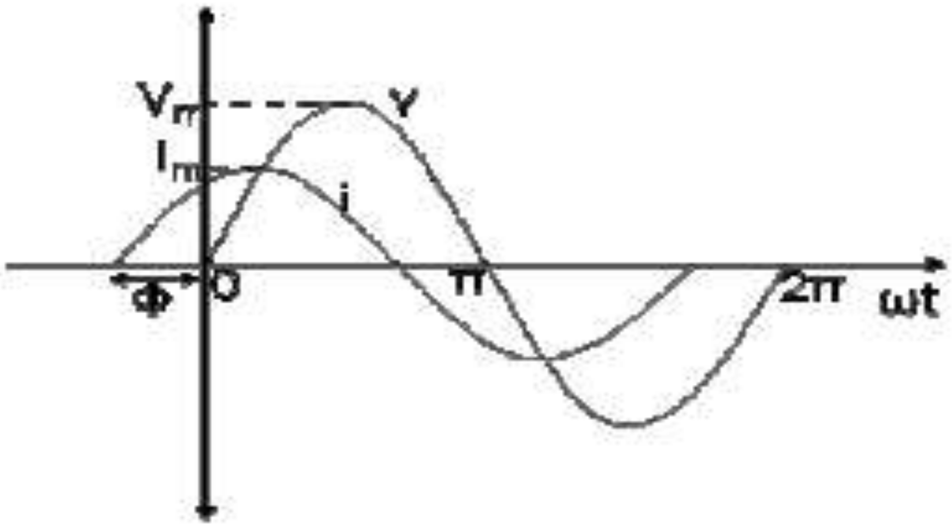


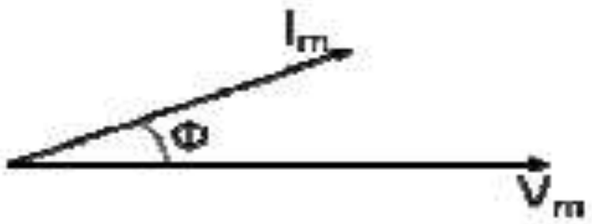


$$v = V_m \sin \omega t$$

$$i = I_m \sin(\omega t - \Phi)$$

LEADING

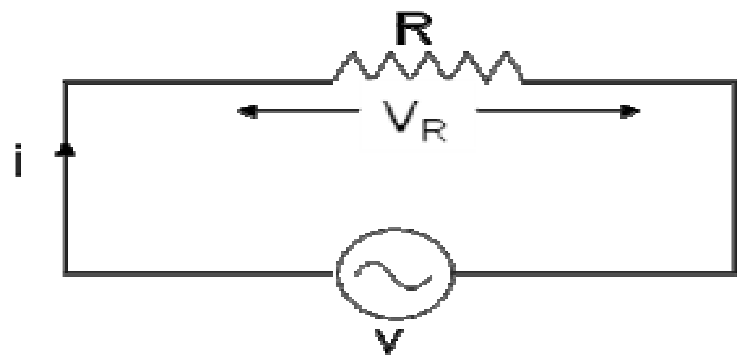




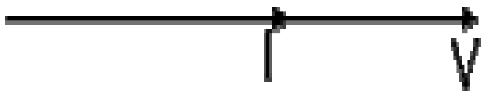
$$v = V_m \sin \omega t$$

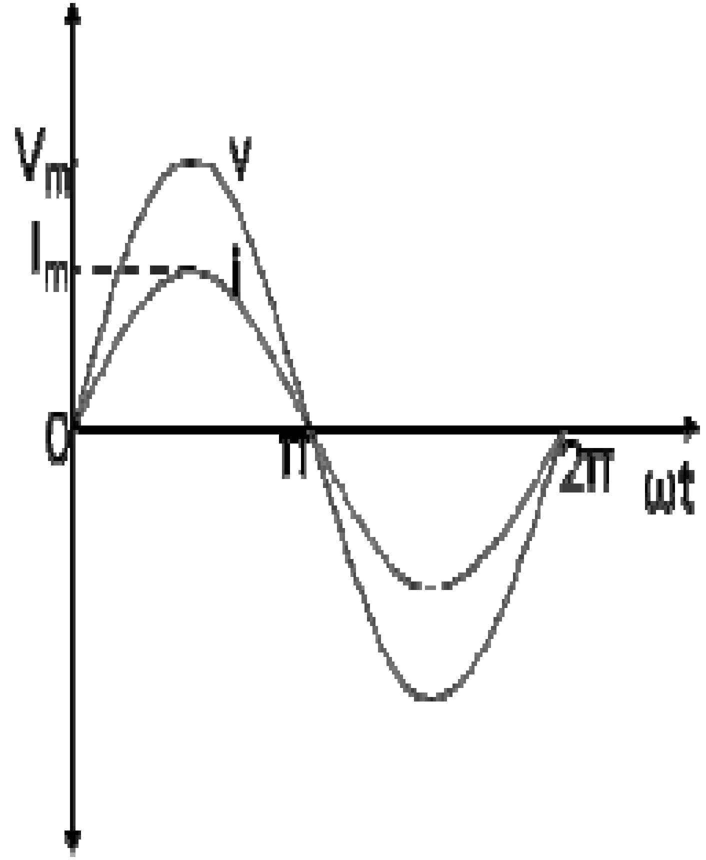
$$i = I_m \sin(\omega t + \Phi)$$

AC circuit with a pure resistance



$$v = V_m \sin \omega t$$





$$i = \frac{v}{R} = \frac{V_m \sin \omega t}{R}$$

$$i = I_m \sin \omega t$$

$$I_m = \frac{V_m}{R}$$

AC circuit with a pure resistance

Q: An ac circuit consists of a pure resistance of 10Ω and is connected to an ac supply of 230 V, 50 Hz. Calculate the (i) current (ii) power consumed and (iii) equations for voltage and current.

