ELECTRICAL CIRCUIT

Course Code : AEEB03
Credits : 4
I B.Tech II Semester
Regulation: IARER-18

SYLLABUS

COURSE - SYLLABUS

SYLLABUS

MODULE -I

INTRODUCTION TO ELECTRICAL CIRCUITS

Circuit concept: Basic definitions, Ohm's law at constant temperature, classifications of elements, R, L, C parameters, independent and dependent sources, voltage and current relationships for passive elements (for different input signals like square, ramp, saw tooth, triangular and complex), temperature dependence of resistance, tolerance, source transformation, Kirchhoff's laws, equivalent resistance

MODULE -II

ANALYSIS OF ELECTRICAL CIRCUITS

Circuit analysis: Star to delta and delta to star transformation, mesh analysis and nodal analysis by Kirchhoff's laws, inspection method, super mesh, super node analysis; Network topology: definitions, incidence matrix, basic tie set and basic cut set matrices for planar networks, duality and dual networks.

MODULE -III

SINGLE PHASE AC CIRCUITS AND RESONANCE

Single phase AC circuits: Representation of alternating quantities, instantaneous, peak, RMS, average, form factor and peak factor for different periodic wave forms, phase and phase difference, ‘j’notation, concept of reactance, impedance, susceptance and admittance, rectangular and polar form, concept of power, real, reactive and complex power, power factor.

Steady state analysis: Steady state analysis of RL, RC and RLC circuits (in series, parallel and series parallel combinations) with sinusoidal excitation; Resonance: Series and parallel resonance, concept of band width and Q factor.

MODULE -IV

MAGNETIC CIRCUITS

Magnetic circuits: Faraday’s laws of electromagnetic induction, concept of self and mutual inductance, dot convention, coefficient of coupling, composite magnetic circuit, analysis of series and parallel magnetic circuits

MODULE -V

NETWORK THEOREMS (DC AND AC)

Network Theorems: Tellegen‟s, superposition, reciprocity, Thevenin‟s, Norton‟s, maximum power transfer, Milliman‟s and compensation theorems for DC and AC excitations, numerical problems..

OBJECTIVES

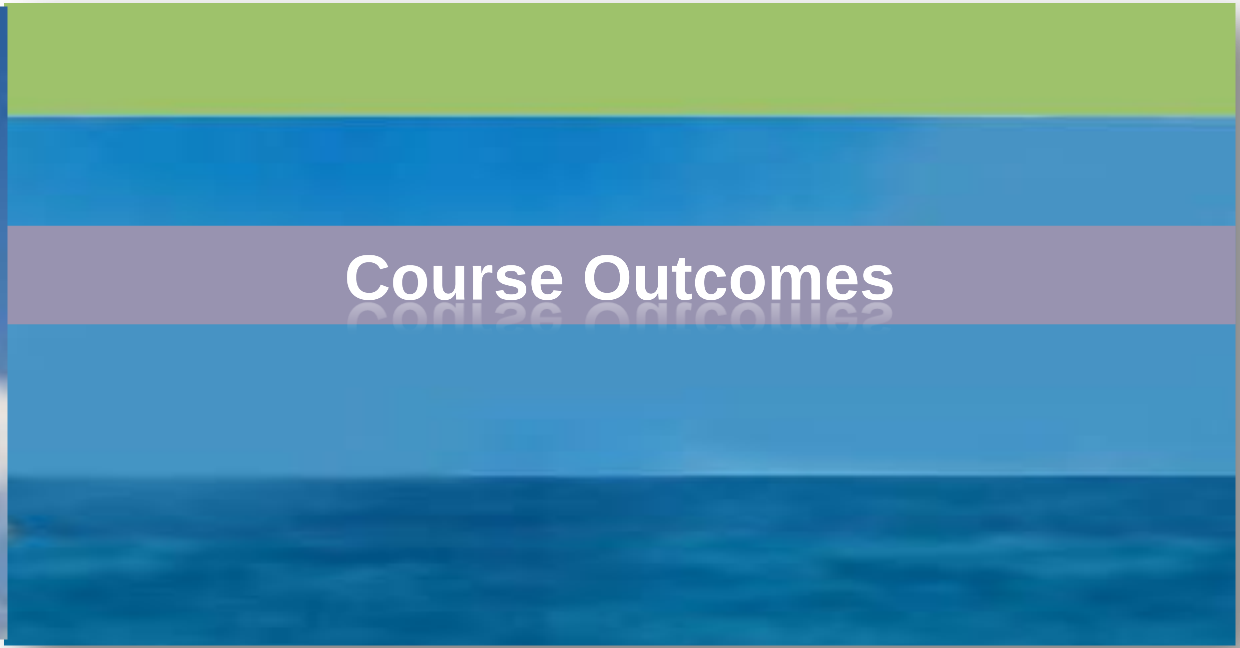
COURSE - OBJECTIVES

OBJECTIVES

The course should enable the students to :

I. Classify circuit parameters and apply Kirchhoff‟s laws for network reduction.
II. Analyze the power in series and parallel AC circuits using complex notation.
III. Illustrate single phase AC circuits and apply steady state analysis to time varying circuits.
IV. Analyze electrical circuits with the help of network theorems.

Course Outcomes



Course Outcomes

COs	Course Outcome
CO 1	Understand and analyze basic AC and DC electrical circuits.
CO 2	Apply mesh analysis and nodal analysis to solve electrical networks. Calculate the two port network parameters.
CO 3	Illustrate single phase AC circuits and apply steady state analysis to time varying circuits.
CO 4	Understand the transient response of series and parallel RL, RC and RLC circuits for DC excitations.
CO 5	Understand the characteristics of complex electrical networks using DC and AC Theorems.

INTRODUCTION

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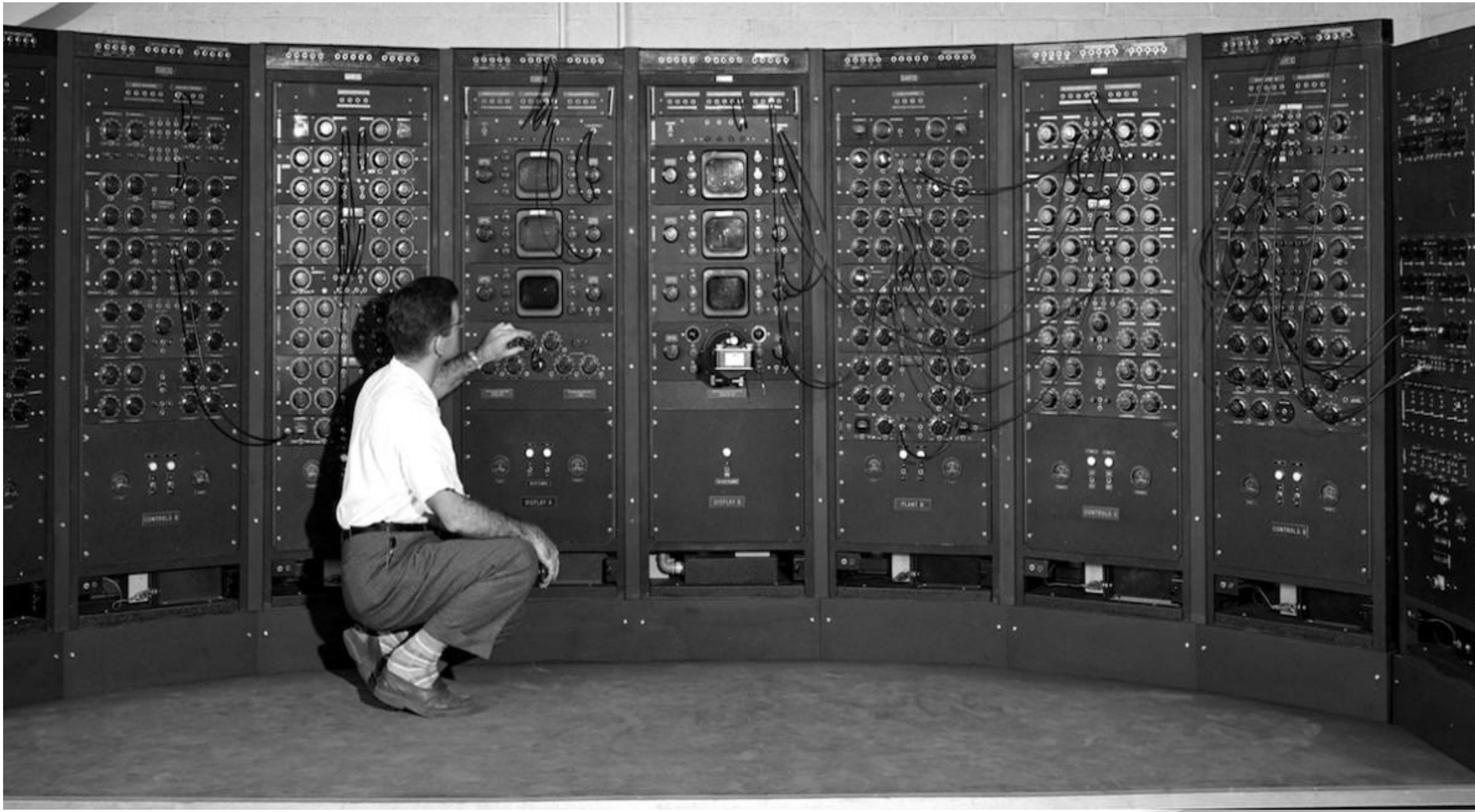
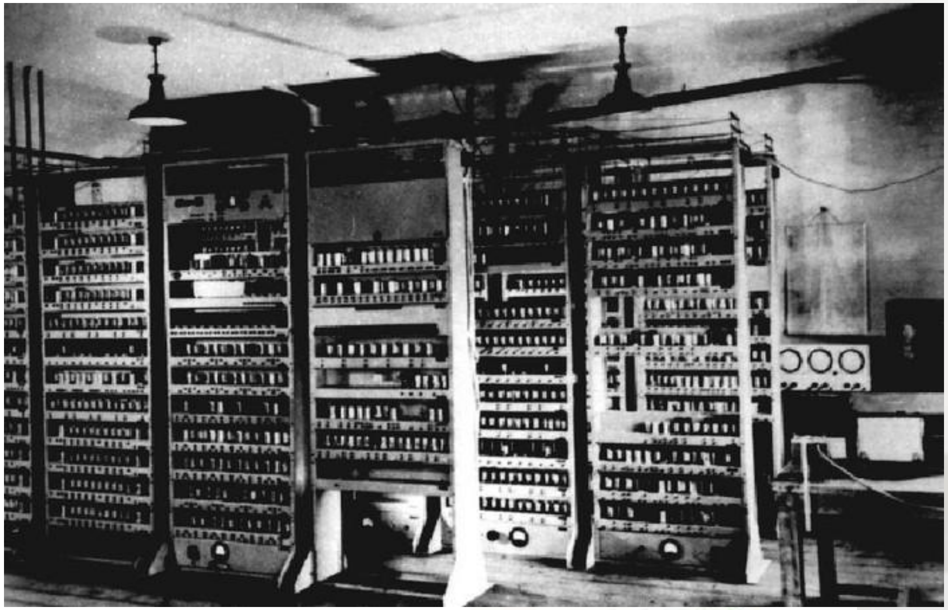
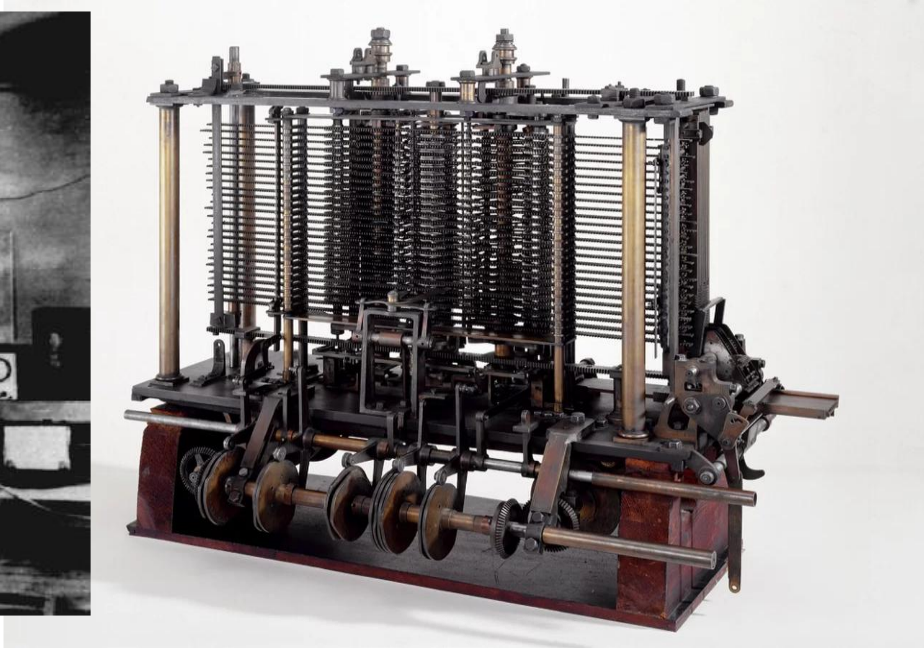


INTRODUCTION





INTRODUCTION

V

VOLTAGE (V)

Home 230V - AC

Controllers 5V to 12V - DC

I

CURRENT (A)

Home - ?A

Controllers - ?A

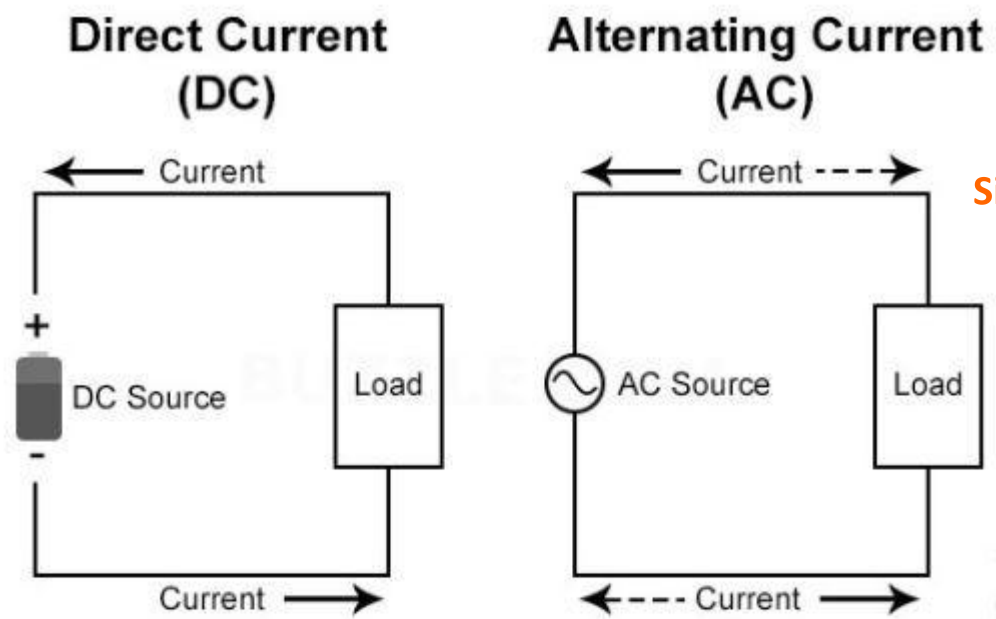
P

POWER (w)

Home - V X I

Controllers – V X I

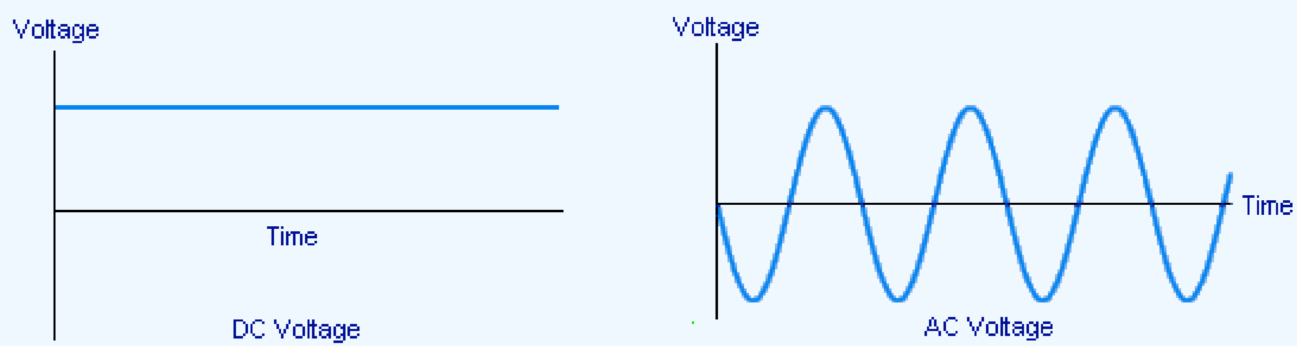
INTRODUCTION



Single Phase 220V

Single Phase 230V

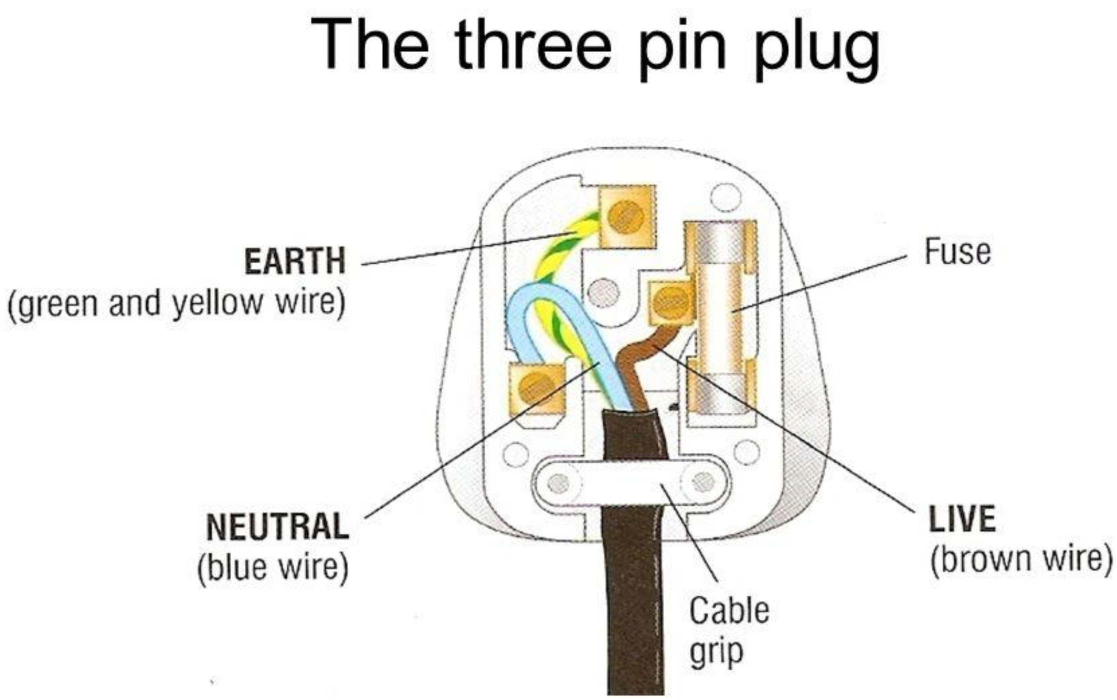
Three Phase 415V



Representation of Visual Difference between DC and AC voltages

INTRODUCTION

INTRODUCTION



MODULE -I

INTRODUCTION TO ELECTRICAL CIRCUITS

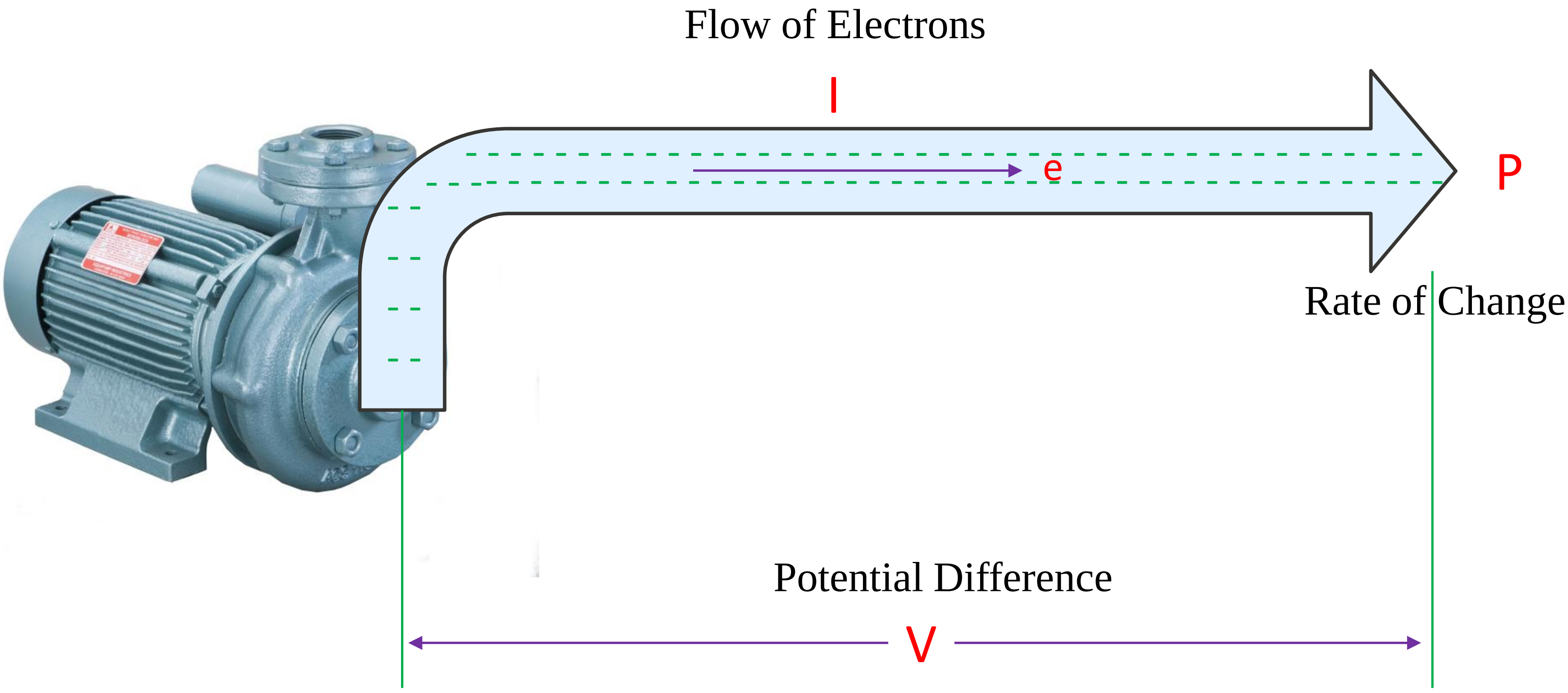
Course Outcomes

CLOs	Course Learning Outcome
CLO 1	Define the various nomenclature used to study the characteristics of DC networks.
CLO 2	Understand the concept of circuit, classification of elements and types of energy sources.
CLO 3	State different laws associated with electrical circuits and apply source transformation technique to determine equivalent resistance and source current.

INTRODUCTION TO ELECTRICAL CIRCUITS

- Basic definitions,
- Ohm’s law at constant temperature,
- Classifications of elements,
- R, L, C parameters,
- Standard symbols for electrical components, Fuses,
- Independent and dependent sources,
- Kirchhoff’s laws,
- Equivalent resistance of series, parallel

Basic Definitions



Basic Definitions

Voltage(V) : The potential difference between force applied to two oppositely charged particles to bring them as near as possible is called as potential difference. (in electrical terminology it's voltage).

A steady voltage can be expressed as $\mathbf{V} = \frac{W}{Q}\ (Volts)$

The time varying voltage can be expressed as $\mathbf{v} = \frac{\mathbf{d}w}{dq}\ (Volts)$

Where W = work done; Q = charge

Basic Definitions

Current(I) : An electric current is the rate of flow of electric charge. or The flow of electrons develops the current.

A steady current can be expressed as $\mathbf{I} = \frac{Q}{T}$ **(Amperes)**

The time varying current can be expressed as $\mathbf{v} = \frac{dq}{dt}$ **(Amperes)**

Where T = time; Q = charge

Basic Definitions

Power(P) : The rate at which electrical energy is converted to other form of energy, qual to the product of current and voltage drop.

Average power is given by $$\mathbf{P} = \frac{W}{T} = \mathbf{VI(watt)}$$

Instantaneous power is given by $$\mathbf{p} = \frac{\mathbf{d}w}{dt}\ \mathbf{(watt)}$$

Where T = time; W = work done

Ohm's law at constant temperature

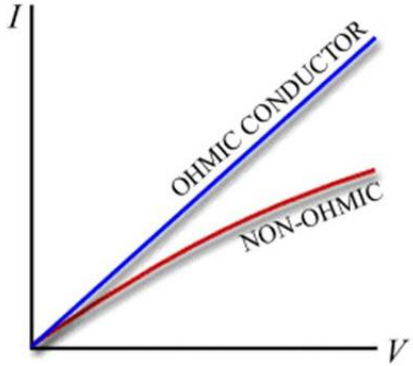
It states that, at constant temperature in an electrical circuit the current (I) flowing through a conductor is directly proportional to potential difference (V) applied.

$$V \propto I \quad \text{or}\ I \propto V \;\Rightarrow V = IR$$

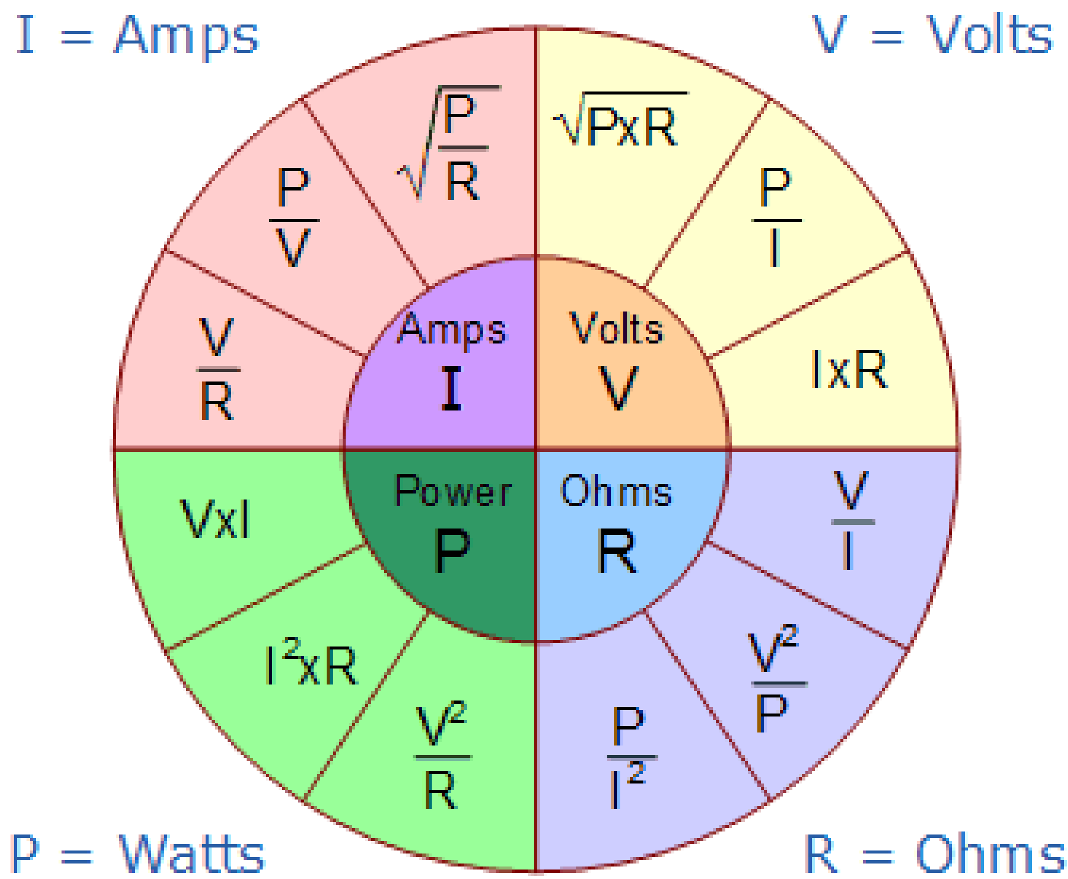
Where R = Resistance of the conductor

Limitations of Ohm's Law

- It is applicable only for metallic conductor such as copper, silver etc.
- It is not applicable for all electrical circuit such semiconductor devices, transistors ect.

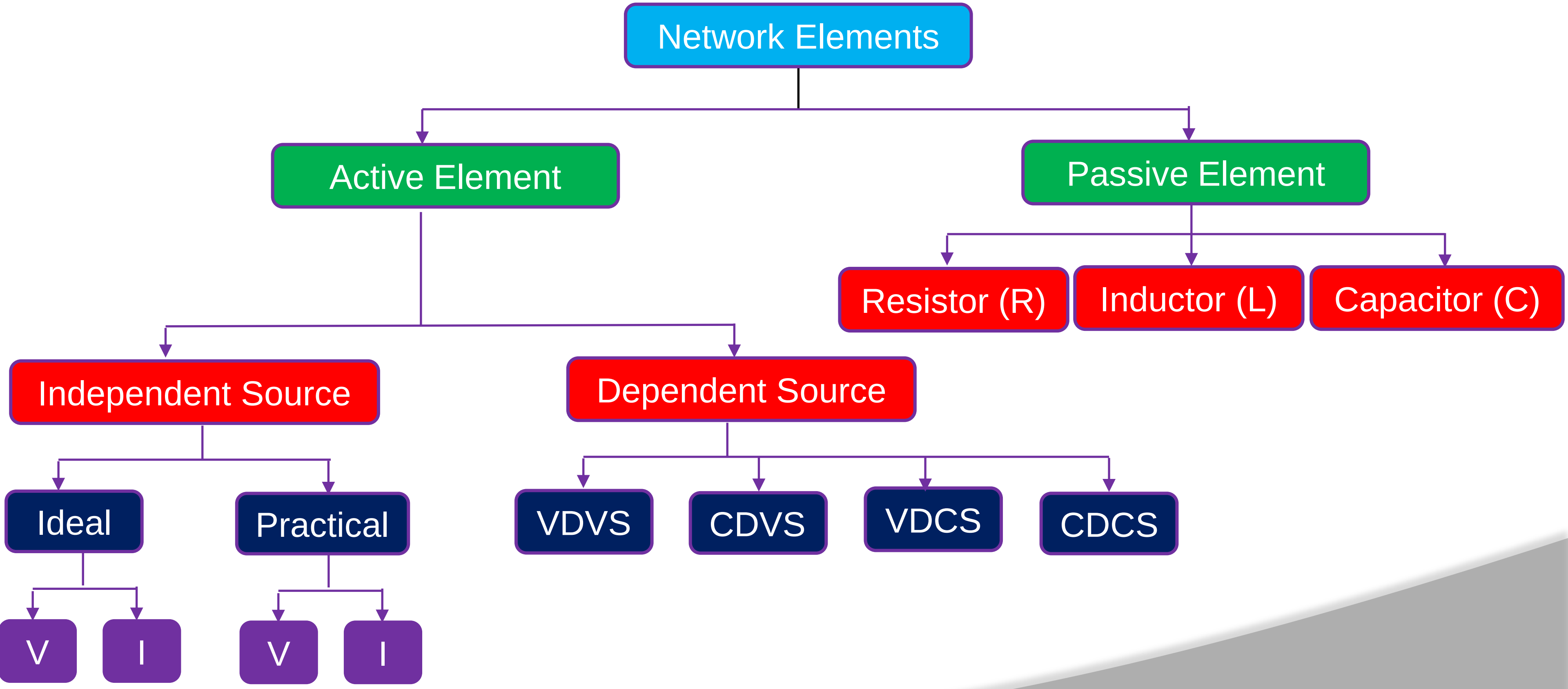


Ohms Law Pie Chart



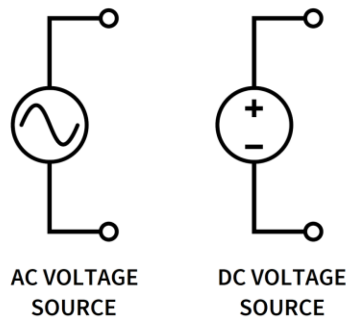
Classifications of Elements

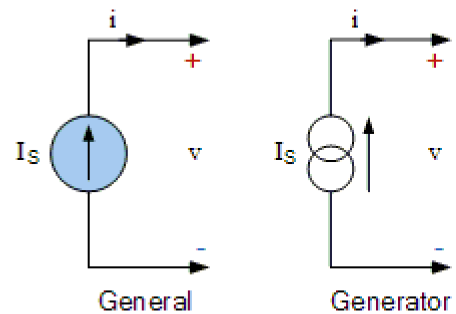
The network elements are the mathematical models of two electric devices which can be characterized by its voltage and current relationship at terminals. These network element can classified as follows.



Classifications of Elements

Active Element : Active elements are the sources of energy or the element which can deliver energy are called active elements.
Example: Voltage source and Current source.





Passive Element : The elements which consume energy either by absorbing or storing are called passive elements.
Example: Resistor, Inductor and Capacitor.

Classifications of Elements

Independent Source : Active elements include independent voltage sources and independent current sources. An independent voltage source maintains (fixed or Varying with time), which is not affected by any other quantity. Similarly an independent current source maintains a current (fixed or time-varying) which is unaffected by any other quantity.

There are two independent energy sources

1. Ideal energy source
   - A. Ideal voltage source
   - B. Ideal current source
2. Practical energy source
   - A. Practical voltage source
   - B. Practical current source

Classifications of Elements

The electrical sources are those devices which provide active power to a circuit. There is two type of sources available in electrical networks, a voltage source or current source. The purpose of the voltage source is to provide voltage rather than the current and current source is to provide current rather voltage. Each source is then categorized as an ideal or practical source.

Ideal sources are those imaginary electrical sources which provide constant voltage or current to the circuit regardless of the load current. These ideal sources don't have any internal resistance. Where it is impossible to build a source with zero internal resistance. So, all the real sources are called **practical sources**.

Classifications of Elements

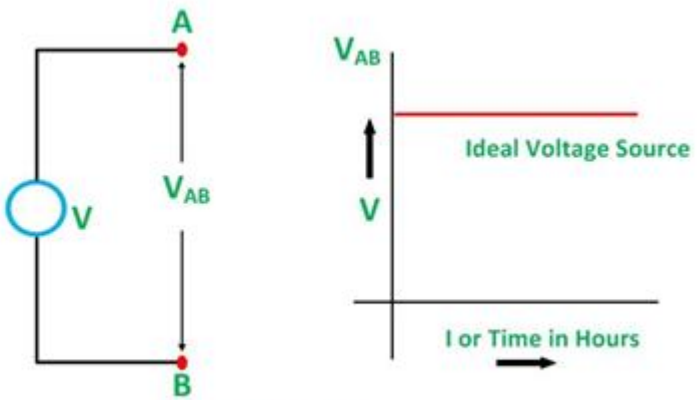


Figure A

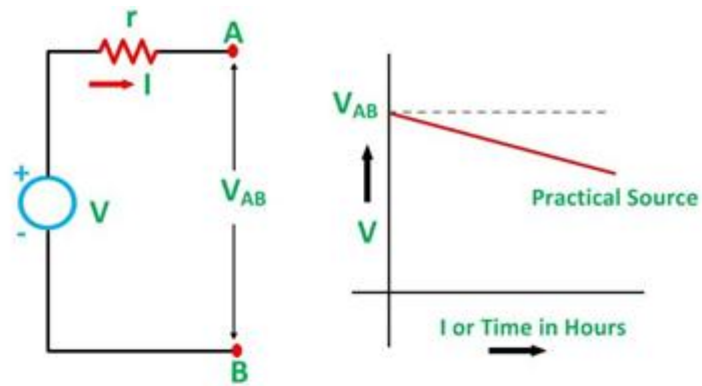


Figure B

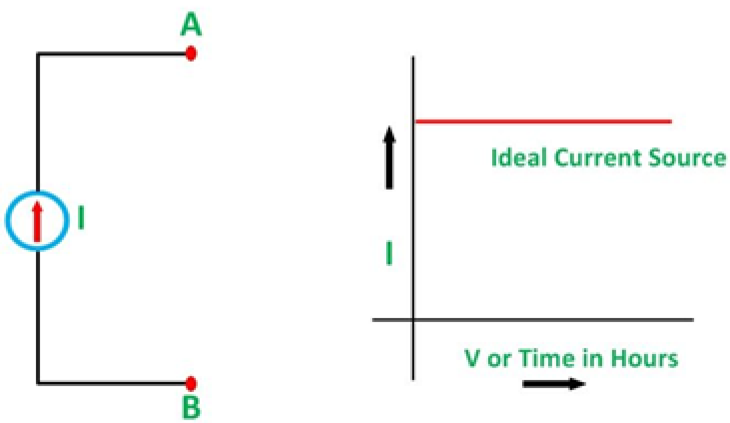


Figure C

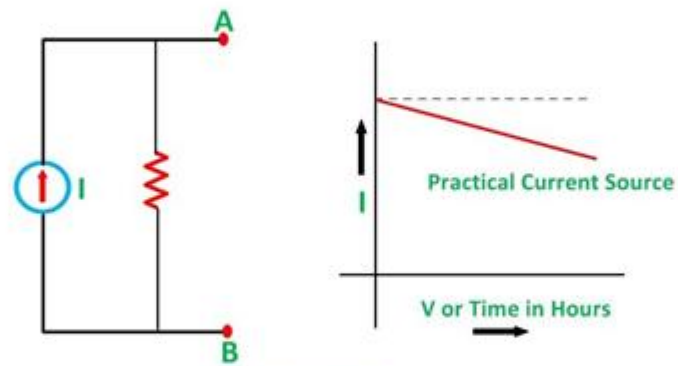


Figure D

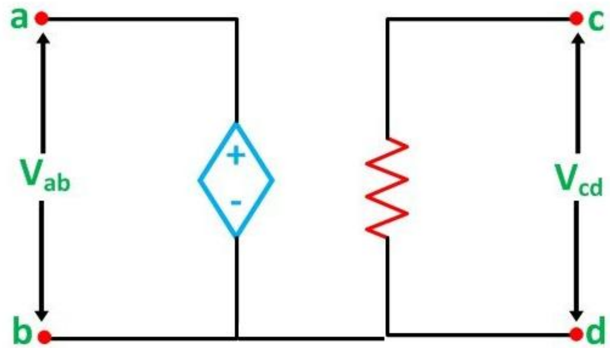
Classifications of Elements

Dependent Source : Active elements include dependent voltage sources and dependent current sources. 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. They are four terminal devices. When the strength of voltage or current changes in the source for any change in the connected network, they are called dependent sources. The dependent sources are represented by a diamond shape.