$$(i) I = \frac{V}{R} = \frac{230}{10} = 23A$$

$$(ii) P = VI = 230 \times 23 = 5260W$$

$$(iii) V_m = \sqrt{2}V = 325.27V$$

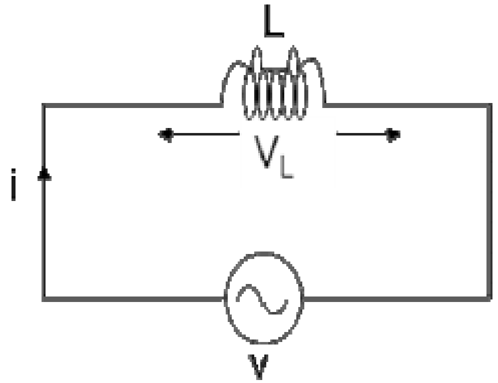
$$I_m = \sqrt{2}I = 32.52A$$

$$\omega = 2\pi f = 314 rad/\sec$$

$$v = 325.25 \sin 314t$$

$$i = 32.52 \sin 314t$$

AC circuit with a pure inductance



$$v = V_m \sin \omega t$$

$$v = L\frac{di}{dt}$$

$$V_m \sin \omega t = L\frac{di}{dt}$$

$$di = \frac{V_m}{L}\sin \omega t dt$$

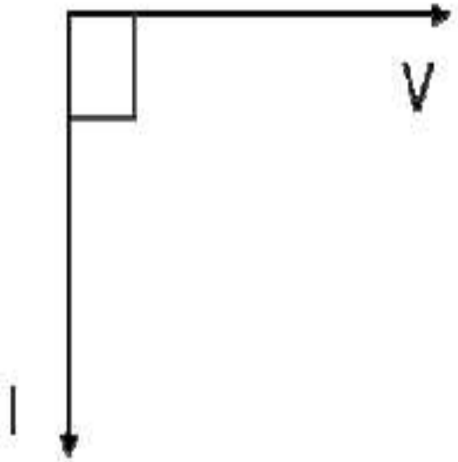
$$i = \frac{V_m}{L}\int \sin \omega t dt$$

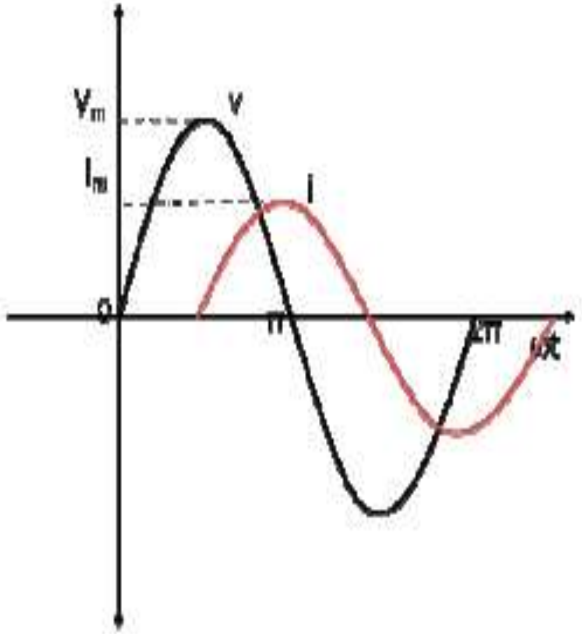
$$i = \frac{V_m}{\omega L}(-\cos \omega t)$$