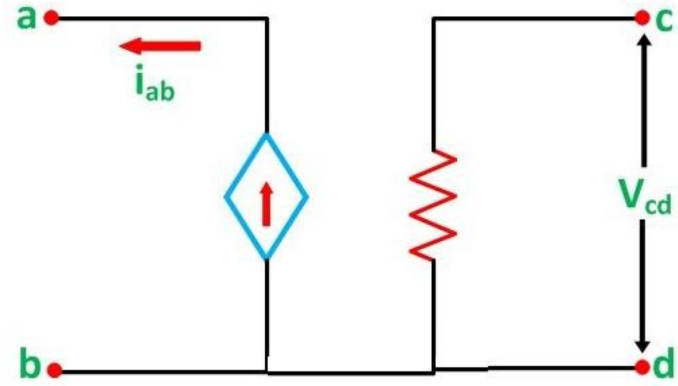
The dependent sources are further categorized as

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

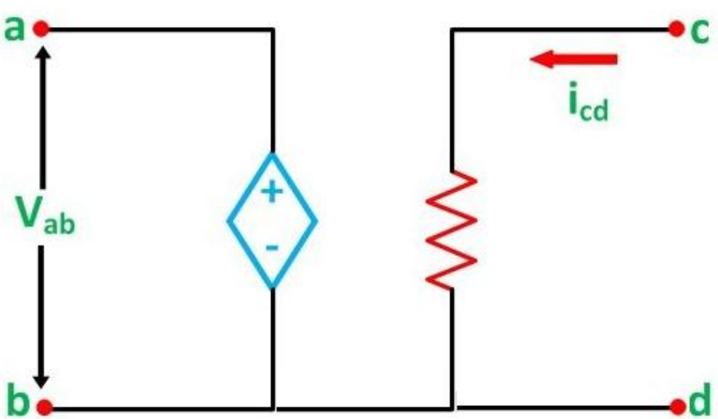
Classifications of Elements



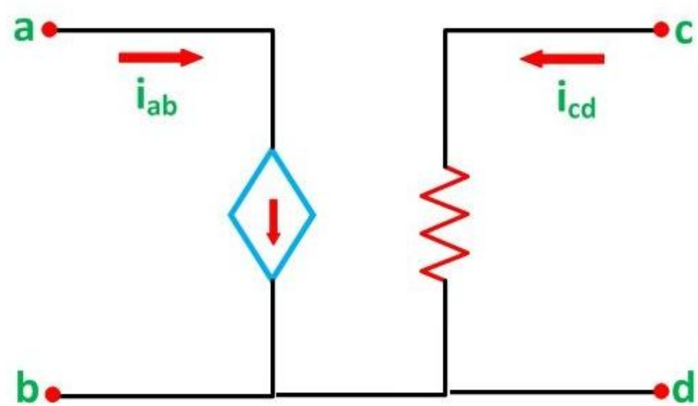
$$V_{ab} \propto V_{cd} \quad \text{or}$$
$$V_{ab} = kV_{cd}$$



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

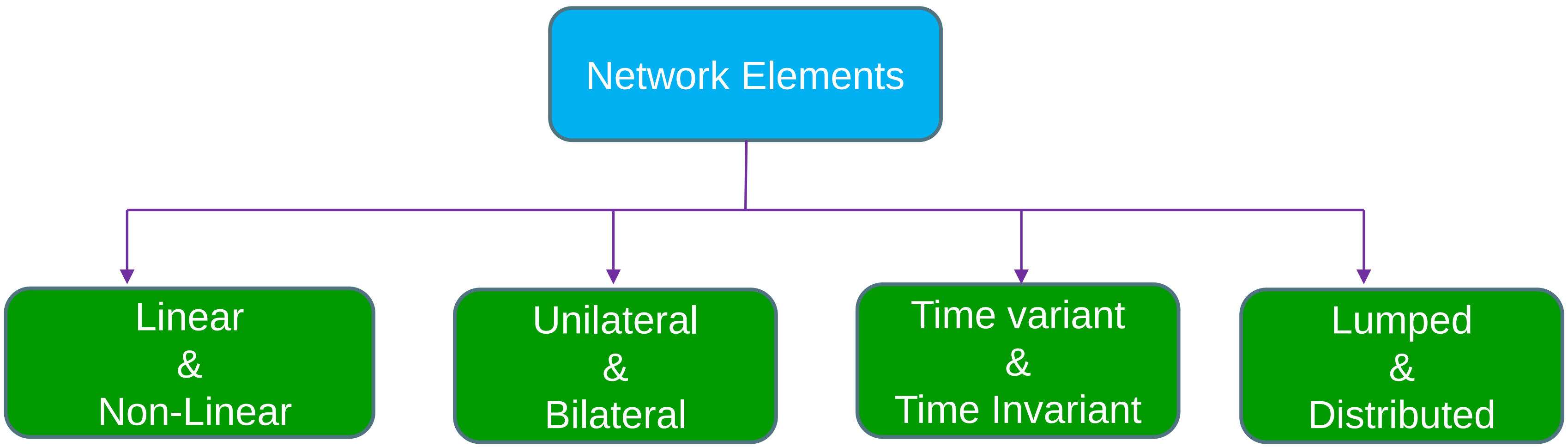


$$V_{ab} \propto i_{cd}$$
$$V_{ab} = r\, i_{cd}$$



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

Classifications of Elements



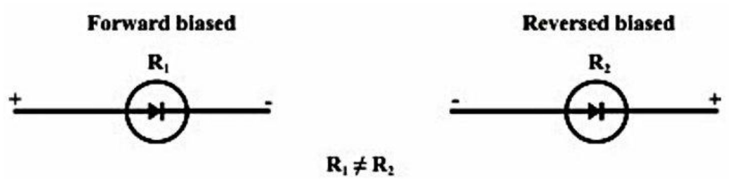
Classifications of Elements

Linear & Non-Linear : A circuit is said to be **linear** if it satisfies the relationship between voltage and current (i.e., OHM's Law).
Example : Resistor, Inductor and Capacitor

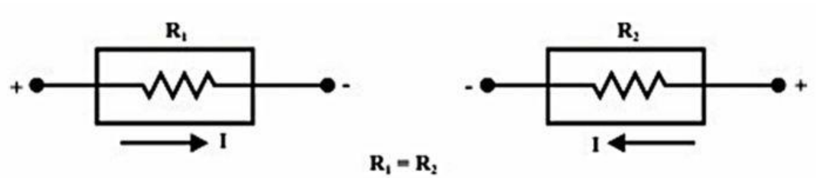
If an element does not satisfy the OHM's Law relation, then it is called a **non linear element.**
Example : Diodes, transistors, thermistors etc.

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

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

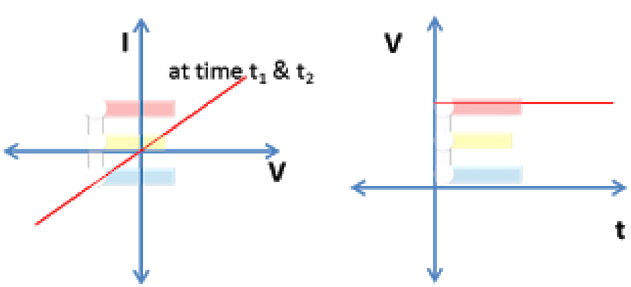


Bilateral Element

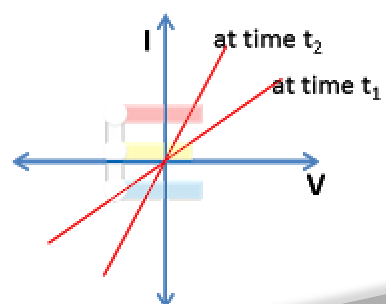
Classifications of Elements

Time Invariant : An element or a system is said to be time invariant if parameters of the element do not vary with time. For example a resistor is a time invariant element whose value of resistance R or any response by it remains same irrespective of the instant of time when the voltage or current is applied to it. Its value may change with change with change in voltage or current like in a non-linear resistor but still it is called as a time invariant element as long as its response won't with respect to time.

Time variant : The parameters of the time variant are not constant with respect to time and may change with change in the instant of time. The given below graph shows the example of V-I characteristics of a time variant element in which the slope of the characteristic of same element is higher at time t2 than at time t1.



Time Invariant



Time variant

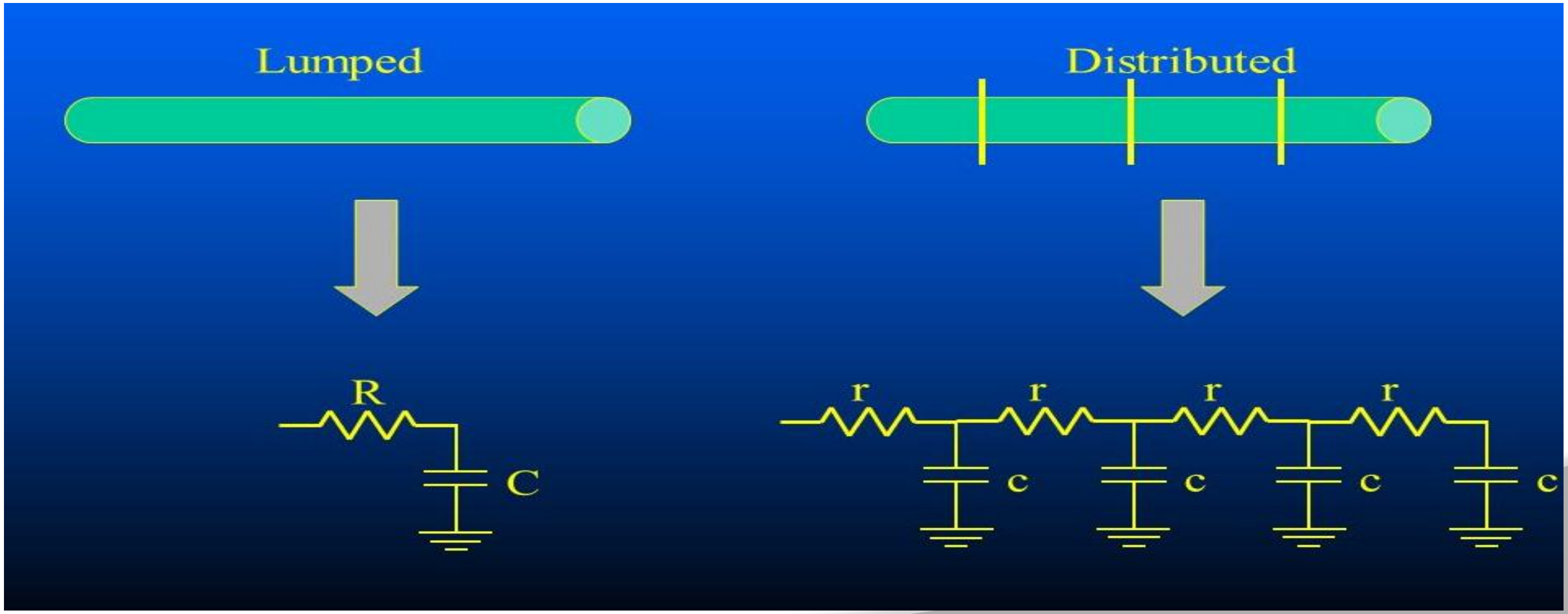
Classifications of Elements

Lumped Elements : The elements which are physically separable are called Lumped Elements.

Example: Resistor, Inductor, Capacitor.

Distributed Elements : The elements which are physically un- separable are called Distributed Elements.

Example: Transmission Line, which has distributed resistance, inductance and Capacitance along its length.



R, L, C Parameters

Resistor (R) : A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses.

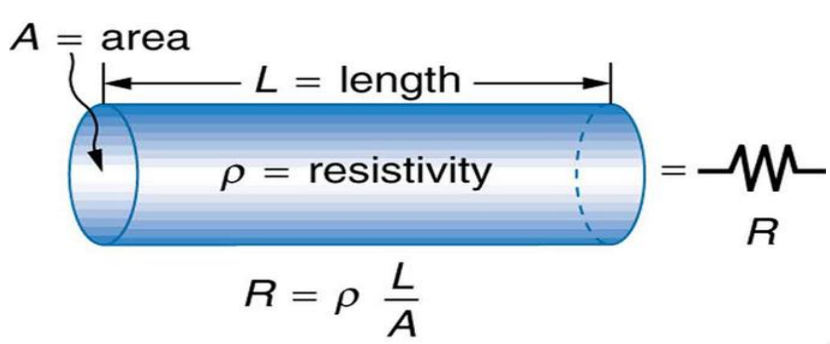
Resistance : Resistance is nothing but this property of resisting the flow of electrons or the current. The unit of resistance is **ohm (Ω)** . One ohm is equal to volt per ampere.

From Ohm's law, we have seen that $R = \frac{V}{I}$

Where V is the voltage and I is the current.

$$V = IR$$

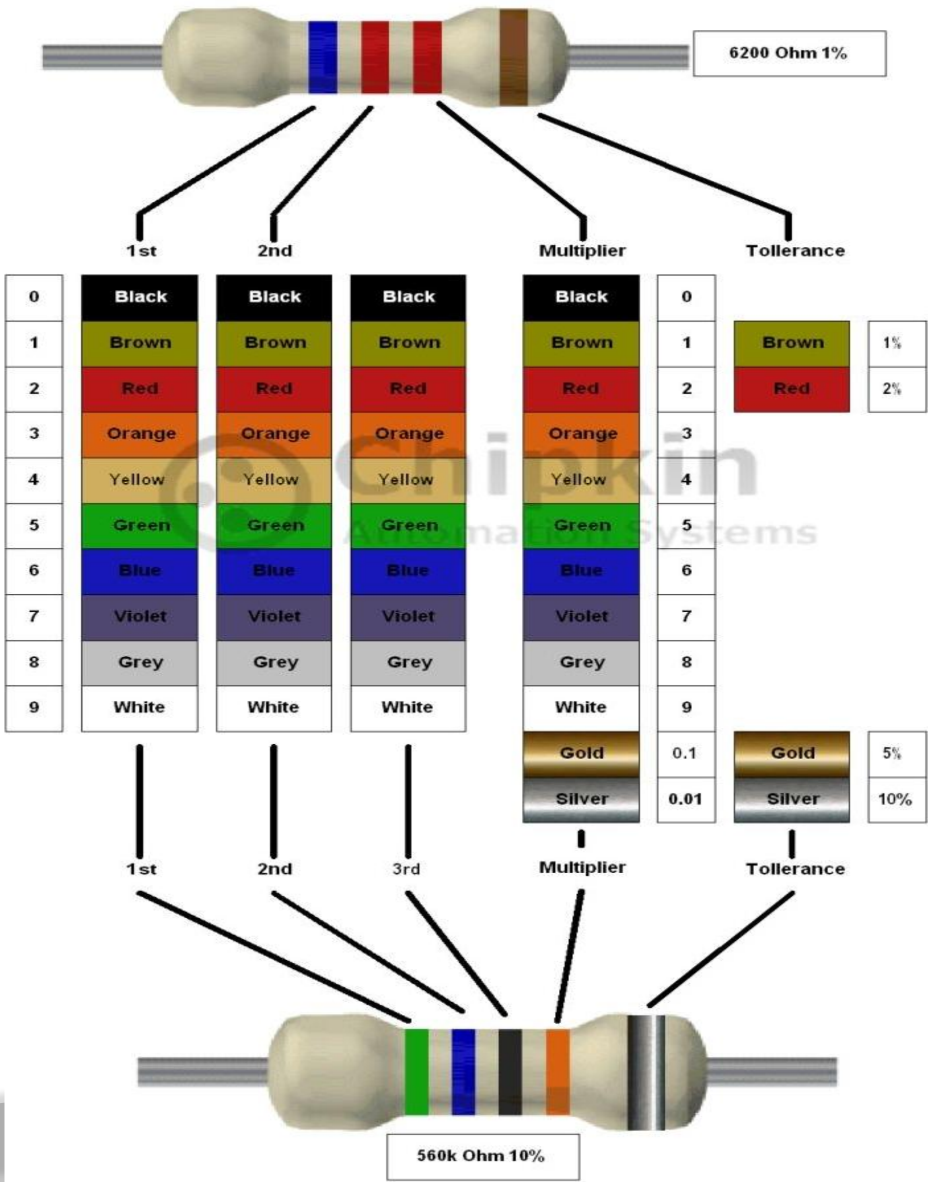
$$\mathrm{I} = \frac{V}{R}$$



R, L, C Parameters

Resistor Color Codes :

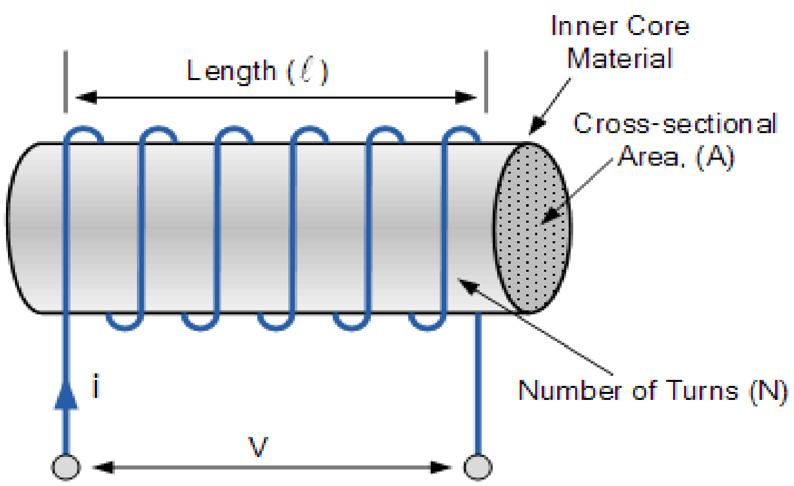
Color	Color	Value	Multiplier	Tolerance
	Black	0	X 1	N/A
	Brown	1	X 10	N/A
	Red	2	X 100	2%
	Orange	3	X 1000	N/A
	Yellow	4	X 10000	N/A
	Green	5	X 100000	N/A
	Blue	6	X 1000000	N/A
	Violet	7	X 10000000	N/A
	Gray	8	X 100000000	N/A
	White	9	X 1000000000	N/A
	Gold	N/A	X 0.1	5%
	Silver	N/A	X 0.01	10%



R, L, C Parameters

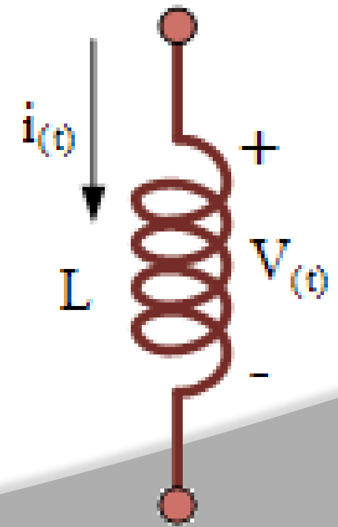
Inductor (L) : An **inductor**, also called a **coil**, **choke**, or **reactor**, is a passive two-terminal electrical component that stores energy in a magnetic field when electric current flows through it. An inductor typically consists of an insulated wire wound into a coil around a core.

The **inductance** is directly proportional to the number of turns in the coil. Inductance also depends on the radius of the coil and on the type of material around which the coil is wound. The units of Inductance is **Henry** (**H**).