$$i = \frac{V_m}{\omega L}\sin(\omega t - \pi/2)$$

$$i = I_m \sin(\omega t - \pi/2)$$

Where $I_m = \frac{V_m}{\omega L}$





AC circuit with a pure inductance

Q: A pure inductive coil allows a current of 10A to flow from a 230V, 50 Hz supply. Find (i) inductance of the coil (ii) power absorbed and (iii) equations for voltage and current.

$$(i) X_L = \frac{V}{I} = \frac{230}{10} = 23\Omega$$

$$X_L = 2\pi f L$$

$$L = \frac{X_L}{2\pi f} = 0.073H$$

$$(ii) P = 0$$

$$(iii) V_m = \sqrt{2}V = 325.27V$$

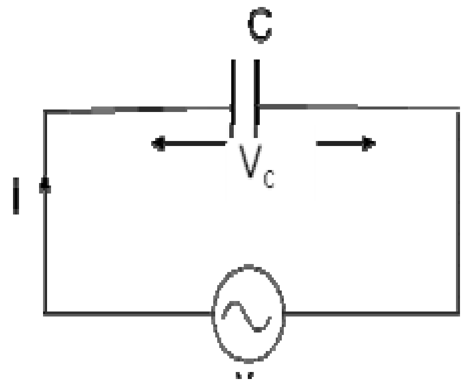
$$I_m = \sqrt{2}I = 14.14A$$

$$\omega = 2\pi f = 314 rad/\sec$$

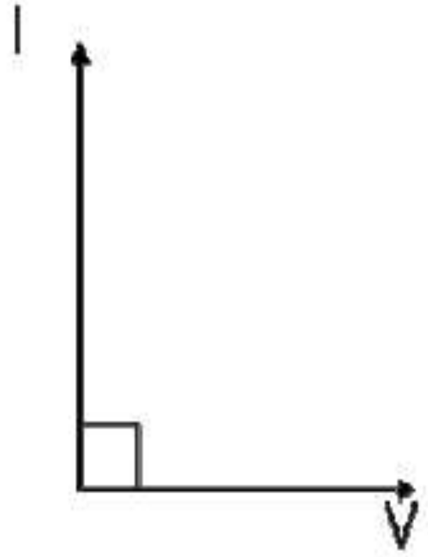
$$v = 325.25 \sin 314t$$

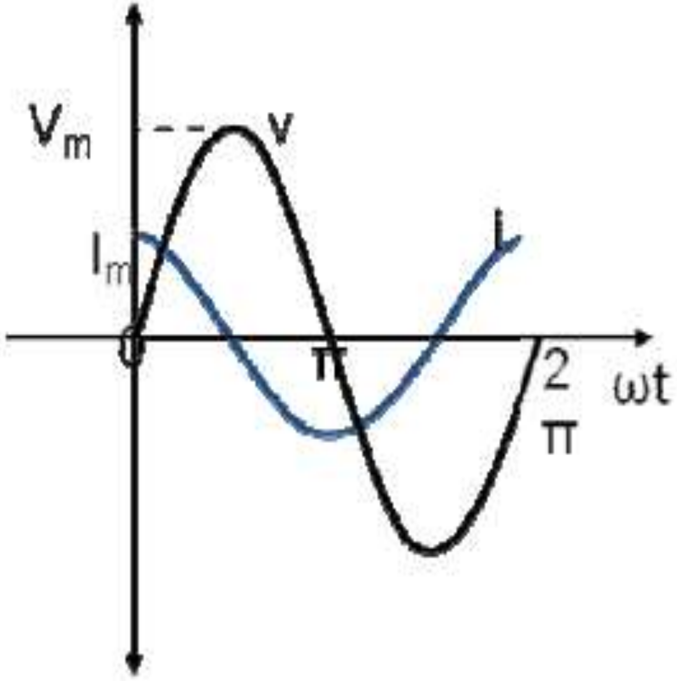
$$i = 14.14 \sin(314t - \pi/2)$$

AC circuit with a pure capacitance



$$v = V_m \sin \omega t$$





$$q = Cv$$

$$q = CV_m \sin \omega t$$

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

$$i = CV_m \omega \cos \omega t$$

$$i = \omega CV_m \sin(\omega t + \pi / 2)$$

$$i = I_m \sin(\omega t + \pi / 2)$$

Where $I_m = \omega CV_m$

AC circuit with a pure capacitance

A 318μF capacitor is connected across a 230V, 50 Hz system. Find (i) the capacitive reactance (ii) rms value of current and (iii) equations for voltage and current.