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

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



R, L, C Parameters

Inductor (L)

Inductors do not have a stable "resistance" as conductors do. However, there is a definite mathematical relationship between voltage and current for an inductor is

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

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

Where V = Instantaneous Voltage across the Inductor

L = Inductance in Henrys

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

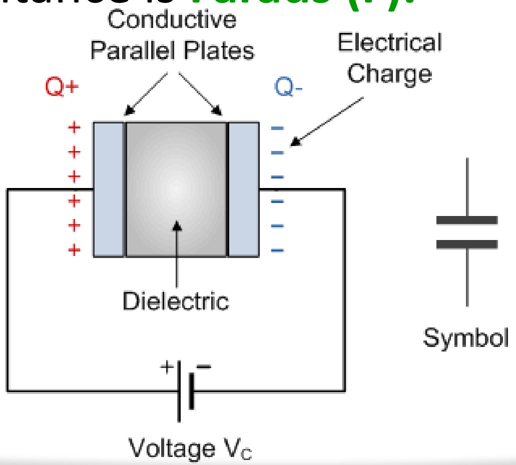
Applications: Filters, Sensors, Transformers, Motors, Energy Storage etc.

R, L, C Parameters

Capacitor (C) : The capacitor is a component which has the ability or "capacity" to store energy in the form of an electrical charge producing a potential difference (*Static Voltage*) across its plates, much like a small rechargeable battery.

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).**



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

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

R, L, C Parameters

Capacitor (C) : Capacitors do not have a stable "resistance" as conductors do. However, there is a definite mathematical relationship between voltage and current for Capacitor is

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

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

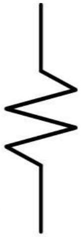
Where I = Instantaneous Current through the capacitor

L = Capacitance in Farads

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

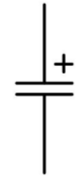
Applications: Filters, Sensors, Energy Storage etc

Standard Symbols for Electrical Components

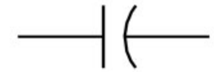



RESISTOR

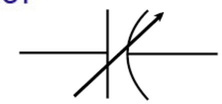

Variable Resistor or Potentiometer

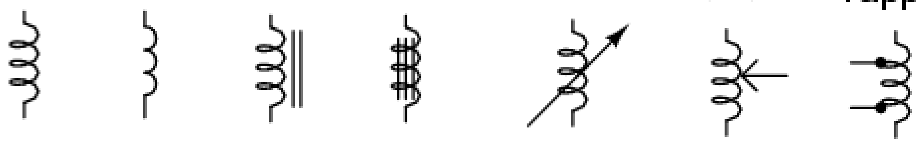
CAPACITOR



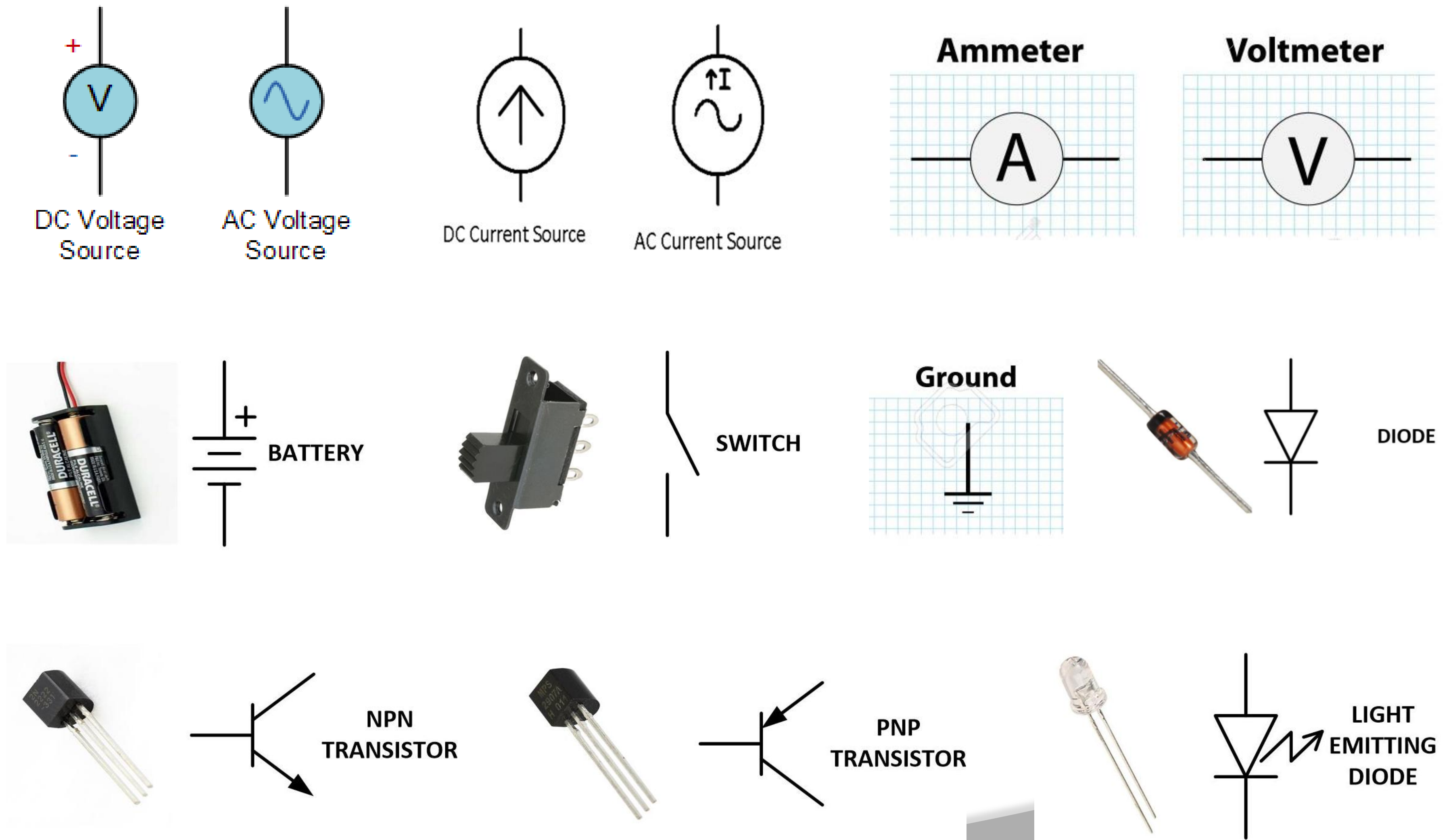
Capacitor



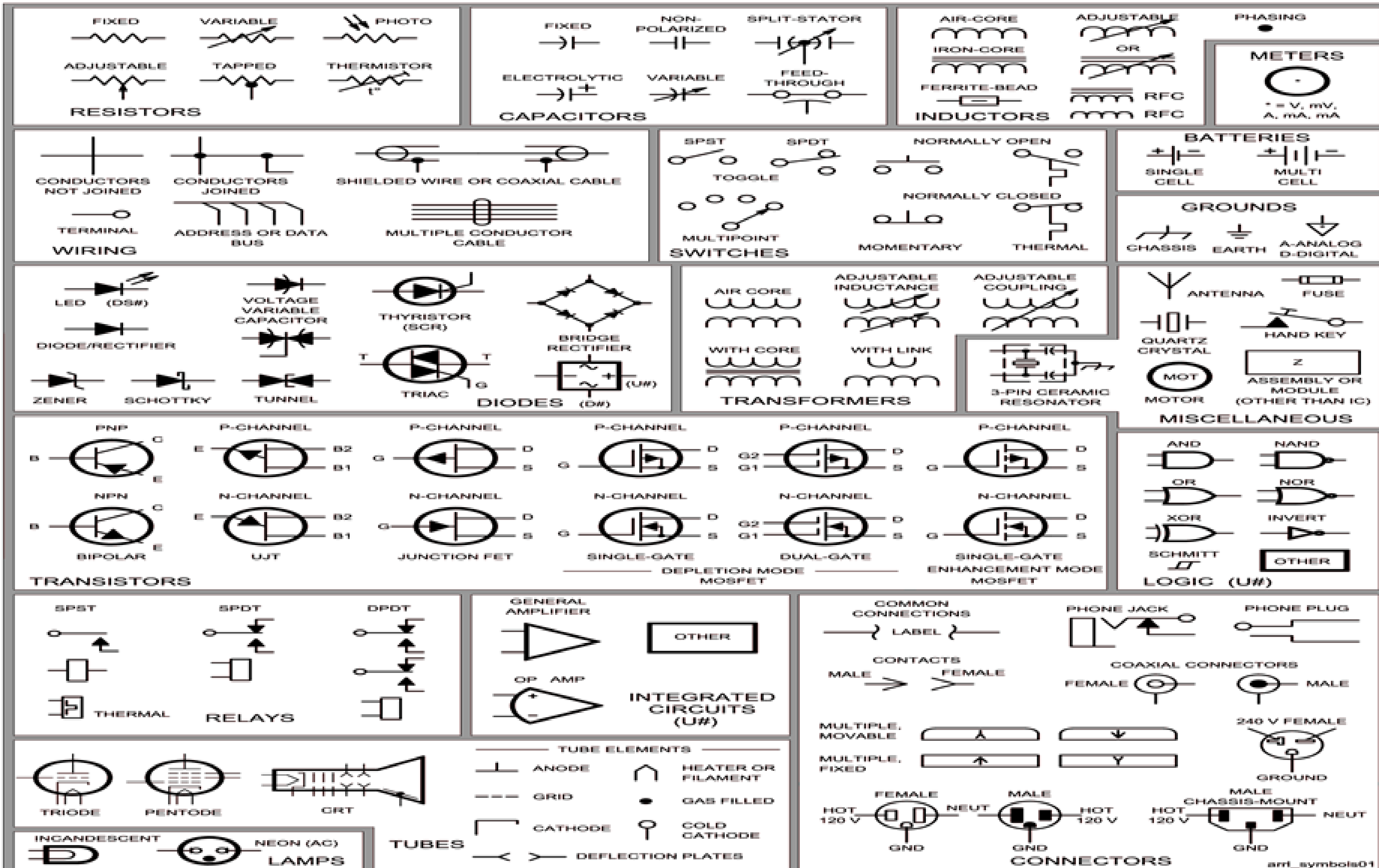
Fixed-value Iron core Variable Variac Tapped



Standard Symbols for Electrical Components



Standard Symbols for Electrical Components



Fuses

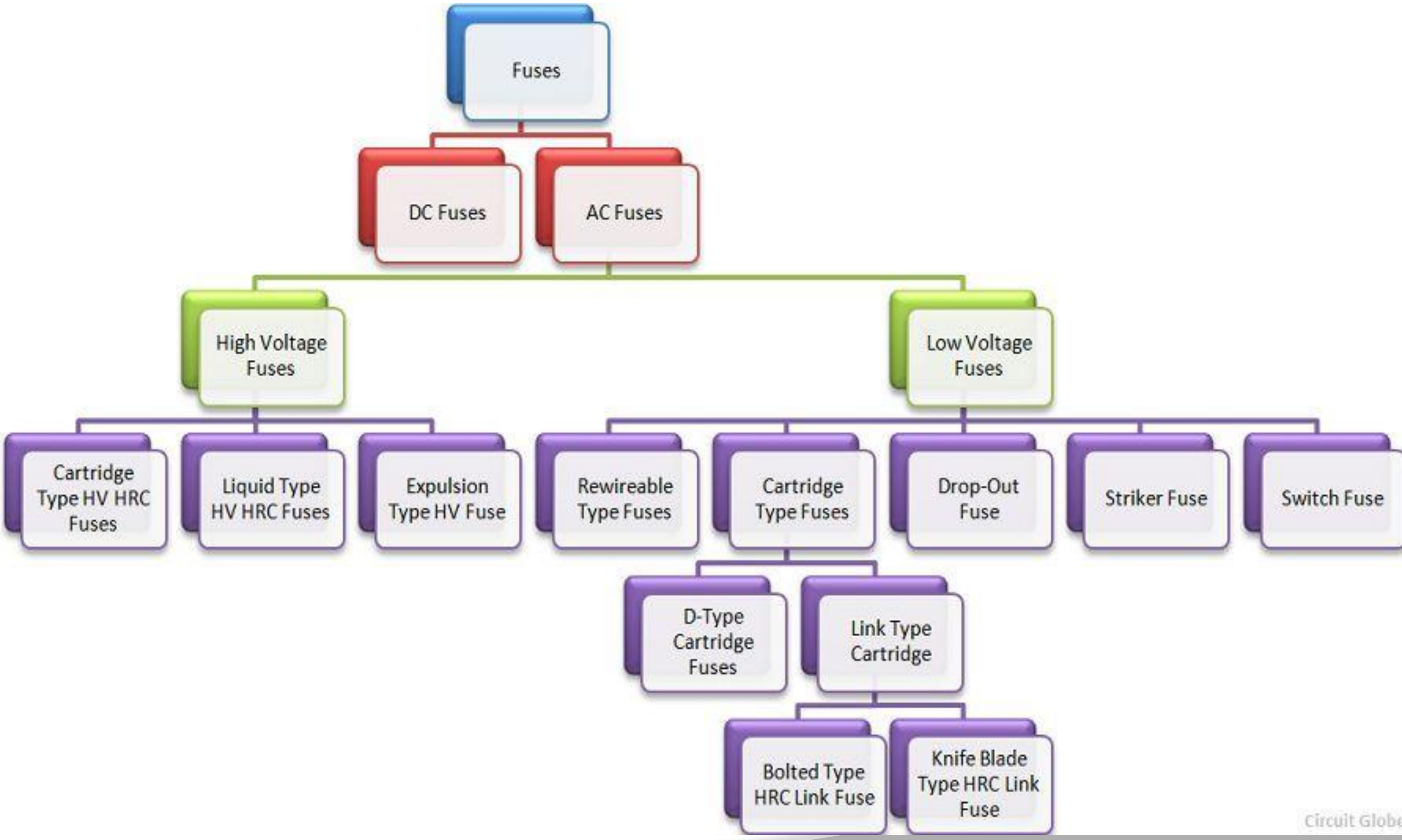
The fuse is the current interrupting devices which break or open the circuit by fusing the element and thus remove the faulty device from the main supply circuit.

If we use a fuse in the homes, the electrical faults cannot happen in the wiring and it doesn't damage the appliances from the fire of wire burning. When the fuse gets break or damage, then sudden sparkle happens which may direct to damage your home appliances. That is the reason we require different types of fuses to guard our home-appliances against damage. The fuses are mainly classified into two types, depends on the input supply voltages they are the AC fuses and the DC fuses.

The working principle of the fuse is "heating consequence of the current". It is fabricated with a lean strip or thread of metallic wire. The connection of the Fuse in an electrical circuit is always in series.

Fuse rating = (power (watts)/voltage (volts)) x 1.25

Fuses


Fuses
DC Fuses
AC Fuses
High Voltage Fuses
Low Voltage Fuses
Cartridge Type HV HRC Fuses
Liquid Type HV HRC Fuses
Expulsion Type HV Fuse
Rewireable Type Fuses
Cartridge Type Fuses
Drop-Out Fuse
Striker Fuse
Switch Fuse
D-Type Cartridge Fuses
Link Type Cartridge
Bolted Type HRC Link Fuse
Knife Blade Type HRC Link Fuse
Circuit Globe

Fuses

LV Fuses

Rewireable Fuses

Cartridge type Fuses

D-type Cartridge Fuse

Link Type Fuse

Blade and Bolted type Fuses

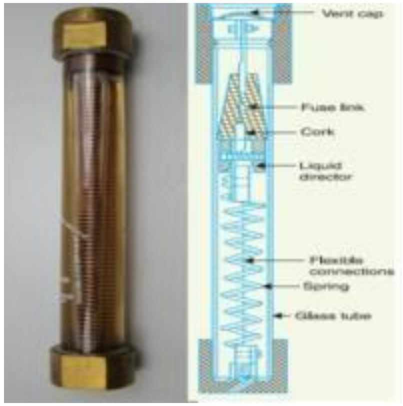
Striker type Fuse

Switch type Fuse

Fuses

HV (High Voltage) Fuses

Cartridge Type HRC Fuse



Liquid Type HRC Fuse

Expulsion Type HV Fuse

Fuses

Applications of Different Types of Fuses

- Power Transformers
- Electrical Appliances, like ACs (Air Conditioners), TV, Washing Machines, Music Systems, and many more.
- Electrical Cabling in Home
- Mobile Phones
- Motor starters
- Laptops
- Power Chargers
- Cameras, Scanners, Printers, and Photocopiers
- Automobiles, electronic devices etc.

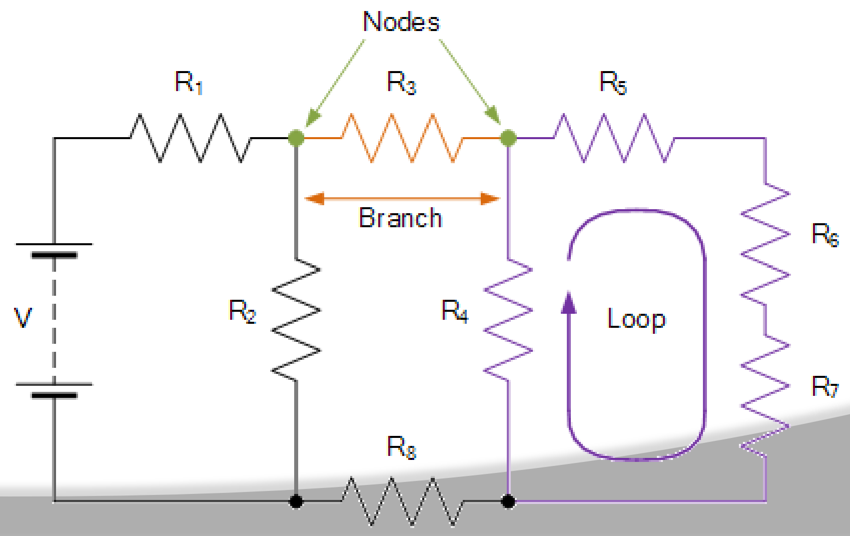
Node, Branch and Closed path

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.

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.

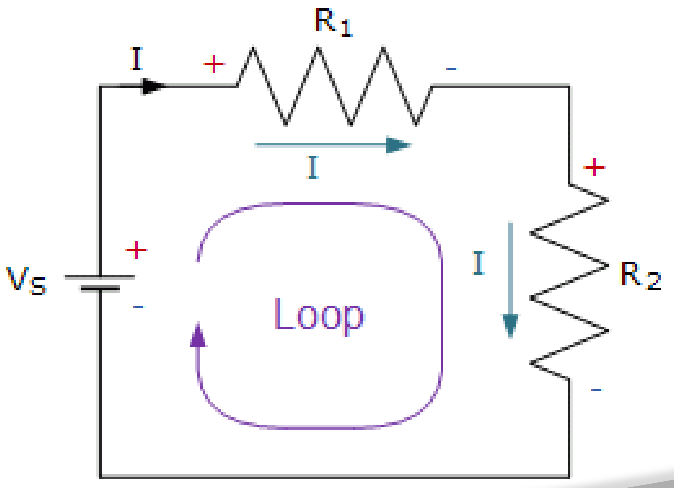
$$b = l + n - 1$$



Kirchhoff's laws

In 1845, German physicist Gustav Kirchhoff was described relationship of two quantities in Current and potential difference (Voltage) inside a circuit. This relationship or rule is called as Kirchhoff's circuit Law.

Kirchhoff's Circuit Law consist two laws, Kirchhoff's First law - which is related with current flowing, inside a closed circuit and called as Kirchhoff's current law (KCL) and the other one is Kirchhoff's Second law which is to deal with the voltage sources of the circuit, known as Kirchhoff's voltage law (KVL).

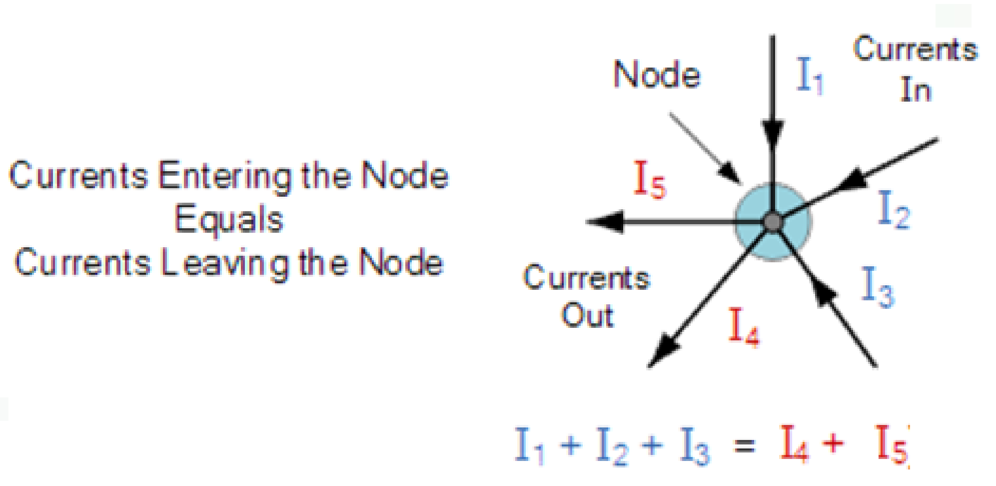


Kirchhoff’s laws

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 as it has no other place to go except to leave, as no charge is lost within 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.

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

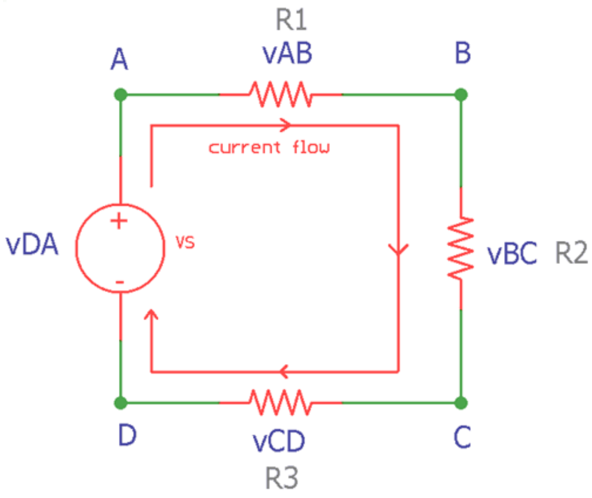


$$I_1 + I_2 + I_3 - I_4 - I_5 = 0$$

Kirchhoff's laws

Kirchhoffs Second Law – The Voltage Law, (KVL)

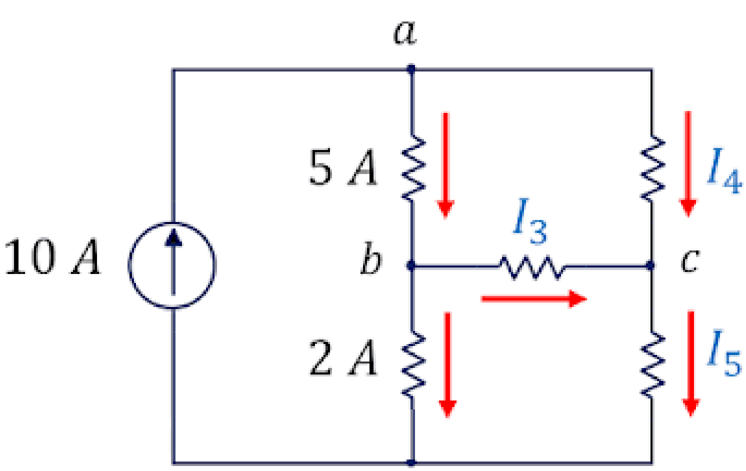
Kirchhoffs Voltage Law, states that "in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop" which is also equal to zero. In other words the algebraic sum of all voltages within the loop must be equal to zero. This idea by Kirchhoff is known as the Conservation of Energy.

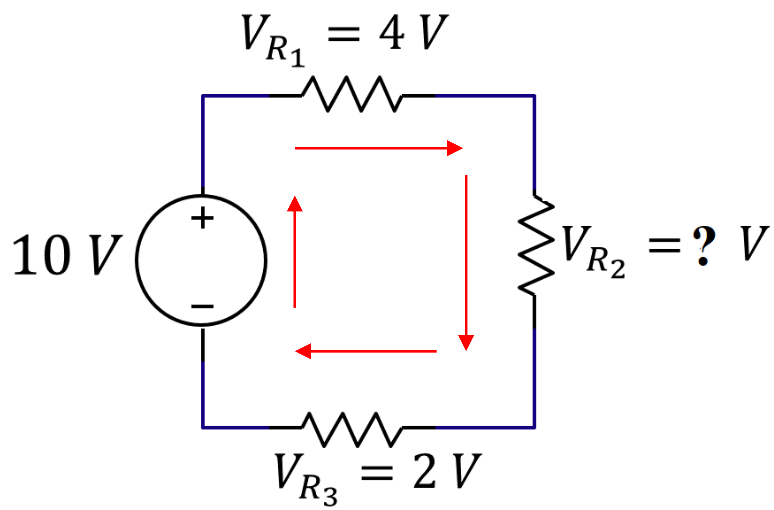


vAB + vBC + vCD – vDA = 0

The voltage source (between D and A) is –vDA. Due to the clockwise current flow, the voltage source is reversed, and due to that reason, it is negative in value.

Kirchhoff's laws





At Node 'a' 10A =5A+I_4 ; I_4=5A

At Node 'b' 5A =2A+I_3 ; I_3=3A

At Node 'c' 5A +3A =I_5 ; I_5=8A

We have only one Loop

$V_{R1} + V_{R2} + V_{R3} - 10V = 0$

$4V + V_{R2} + 2V - 10V = 0$

$V_{R2} = 4V$

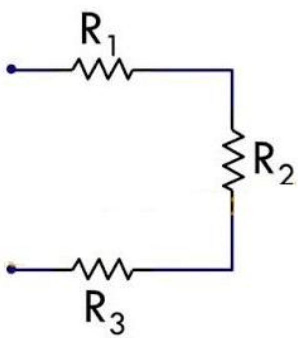
Equivalent resistance of series, parallel

Resistor circuits that combine series and parallel resistors networks together are generally known as Resistor Combination or mixed resistor circuits.

The method of calculating the circuits equivalent resistance is the same as that for any individual series or parallel circuit and that resistors in series carry the same current and that resistors in parallel have the same voltage across them.

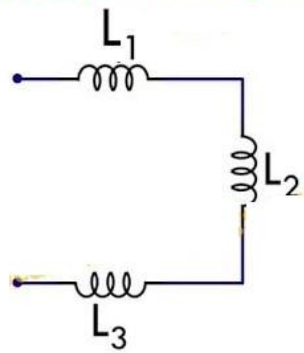
Equivalent resistance of series, parallel

Resistors in Series



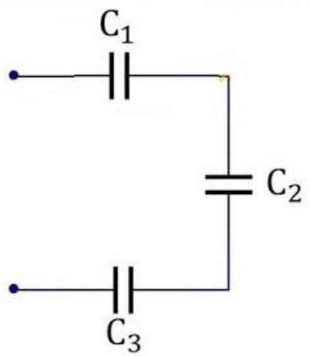
$$R_{eq} = R_1 + R_2 + R_3$$

Inductors in Series



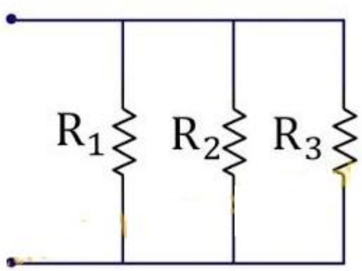
$$L_{eq} = L_1 + L_2 + L_3$$

Capacitors in Series



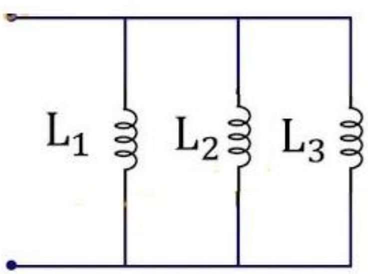
$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Resistors in Parallel



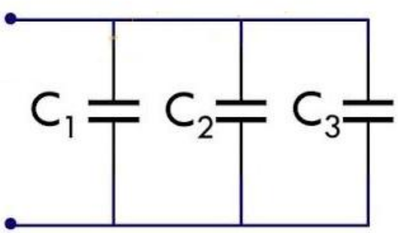
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Inductors in Parallel



$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}$$

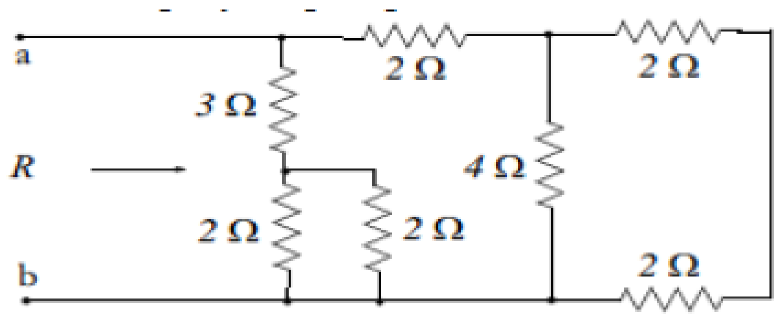
Capacitors in Parallel



$$C_{eq} = C_1 + C_2 + C_3$$

Problems

Calculate the equivalent resistance for the given circuit shown in figure below with step by step explanation?



If three capacitors are 10F, 12F and 5F capacitance, Calculate the equivalent capacitance for series and parallel connection.

Consider an coil allowing an current of i(t) = 4t2 for 1 ms, derive the voltage induced, power absorbed and energy stored by inductor, if its inductance is 5H.

Problems

Consider an capacitor allowing an current of v(t) = 4t2+ 2t + 1 , deduce the expression for current flowing, power absorbed and energy stored by capacitor, if its capacitance is 5H.

An inductor shown in fig1 (a) is supplied with a current wave from given in fig1(b) Draw the wave forms for voltage and energy in the inductor

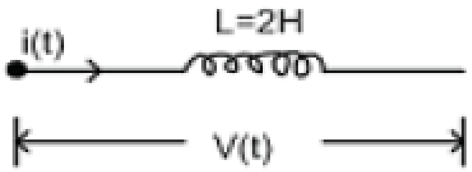


Fig. 1.a

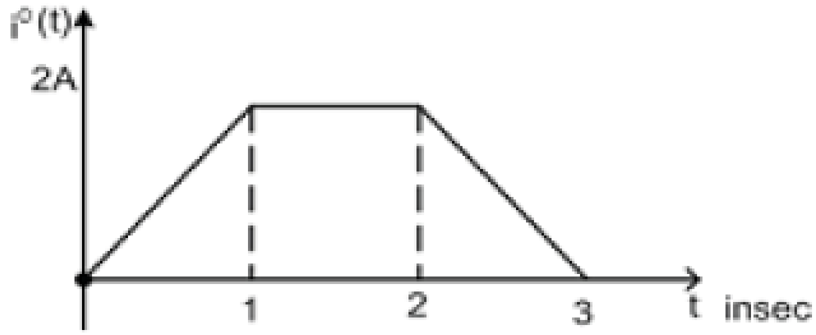


Fig.1.b

Problems

Reduce the network shown in fig (2) to a single loop network by source transformation, to obtain the current in the 12Ω resistor.

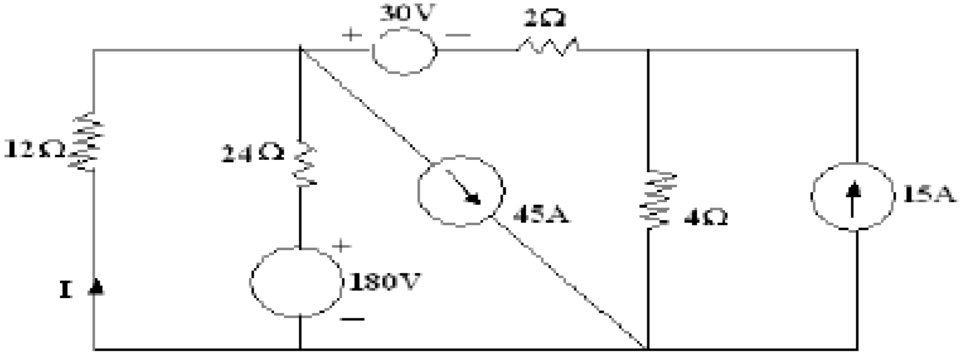
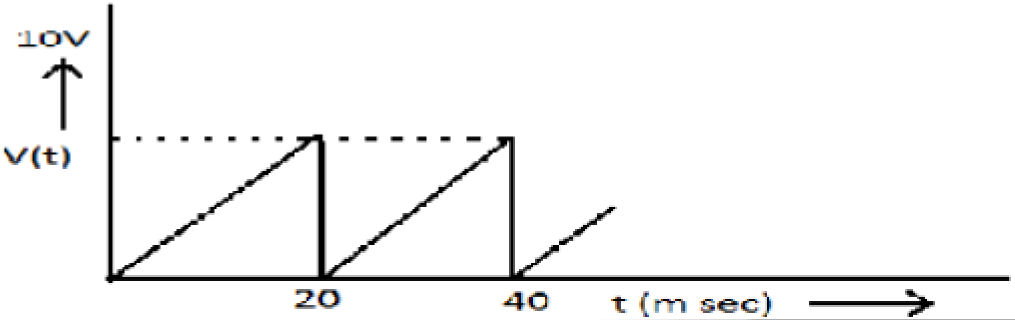


Fig (2)

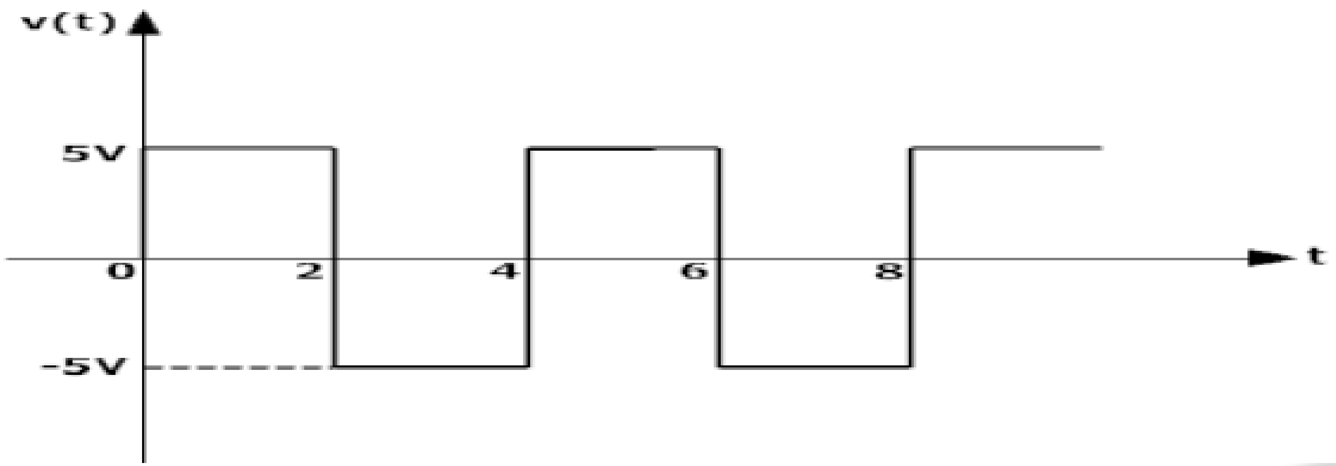
A saw tooth voltage as shown in figure is applied to a capacitor of C= 30micro Farad. Determine the capacitor current.



Problems

If three inductors are connected in parallel having 100mH, 25mH and 35mH inductance respectively, calculate the equivalent inductance.

The following voltage waveform is applied to an inductor of 2H.draw the waveform for current through an inductor as shown in figure below?



Problems

Calculate the equivalent resistance and source current for the given data.

Element	From node	To node
30 V source	A	0
4 ohms	A	B
5 ohms	B	0
2 ohms	B	C
3 ohms	C	0
5 ohms	C	D
6 ohms	D	0

Problems

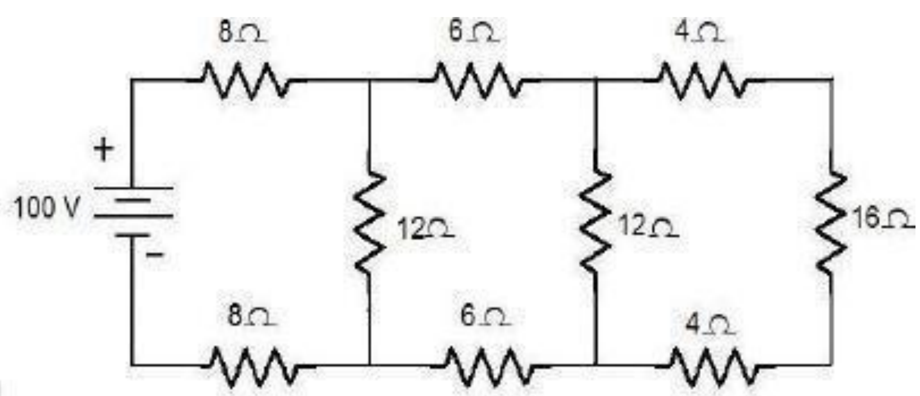
Calculate the equivalent resistance and source current for the given data.

Element	From node	To node
25 V source	A	0
6 ohms	A	B
8 ohms	B	0
2 ohms	B	C
3 ohms	B	C
5 ohms	C	0

Problems

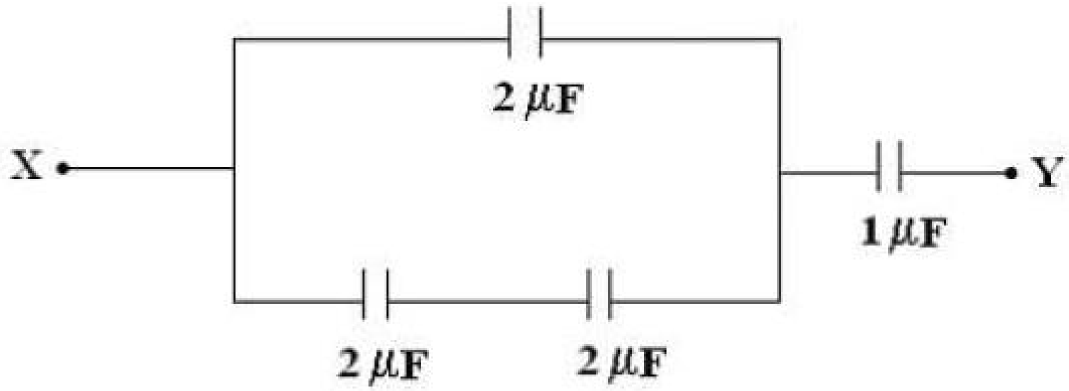
In a circuit branch AB = 10 ohm, BC = 20 ohm , CD = 15 ohm ,BD = 8 ohm and DA = 5 ohm and an source of 100V in series with 5ohm connected across A and C. Calculate equivalent resistance

The equivalent resistances across the terminals of the supply

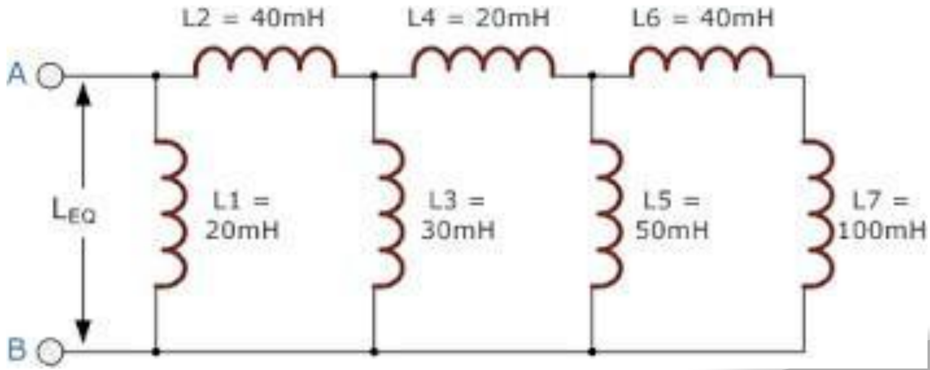


Problems

Calculate the equivalent capacitance of the combination shown figure below across X and Y.