$$(i) X_C = \frac{1}{2\pi fC} = 10\Omega$$

$$(ii) I = \frac{V}{X_C} = 23A$$

$$(iii) V_m = \sqrt{2}V = 325.27V$$

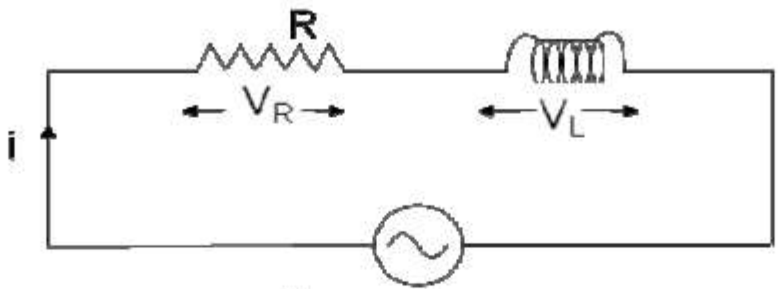
$$I_m = \sqrt{2}I = 32.53A$$

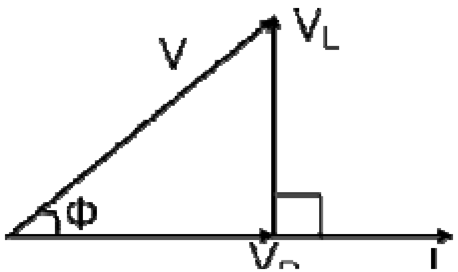
$$\omega = 2\pi f = 314 rad/\sec$$

$$v = 325.25 \sin 314t$$

$$i = 32.53 \sin(314t + \pi/2)$$

R-L Series circuit





From the phasor diagram, the expressions for the resultant voltage V and the angle Φ can be derived as follows.

$$V = \sqrt{V_R^2 + V_L^2}$$

$$V_R = IR$$

$$V_L = IX_L$$

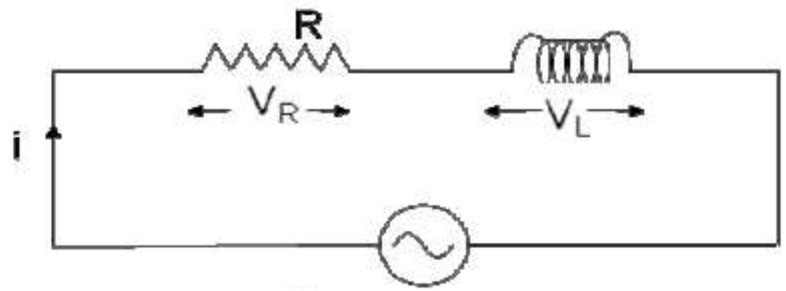
$$V = \sqrt{(IR)^2 + (IX_L)^2}$$

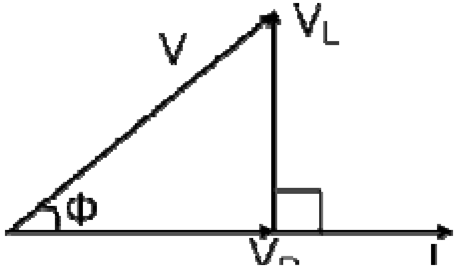
$$V = I\sqrt{R^2 + X_L^2}$$

$$V = IZ$$

Where impedance $Z = \sqrt{R^2 + X_L^2}$

R-L Series circuit





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$$V = I\sqrt{R^2 + X_L^2}$$

$$V = IZ$$

Where impedance $Z = \sqrt{R^2 + X_L^2}$

R-L Series circuit

Phase angle:

$$\Phi = \tan^{-1}\left(\frac{V_L}{V_R}\right)$$

$$\Phi = \tan^{-1}\left(\frac{IX_L}{IR}\right)$$

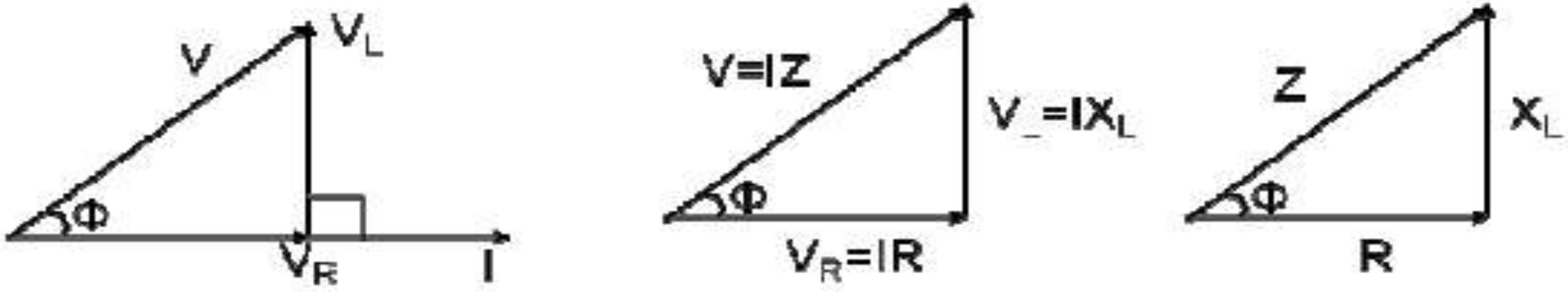
$$\Phi = \tan^{-1}\left(\frac{X_L}{R}\right)$$

$$\Phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$$

Average power:

$$P = VI\cos\Phi$$

R-L Series circuit



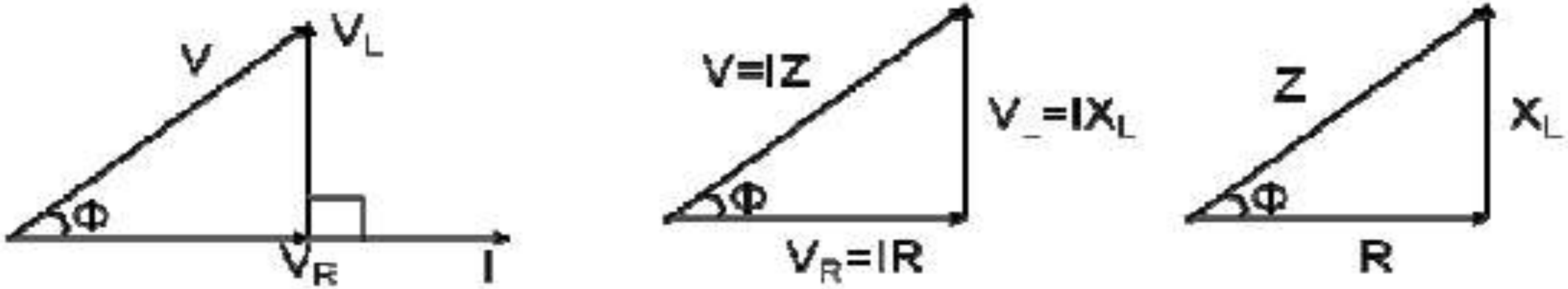
1. Impedance $Z = \sqrt{R^2 + X_L^2}$

2. Power Factor $\cos\Phi = \dfrac{R}{Z}$

3. Phase angle $\Phi = \tan^{-1}\left(\dfrac{X_L}{R}\right)$

4. Whether current leads or lags behind the voltage

R-L Series circuit



1. Impedance $Z = \sqrt{R^2 + X_L^2}$
2. Power Factor $\cos\Phi = \frac{R}{Z}$
3. Phase angle $\Phi = \tan^{-1}\left(\frac{X_L}{R}\right)$
4. Whether current leads or lags behind the voltage

R-L Series circuit

A coil having a resistance of 7Ω and an inductance of 31.8mH is connected to 230V, 50Hz supply. Calculate (i) the circuit current (ii) phase angle (iii) power factor (iv) power consumed

$$X_L = 2\pi fL = 2\times3.14\times50\times31.8\times10^{-3} = 10\Omega$$

$$Z = \sqrt{R^2 + X_L^2} = \sqrt{7^2 + 10^2} = 12.2\Omega$$

$$(i) I = \frac{V}{Z} = \frac{230}{12.2} = 18.85A$$

$$(ii) \phi = \tan^{-1}\left(\frac{X_L}{R}\right) = \tan^{-1}\left(\frac{10}{7}\right) = 55^\circ lag$$

$$(iii) PF = \cos\Phi = \cos(55^\circ) = 0.573 lag$$

$$(iv) P = VI\cos\Phi = 230\times18.85\times0.573 = 2484.24W$$

R-L Series circuit

A 200 V, 50 Hz, inductive circuit takes a current of 10A, lagging 30 degree. Find (i) the resistance (ii) reactance (iii) inductance of the coil

$$Z = \frac{V}{I} = \frac{200}{10} = 20\Omega$$

$$(i) R = Z\cos\phi = 20 \times \cos 30^{\circ} = 17.32\Omega$$

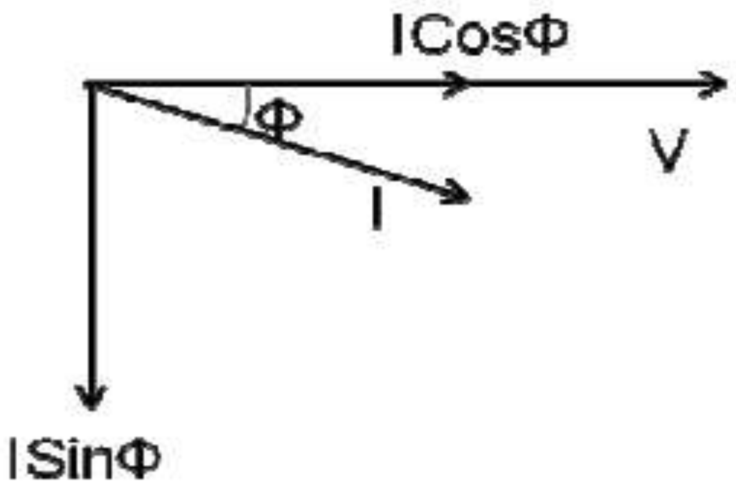
$$(ii) X_L = Z\sin\phi = 20 \times \sin 30^{\circ} = 10\Omega$$

$$(iii) L = \frac{X_L}{2\pi f} = \frac{10}{2 \times 3.14 \times 50} = 0.0318H$$

Power

In an AC circuit, the various powers can be classified as

1. Real or Active power
2. Reactive power
3. Apparent power



Real Power

- The power due to the active component of current is called as the active power or real power. It is denoted by P.

$$P = V \times I\cos\Phi = I^2R$$

- Real power is the power that does useful power. It is the power that is consumed by the resistance.
- The unit for real power in Watt(W).

Reactive Power

- The power due to the reactive component of current is called as the reactive power. It is denoted by Q.

$$Q = V \times I \sin\Phi = I^2 X_L$$

- Reactive power does not do any useful work. It is the circulating power in the L and C components.
- The unit for reactive power is Volt Amperes Reactive (VAR).

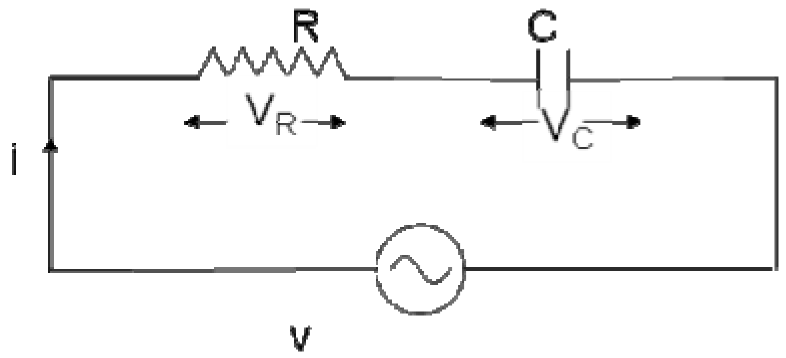
Apparent Power

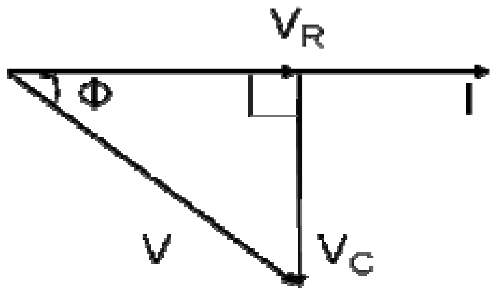
The apparent power is the total power in the circuit. It is denoted by S.