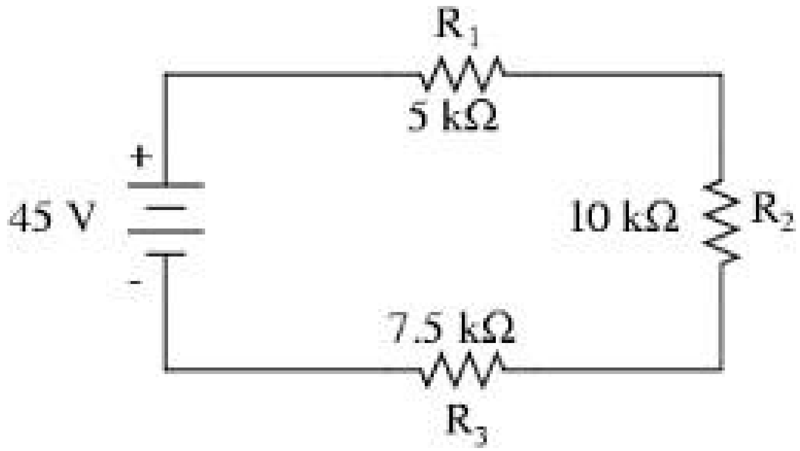


Calculate equivalent inductance in the given circuit

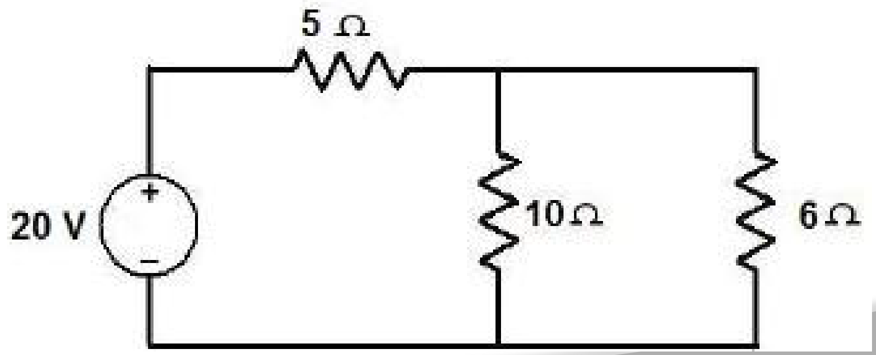


Problems

Calculate power across each element in the given circuit.

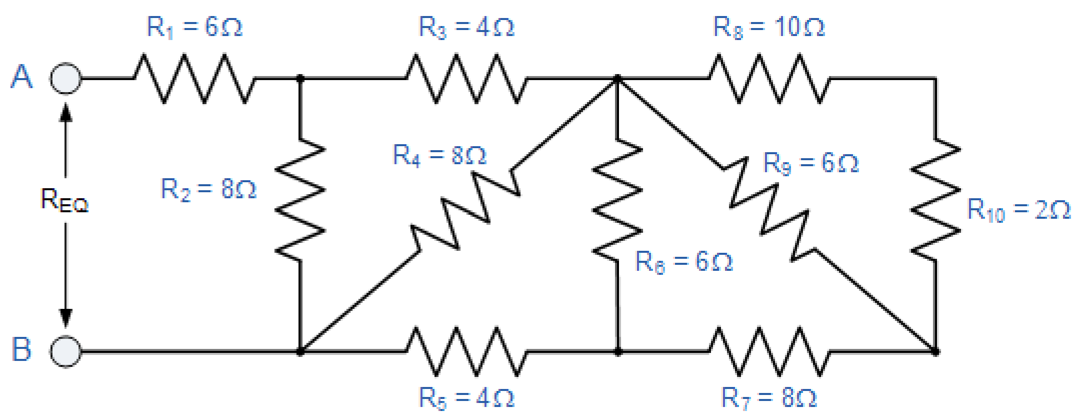


Calculate the power consumed by each resistor.

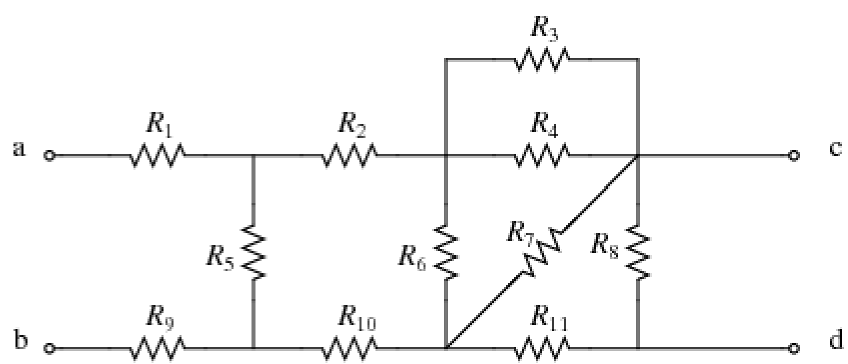


Problems

The equivalent resistances across the terminals of A and B



The equivalent resistances across the terminals of c and d



MODULE -II

ANALYSIS OF ELECTRICAL CIRCUITS

Course Outcomes

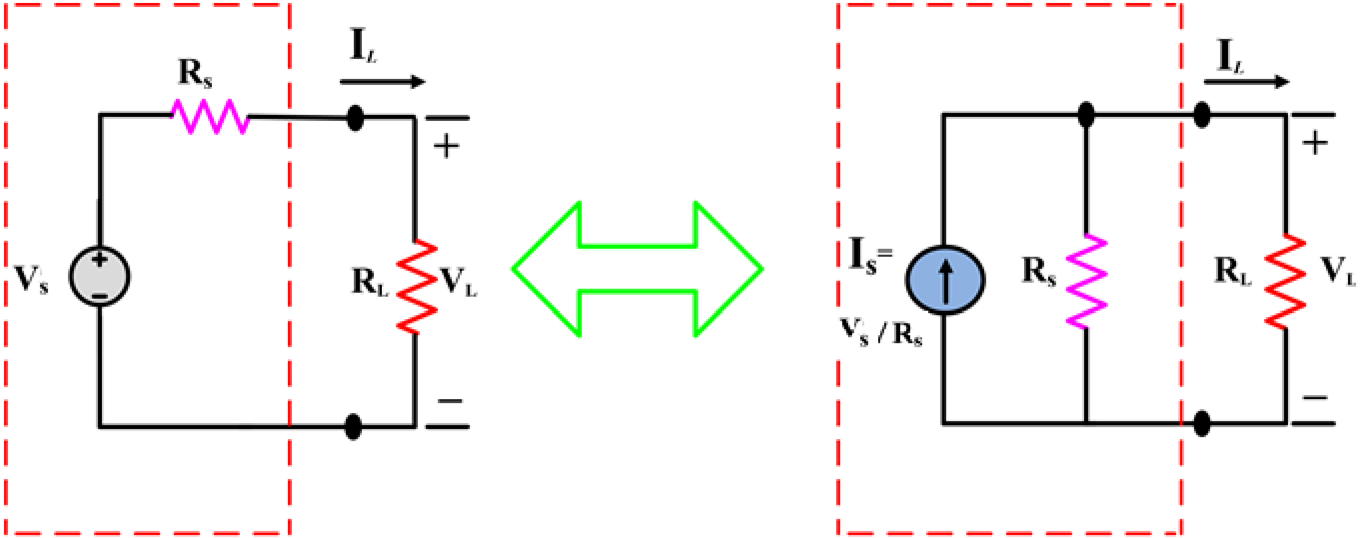
CLOs	Course Learning Outcome
CLO 4	Apply the network reduction techniques directly.
CLO 5	Indirectly to calculate quantities associated with electrical circuit.
CLO 6	Define the various nomenclature related with network topology and give the importance of dual network.

Source Transformation

By using source transformation technique we can convert a piratical voltage source into a practical current source and vice versa without changing the terminal behavior of the network.

According to source transformation technique a voltage source in series with resistance can be converted into a current source in parallel with a resistance and a current source in parallel with resistance can be converted into a voltage source in series with a resistance

Source Transformation



(a) Voltage source *(b) Current source*

$$V_s = IR_s + V_L$$

$$\frac{V_s}{R_s} = I + \frac{V_L}{R_s}$$

$$I_s = I + I_L$$

$$I_s = \frac{V_s}{R_s}$$

$$I_s = I + I_L$$

$$I_s = \frac{V_s}{R_s} + I_L$$

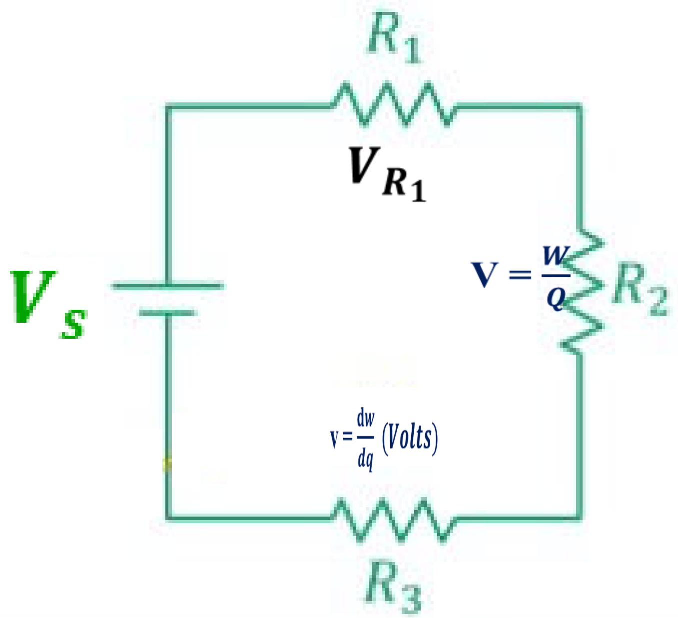
$$V_s = IR_s$$

$$I_sR_s = V_s + \frac{I_L}{R_s}$$

$$V_s = IR_s + V_L$$

Voltage Division Rule

The series circuit acts as a voltage divider.



$$v = \frac{dq}{dt} \text{ (Amperes)}$$

$$P = \frac{W}{T} = VI\text{(watt)}$$

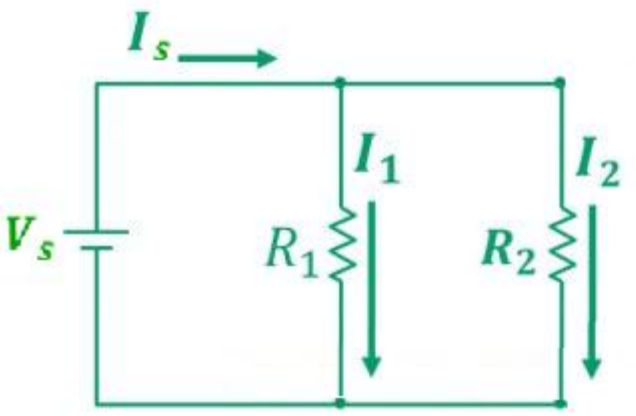
$$p = \frac{dw}{dt} \text{ (watt)}$$

$$V \propto I \text{ or } I \propto V \Rightarrow V = IR$$

$$I = \frac{Q}{T} \text{ (Amperes)}$$

Current Division Rule

The series circuit acts as a voltage divider.



$$I_s = \frac{V_s}{R_T} \qquad I_s = \frac{V_s}{\frac{R_1 R_2}{R_1+R_2}}$$

$$I_s = V_s \frac{R_1+R_2}{R_1 R_2}$$

$$I_s = I_1 R_1 \frac{R_1+R_2}{R_1 R_2}$$

$$I_1 = \frac{V_s}{R_1} \qquad I_2 = \frac{V_s}{R_2}$$

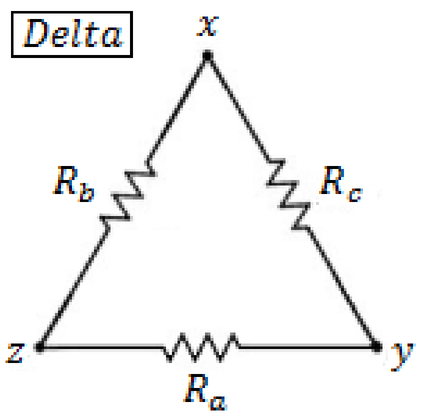
$$I_1 = I_S \frac{R_2}{R_1+R_2} \qquad I_2 = I_S \frac{R_1}{R_1+R_2}$$

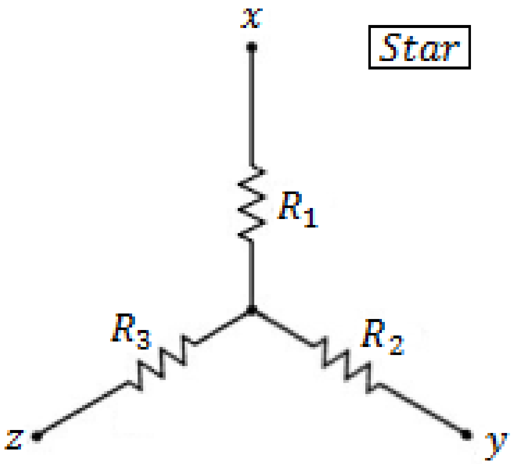
$$R_T = \frac{R_1 R_2}{R_1 + R_2}$$

$$I_N = I_S \frac{R_T}{R_1+R_2}$$

Star to delta and delta to star transformation

Delta-star and star-delta transformation is quite useful to simplify certain network problems. If three elements meet at a node then the three elements are said to be in star connection, whereas if three elements form closed path then they are said to be in delta connection.



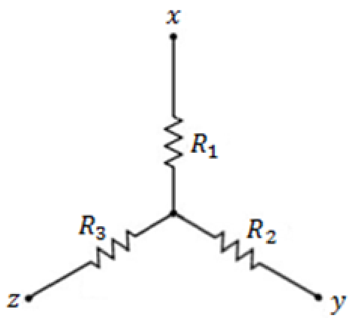


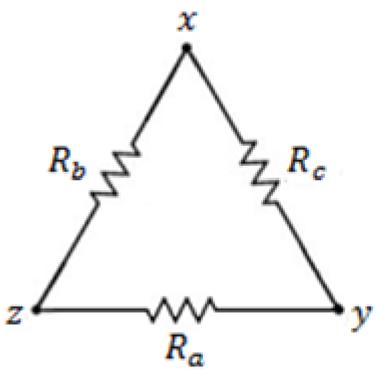
$$R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1} \qquad R_1 = \frac{R_bR_c}{R_a + R_b + R_c}$$

$$R_b = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2} \qquad R_2 = \frac{R_aR_c}{R_a + R_b + R_c}$$

$$R_c = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3} \qquad R_3 = \frac{R_aR_b}{R_a + R_b + R_c}$$

Star to delta and delta to star transformation





The equivalent resistance between any Two terminals

for Star

At X//Y $R_1 + R_2$

At Y//Z $R_2 + R_3$

At X//Z $R_1 + R_3$

terminals

for Delta

At X//Y $\frac{R_c(R_a+R_b)}{R_a+R_b+R_c}$

At Y//Z $\frac{R_a(R_c+R_b)}{R_a+R_b+R_c}$

At X//Z $\frac{R_b(R_c+R_a)}{R_a+R_b+R_c}$

Star to delta and delta to star transformation

Compare the values

$$R_1 + R_2 = \frac{R_c(R_a + R_b)}{R_a + R_b + R_c} \qquad (1)$$

$$R_2 + R_3 = \frac{R_a(R_c + R_b)}{R_a + R_b + R_c} \qquad (2)$$

$$R_1 + R_3 = \frac{R_b(R_c + R_a)}{R_a + R_b + R_c} \qquad (3)$$

Equation (3) – (2)

$$R_1 - R_2 = \frac{R_b R_c - R_a R_c}{R_a + R_b + R_c} \qquad (4)$$

Equation (1) + (4)

Resistor (R) : A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses.

Resistance : Resistance is nothing but this property of resisting the flow of electrons or the current. The unit of resistance is **ohm (Ω)** . One ohm is equal to volt per ampere.

From Ohm's law, we have seen that $R = \frac{V}{I}$

Where V is the voltage and I is the current.

Delta to Star values

$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$$

$$V = IR$$

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

$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c}$$

Star to delta and delta to star transformation

$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c} \qquad R_2 = \frac{R_a R_c}{R_a + R_b + R_c}$$

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

$$L = \frac{\mu N^2 A}{l} \qquad C = \frac{\varepsilon_0 A}{d}$$

Equation (R_1) * (R_3)

$$R_1 * R_2 = \frac{(R_b R_c)(R_a R_c)}{(R_a + R_b + R_c)^2}$$

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

$$R_1 * R_3 = \frac{(R_b R_c)(R_a R_b)}{(R_a + R_b + R_c)^2}$$

Equation (R_1) * (R_2) + Equation (R_2) * (R_3)+ Equation (R_1) * (R_3)

$$R_1 * R_2 + R_2 * R_3 + R_1 * R_3 = \frac{(R_b R_c)(R_a R_c)}{(R_a + R_b + R_c)^2} + \frac{(R_a R_c)(R_a R_b)}{(R_a + R_b + R_c)^2} + \frac{(R_b R_c)(R_a R_b)}{(R_a + R_b + R_c)^2}$$

$$R_1 * R_2 + R_2 * R_3 + R_1 * R_3 = \frac{(R_b R_c)(R_a R_c) + (R_a R_c)(R_a R_b) + (R_b R_c)(R_a R_b)}{(R_a + R_b + R_c)^2}$$

$$R_1 * R_2 + R_2 * R_3 + R_1 * R_3 = \frac{(R_a R_b R_c)(R_a + R_b + R_c)}{(R_a + R_b + R_c)^2}$$

$$R_1 * R_2 + R_2 * R_3 + R_1 * R_3 = \frac{(R_a R_b R_c)}{(R_a + R_b + R_c)}$$

Star to delta and delta to star transformation

$$R_1 * R_2 + R_2 * R_3 + R_1 * R_3 = \frac{(R_a R_b R_c)}{(R_a + R_b + R_c)}$$

$$R_1 * R_2 + R_2 * R_3 + R_1 * R_3 = R_a \frac{(R_b R_c)}{(R_a + R_b + R_c)}$$

$$but\ R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$$

$$R_1 * R_2 + R_2 * R_3 + R_1 * R_3 = R_a * R_1 \qquad \frac{R_1 * R_2 + R_2 * R_3 + R_1 * R_3}{R_1} = R_a$$

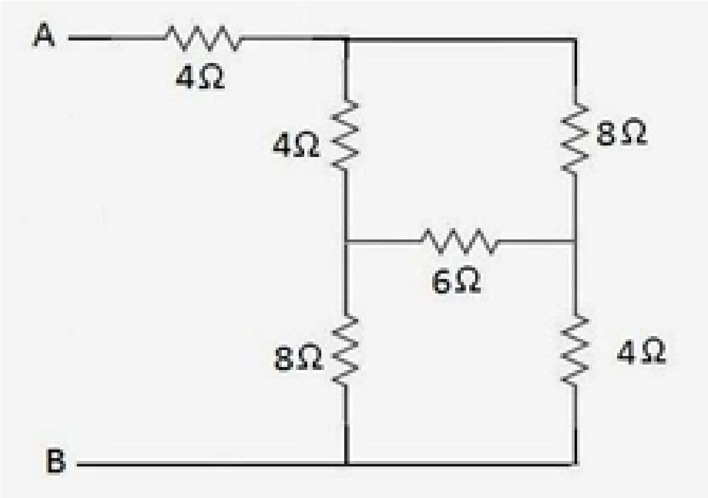
Star to delta

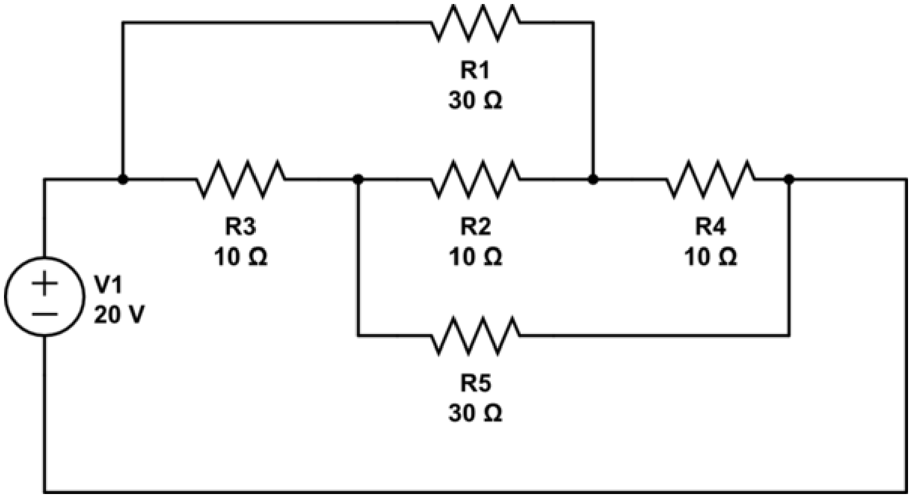
$$\frac{R_1 * R_2 + R_2 * R_3 + R_1 * R_3}{R_1} = R_a \qquad \frac{R_1 * R_2 + R_2 * R_3 + R_1 * R_3}{R_2} = R_b$$

$$\frac{R_1 * R_2 + R_2 * R_3 + R_1 * R_3}{R_3} = R_c$$

Star to delta and delta to star transformation

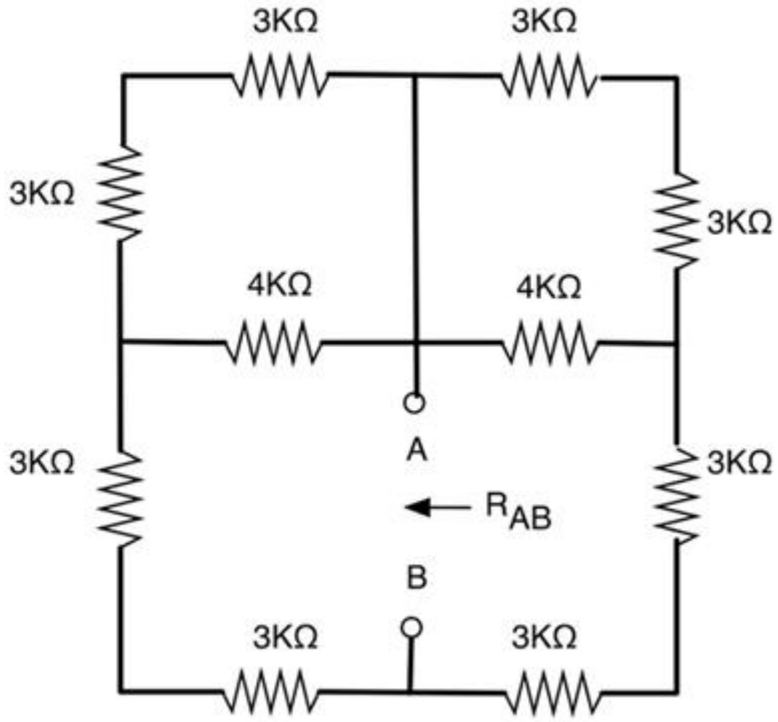
Calculate the equivalent resistance

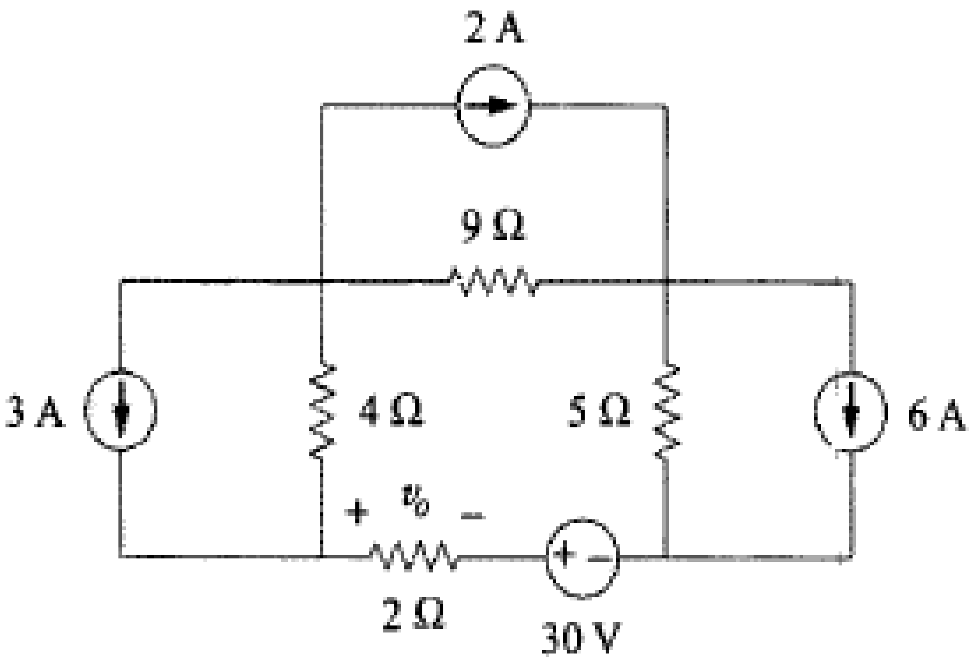




Star to delta and delta to star transformation

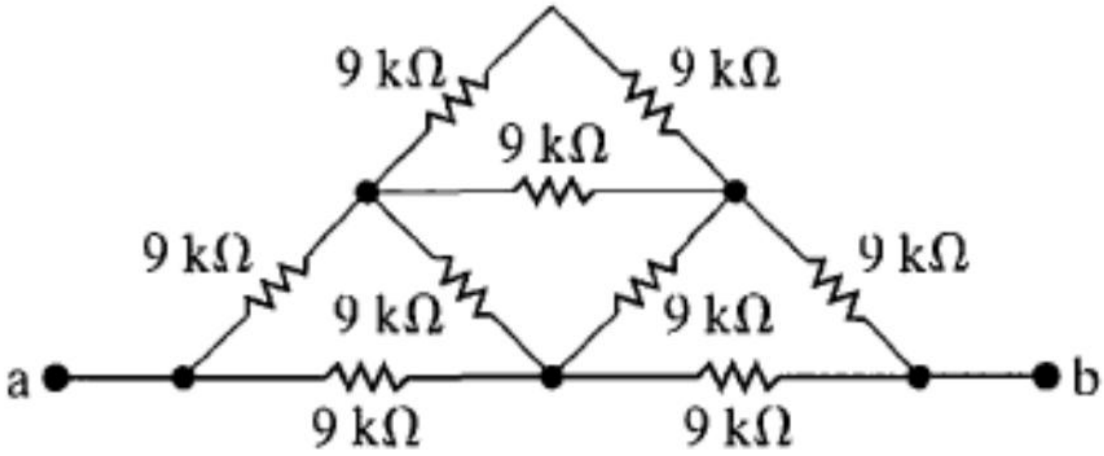
Calculate the equivalent resistance




2 A
9 Ω
3 A
4 Ω
5 Ω
6 A
+ v_0 −
2 Ω
30 V

Star to delta and delta to star transformation

Calculate the equivalent resistance R_{ab}



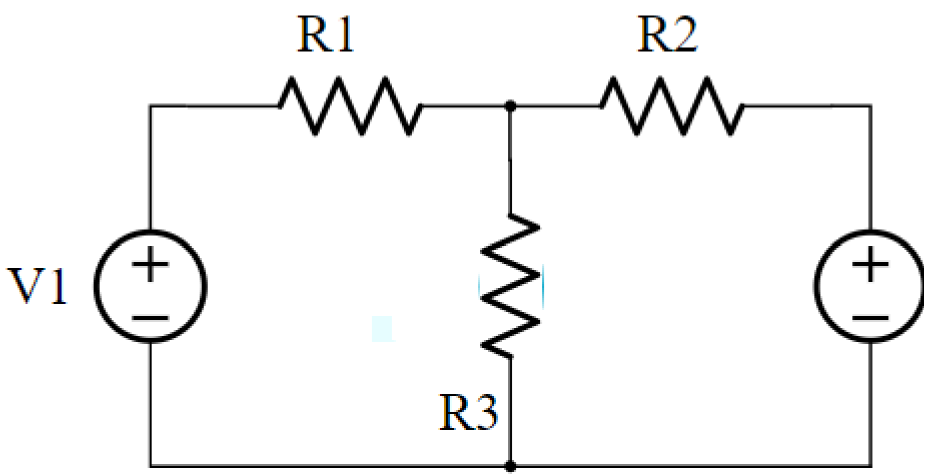
Mesh Current Analysis

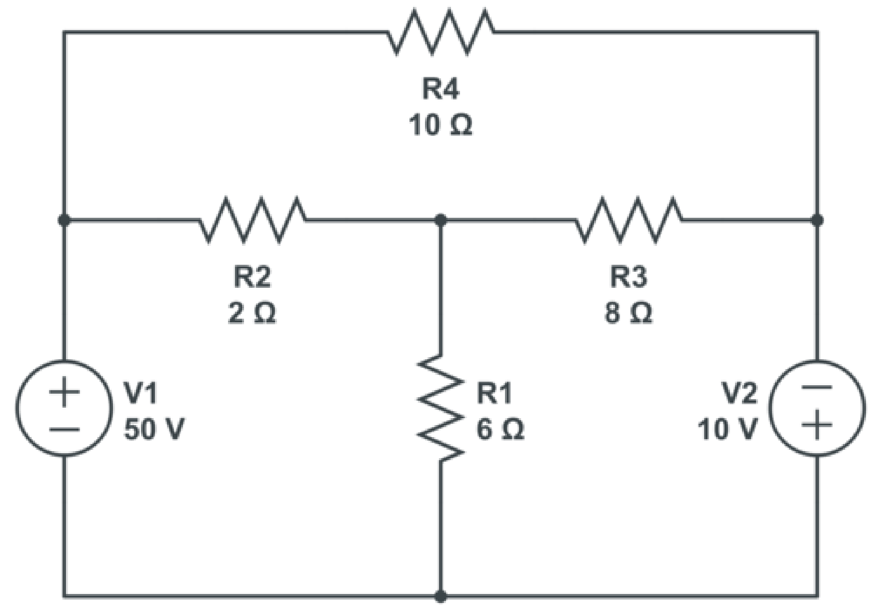
Any closed electrical path is called loop. Mesh is defined as a loop which does not contain any other loops within it. If a network has a larger number of voltage sources, it is better to use mesh analysis, which mainly depends on KVL.

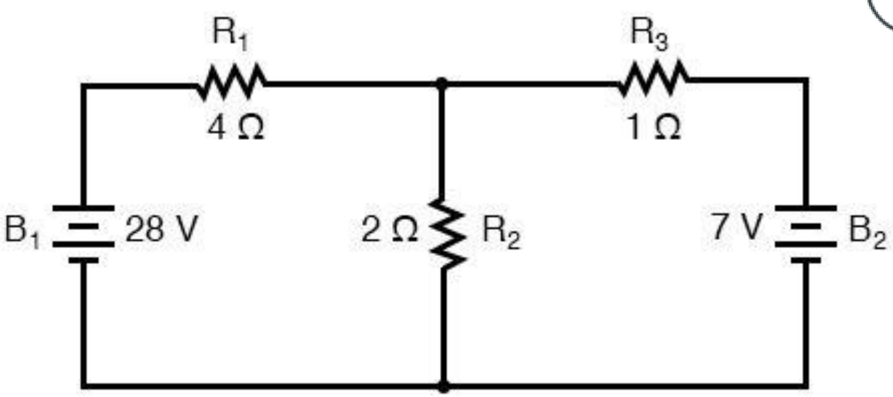
Steps to be followed in Mesh Analysis:

- Identify all the meshes in network and select Loop/Mesh currents.
- Sign conventions for the IR drops and source/ battery emfs are the same as for Kirchoff's Law.
- Apply KVL around the mesh and use ohm's law to express the branch voltages in terms of unknown mesh currents and the resistance.
- Solve the simultaneous equations for unknow mesh currents.

Mesh Current Analysis







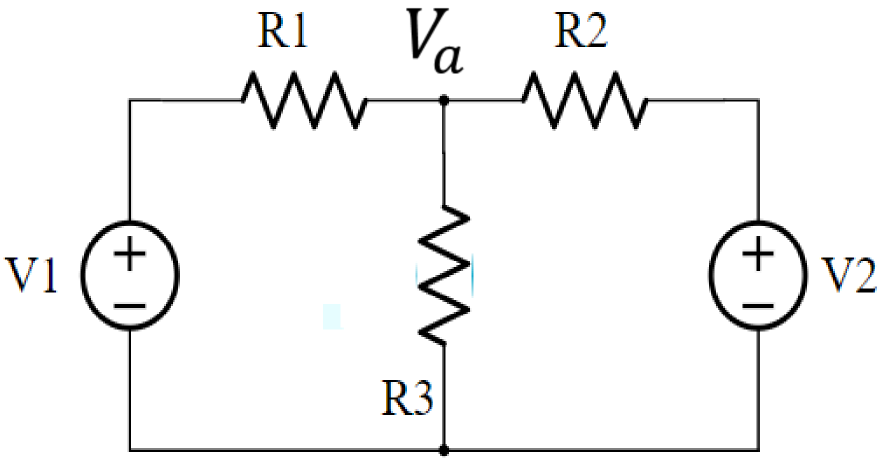
Nodal Voltage Analysis

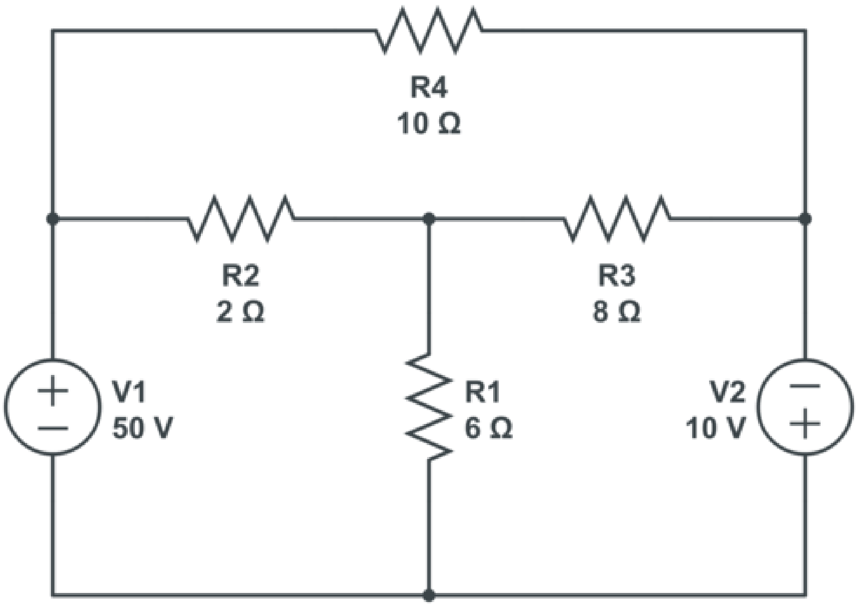
A node is a point in a network common to two or more circuit elements. If three or more elements meet at a node, that node is called a principle node. A node voltage is the voltage of given node with respective to one particulate node, called the reference node, which we assume at zero potential. If the network has more number of current sources, then the nodal analysis is useful method, mainly depends on KCL. An ‘N’ node circuit will be require (N-1) unknown voltages and (n-1) equations.

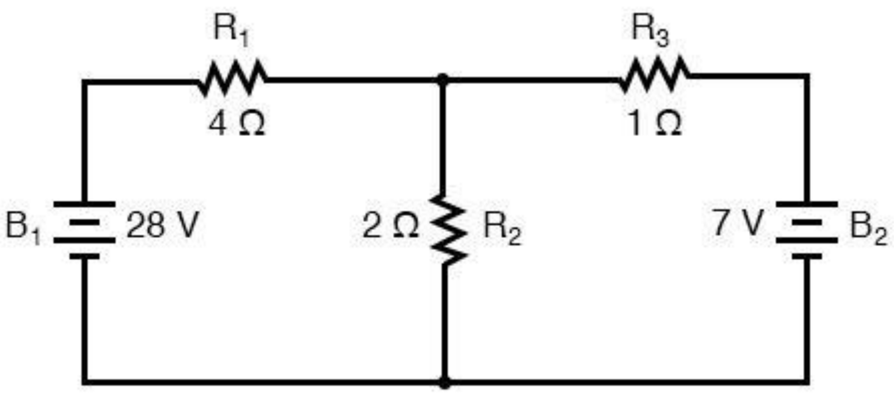
Steps to be followed in Mesh Analysis:

- Identify all the nodes in network and select node voltages.
- One of these nodes is taken as reference node, which is at zero potential.
- Node voltages are measured with respective to the reference node.
- Apply KCL at each node and use ohm’s law to the branch currents.
- Solve the simultaneous equations for unknow node voltages.