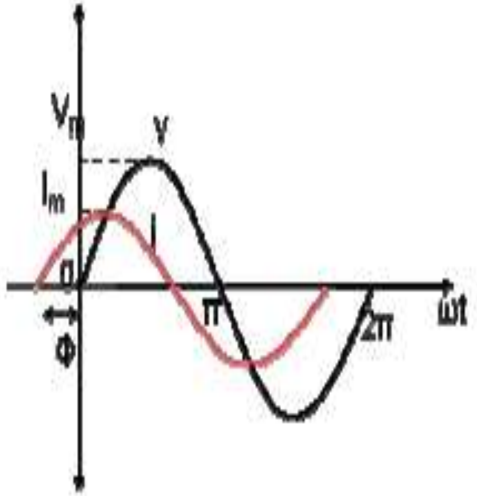
$$S = V \times I = I^2 Z$$

$$S = \sqrt{P^2 + Q^2}$$

R-C Series circuit







$$V = V_m \sin \omega t$$

$$I = I_m \sin(\omega t + \Phi)$$

R-C Series circuit

$$V = \sqrt{V_R^2 + V_C^2}$$

$$V_R = IR$$

$$V_C = IX_C$$

$$V = \sqrt{(IR)^2 + (IX_C)^2}$$

$$V = I\sqrt{R^2 + X_C^2}$$

$$V = IZ$$

Where impedance $Z = \sqrt{R^2 + X_C^2}$

Phase angle

$$\Phi = \tan^{-1}\left(\frac{V_C}{V_R}\right)$$

$$\Phi = \tan^{-1}\left(\frac{IX_C}{IR}\right)$$

$$\Phi = \tan^{-1}\left(\frac{X_C}{R}\right)$$

$$\Phi = \tan^{-1}\left(\frac{1}{\omega CR}\right)$$

R-C Series circuit

A Capacitor of capacitance 79.5μF is connected in series with a non inductive resistance of 30Ω across a 100V, 50Hz supply. Find (i) impedance (ii) current (iii) phase angle (iv) Equation for the instantaneous value of current

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\times3.14\times50\times79.5\times10^{-6}} = 40\Omega$$

$$(i) Z = \sqrt{R^2 + X_C^2} = \sqrt{30^2 + 40^2} = 50\Omega$$

$$(ii) I = \frac{V}{Z} = \frac{100}{50} = 2A$$

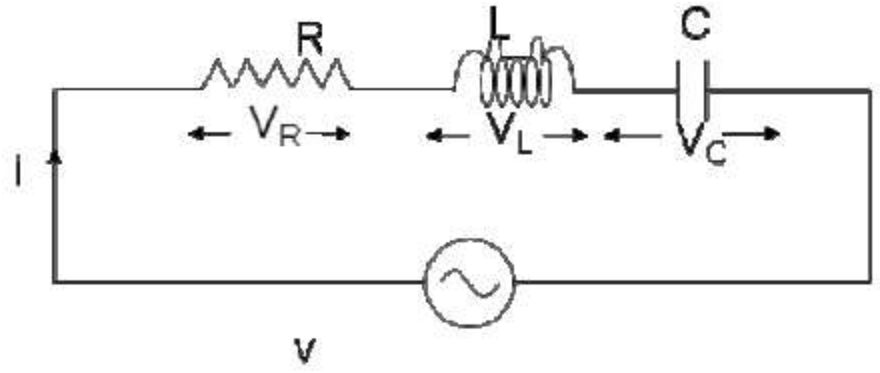
$$(iii) \Phi = \tan^{-1}\left(\frac{X_C}{R}\right) = \tan^{-1}\left(\frac{40}{30}\right) = 53^\circ \, lead$$

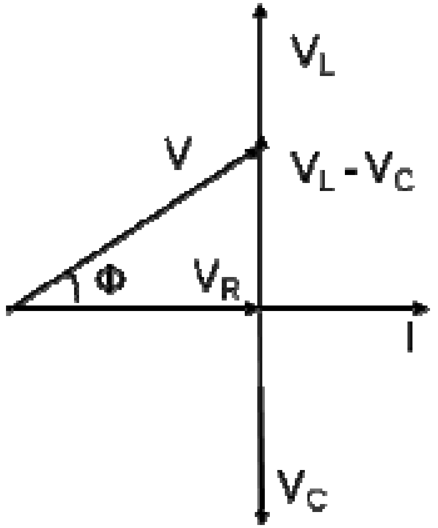
$$(iv) I_m = \sqrt{2}I = \sqrt{2}\times2 = 2.828A$$

$$\omega = 2\pi f = 2\times3.14\times50 = 314 rad/\sec$$

$$i = 2.828\sin(314t + 53^\circ)$$

R-L-C Series circuit





$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$

$$V = \sqrt{(IR)^2 + (IX_L - IX_C)^2}$$

$$V = I\sqrt{R^2 + (X_L - X_C)^2}$$

$$V = IZ$$

Where impedance $Z = \sqrt{R^2 + (X_L - X_C)^2}$

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Phase angle

$$\Phi = \tan^{-1}\left(\frac{V_L - V_C}{V_R}\right)$$

$$\Phi = \tan^{-1}\left(\frac{IX_L - IX_C}{IR}\right)$$

$$\Phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

R-L-C Series circuit

A 230 V, 50 Hz ac supply is applied to a coil of 0.06 H inductance and 2.5 Ω resistance connected in series with a 6.8 μF capacitor. Calculate (i) Impedance (ii) Current (iii) Phase angle between current and voltage (iv) power factor (v) power consumed

$$X_L = 2\pi fL = 2\times3.14\times50\times0.06 = 18.84\Omega$$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\times3.14\times50\times6.8\times10^{-6}} = 468\,\Omega$$

$$(i)Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{2.5^2 + (18.84 - 468)^2} = 449.2\Omega$$

$$(ii)I = \frac{V}{Z} = \frac{230}{449.2} = 0.512\,A$$

$$(iii)\Phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right) = \tan^{-1}\left(\frac{18.84 - 468}{30}\right) = -89.7^\circ$$

$$(iv)\,pf = \cos\Phi = \cos 89.7 = 0.0056\,lead$$

$$(v)P = VI\cos\Phi = 230\times0.512\times0.0056 = 0.66W$$

R-L-C Series circuit

A coil of pf 0.6 is in series with a 100μF capacitor. When connected to a 50Hz supply, the potential difference across the coil is equal to the potential difference across the capacitor. Find the resistance and inductance of the coil.

$\cos\Phi_{coil} = 0.6$
$C = 100\mu F$
$f = 50Hz$
$V_{coil} = V_c$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\times 3.14\times 50\times 100\times 10^{-6}} = 31.83\Omega$$

$$V_{coil} = V_c$$

$$IZ_{coil} = IX_C$$

$$Z_{coil} = X_C = 31.83\Omega$$

$$R = Z_{coil}\cos\Phi_{coil} = 31.83\times 0.6 = 19.09\Omega$$

$$X_L = \sqrt{Z_{coil}^2 - R^2} = \sqrt{31.83^2 - 19.09^2} = 25.46\Omega$$

$$L = \frac{1}{2\pi fL} = \frac{1}{2\times 3.14\times 50\times 25.46} = 0.081H$$

R-L-C Series circuit

A resistance R, an inductance L=0.01 H and a capacitance C are connected in series. When an alternating voltage v=400sin(3000t-20°)is applied to the series combination, the current flowing is $10\sqrt{2}\sin(3000t-65^\circ)$. Find the values of R and C.

$$\Phi = 65^\circ - 20^\circ = 45^\circ \, lag$$

$$X_L = \omega L = 3000 \times 0.01 = 30\Omega$$

$$\tan\Phi = \tan 45^\circ = 1$$

$$\tan\Phi = \frac{X_L - X_C}{R} = 1$$

$$R = X_L - X_C$$

$$Z = \frac{V_m}{I_m} = \frac{400}{10\sqrt{2}} = 28.3\Omega Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + R^2}$$

$$\sqrt{2}R = 28.3$$

$$R = 20\Omega$$

$$X_L - X_C = 20\Omega$$

$$X_C = 30 - 20 = 10\Omega$$

$$C = \frac{1}{\omega X_C} = \frac{1}{3000 \times 10} = 33.3\mu F$$

R-L-C Series circuit

A series RLC circuit is connected across a 50Hz supply. R=100Ω, L=159.16mH and C=63.7μF. If the voltage across C is 150Ļ-90^{0}V. Find the supply voltage

$$X_L = 2\pi fL = 2\times3.14\times50\times159.16\times10^{-3} = 50\Omega$$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\times3.14\times50\times63.7\times10^{-6}} = 50\Omega$$

$$V_C = I(-jX_C) = 150\angle-90^\circ = -j150$$

$$I = \frac{-j150}{-jX_C} = \frac{-j150}{-j50} = 3\angle0^\circ A$$

$$Z = R + j(X_L - X_C) = 100 + j(50-50) = 100\Omega$$

$$V = IZ = 3\times100 = 300V$$