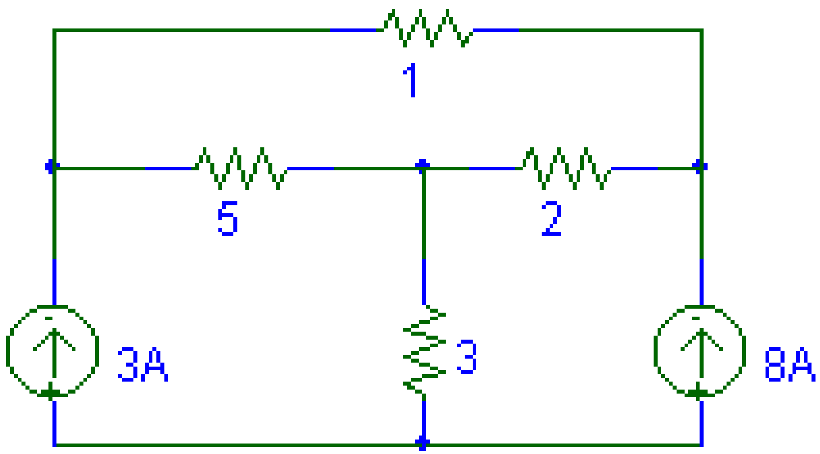
Nodal Voltage Analysis

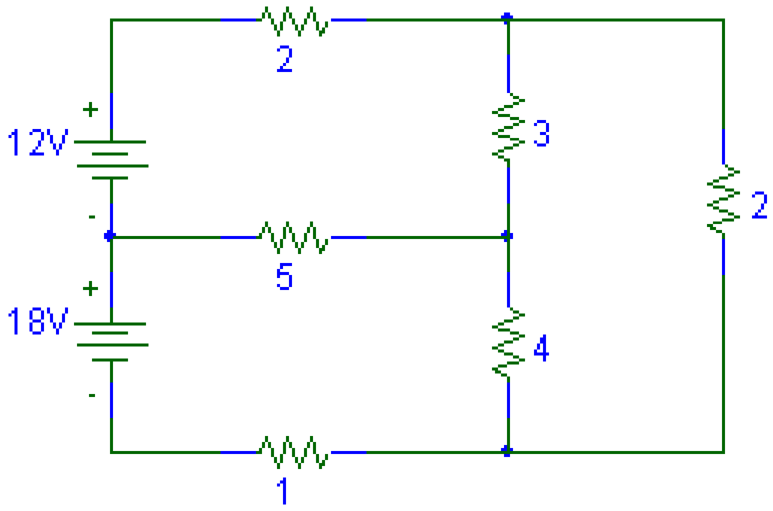






Mesh Current Analysis & Nodal Voltage Analysis





Inspection Method

The mesh or nodal equations are to be solved for finding loop currents or node voltages using Matrix form known as Inspection Method. These equations are algebraic equations of form [A][X]=[B], where [X] is unknown values. The Cramer's rule is a simple method used for solving these equations. It is also known as Method of Determinations. Consider the Equations

$$A_1X + B_1Y + C_1Z = D_1$$
$$A_2X + B_2Y + C_2Z = D_2$$
$$A_3X + B_3Y + C_3Z = D_3$$

The above equations can be written matrix form as

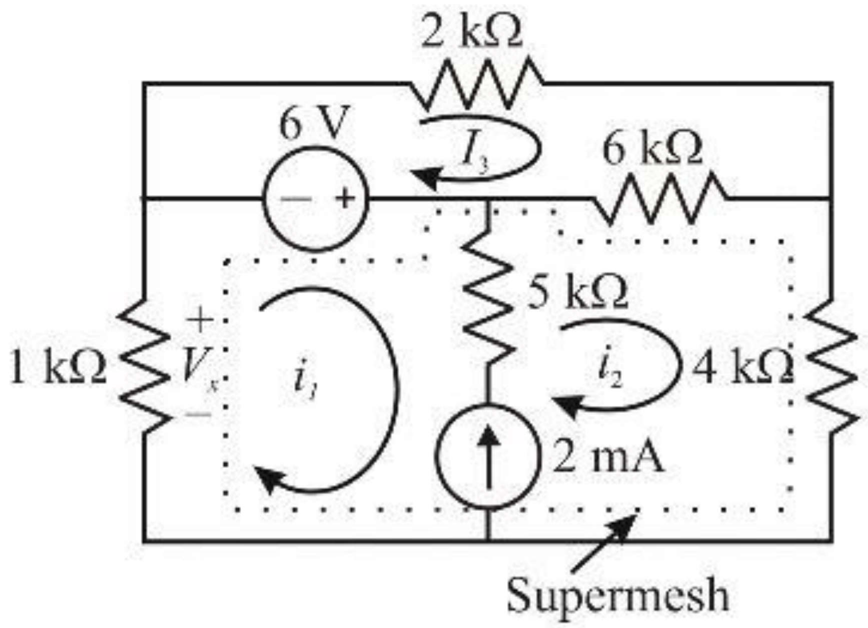
$$\begin{bmatrix} A_1 & B_1 & C_1 \\ A_2 & B_2 & C_2 \\ A_3 & B_3 & C_3 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} D_1 \\ D_2 \\ D_3 \end{bmatrix}$$

Using Cramer's rule $X = \frac{|\Delta_1|}{|\Delta|}$; $Y = \frac{|\Delta_2|}{|\Delta|}$; $Z = \frac{|\Delta_3|}{|\Delta|}$

$$\Delta = \begin{bmatrix} A_1 & B_1 & C_1 \\ A_2 & B_2 & C_2 \\ A_3 & B_3 & C_3 \end{bmatrix}; \ \Delta_1 = \begin{bmatrix} D_1 & B_1 & C_1 \\ D_2 & B_2 & C_2 \\ D_3 & B_3 & C_3 \end{bmatrix}; \ \Delta_2 = \begin{bmatrix} A_1 & D_1 & C_1 \\ A_2 & D_2 & C_2 \\ A_3 & D_3 & C_3 \end{bmatrix} \ \Delta_3 = \begin{bmatrix} A_1 & B_1 & D_1 \\ A_2 & B_2 & D_2 \\ A_3 & B_3 & D_3 \end{bmatrix}$$

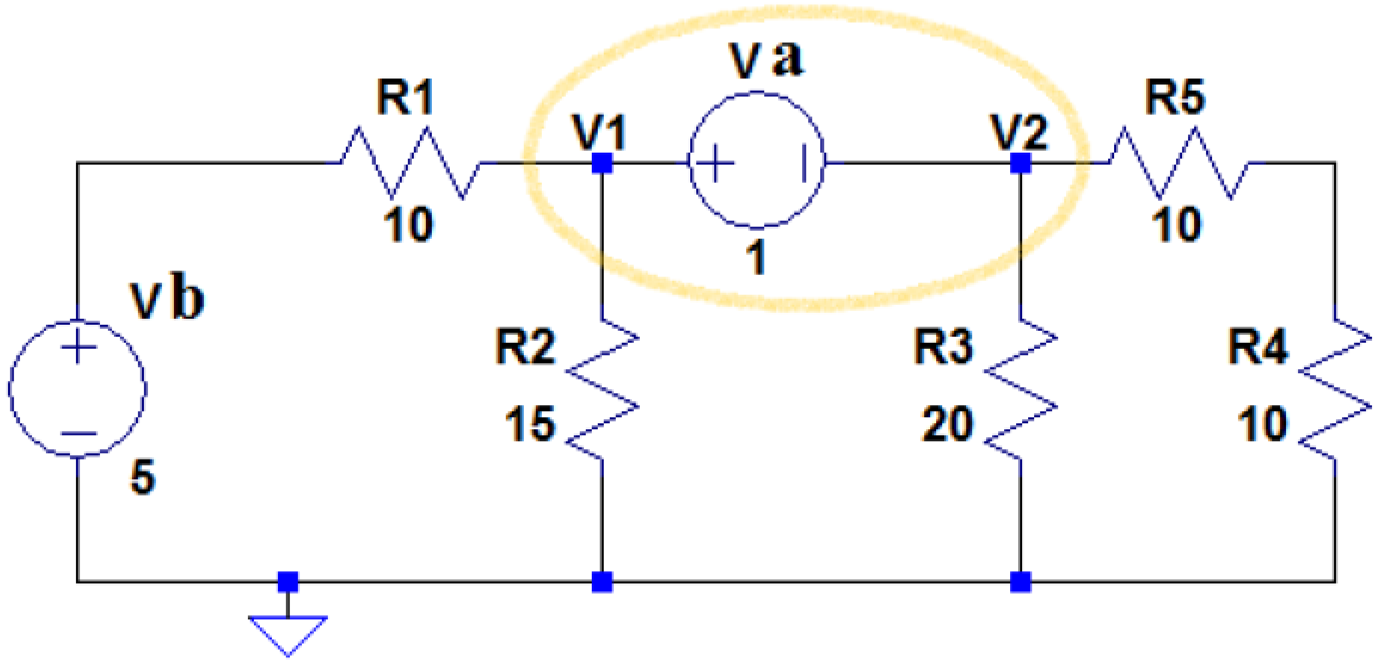
Super Mesh Analysis

Suppose any of branches in the network has a current source, then it is slightly difficult to apply mesh analysis. This difficulty can overcome by using Supper Mesh Technique. A Supper Mesh is constituted by two adjacent loop that have a common current source.



Super Node Analysis

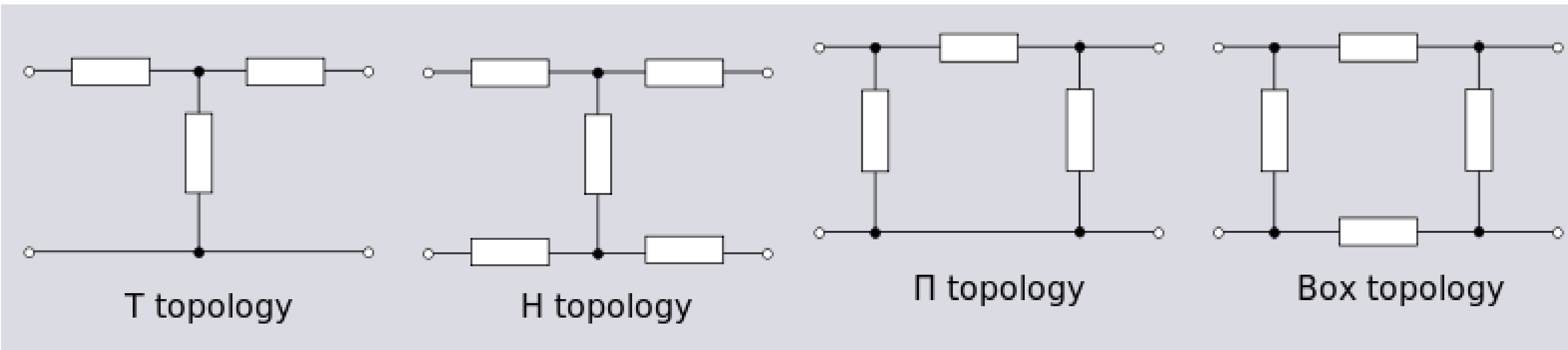
Suppose any of branches in the network has single voltage source, then it is slightly difficult to apply node analysis. This difficulty can overcome by using Supper Node Technique. A Supper Node is constituted by two adjacent nodes that are connected by a voltage source are reduced to single node and the equations are formed as usual by applying KCL.

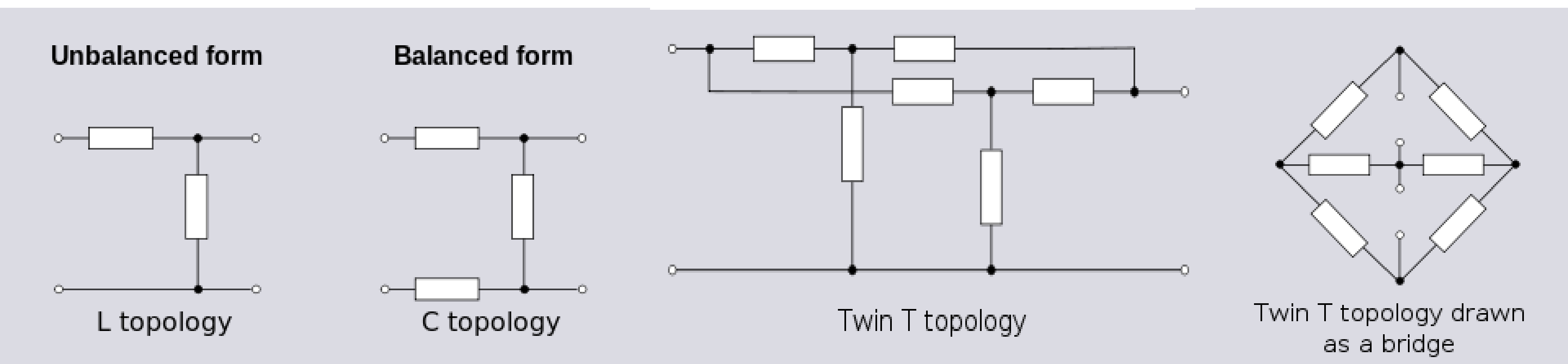


NETWORK TOPOLOGY

Network Topology

Network topology is a graphical representation of **electric** circuits. It is useful for analyzing complex electric circuits by converting them into network graphs. **Network topology** is also called as **Graph theory**.





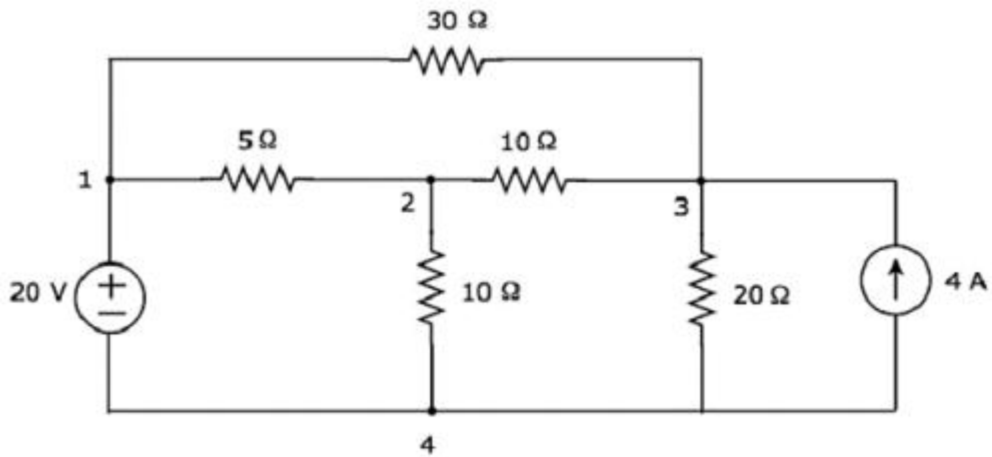
Graph

Network graph is simply called as **graph**. It consists of a set of nodes connected by branches. In graphs, a node is a common point of two or more branches. Sometimes, only a single branch may connect to the node. A branch is a line segment that connects two nodes.

Any electric circuit or network can be converted into its equivalent **graph** by replacing the passive elements and **voltage sources with short circuits** and the **current sources with open circuits**. That means, the line segments in the graph represent the branches corresponding to either passive elements or voltage sources of electric circuit.

Graph

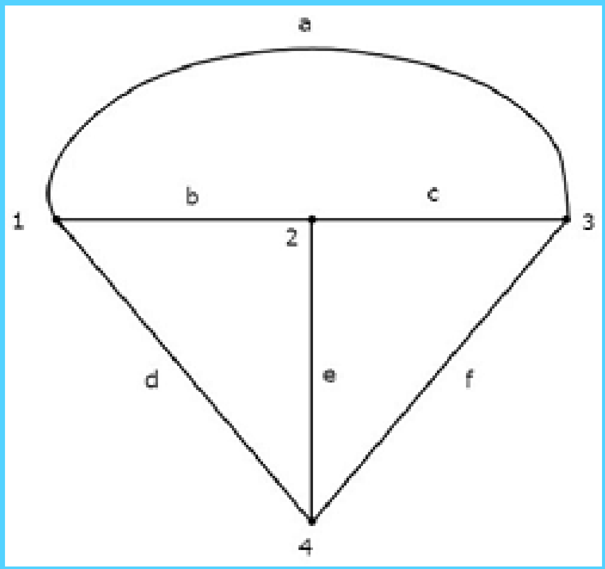
Example



Four Principal Node

Seven Branches

An equivalent graph corresponding to the above electric circuit is



Four Nodes

Six Branches

one branch less in the graph because the 4 A current source is made as open circuit

Graph

The **number of nodes** present in a graph will be equal to the number of principal nodes present in an electric circuit.

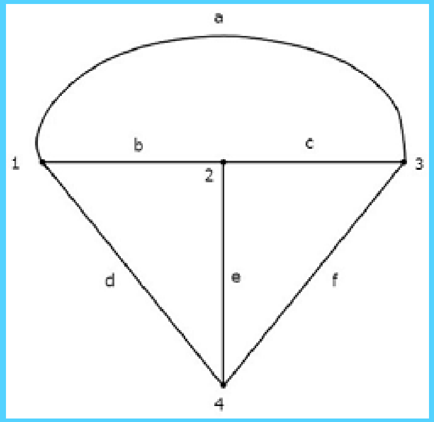
The **number of branches** present in a graph will be less than or equal to the number of branches present in an electric circuit.

Types of Graphs

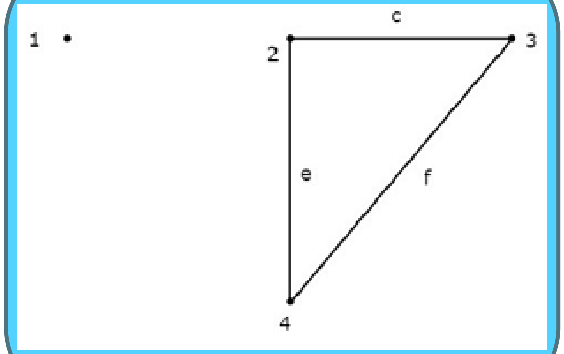
- Connected Graph
- Unconnected Graph
- Directed Graph
- Undirected Graph

Graph

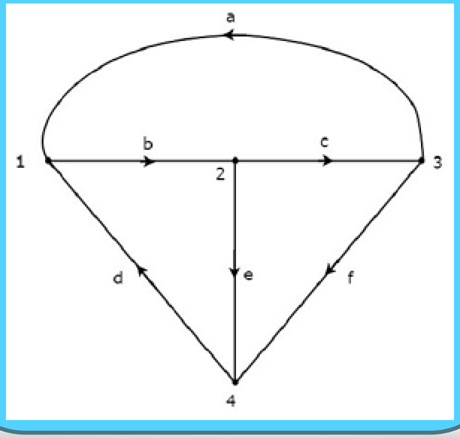
•Connected Graph



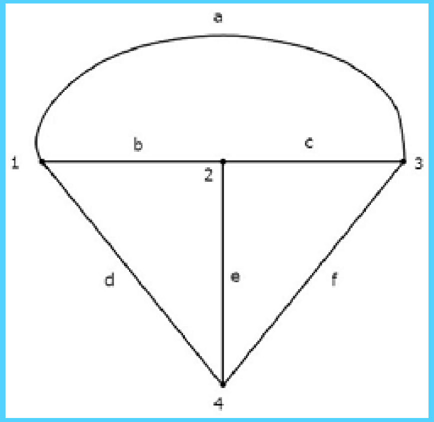
•Unconnected Graph



•Directed Graph



•Undirected Graph



Subgraph

A part of the graph is called as a **subgraph**. We get subgraphs by removing some nodes and/or branches of a given graph. So, the number of branches and/or nodes of a subgraph will be less than that of the original graph. Hence, we can conclude that a subgraph is a subset of a graph.

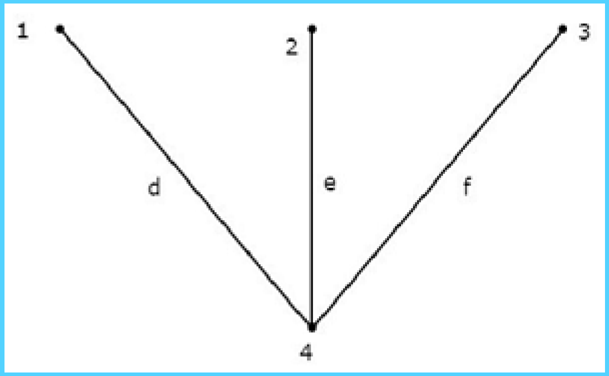
Types of Subgraph

- Tree
- Co-Tree

Tree is a connected subgraph of a given graph, which contains all the nodes of a graph. But, there should not be any loop in that subgraph. The branches of a tree are called as **twigs**

Tree

Tree is a connected subgraph of a given graph, which contains all the nodes of a graph. But, there should not be any loop in that subgraph. The branches of a tree are called as **twigs**



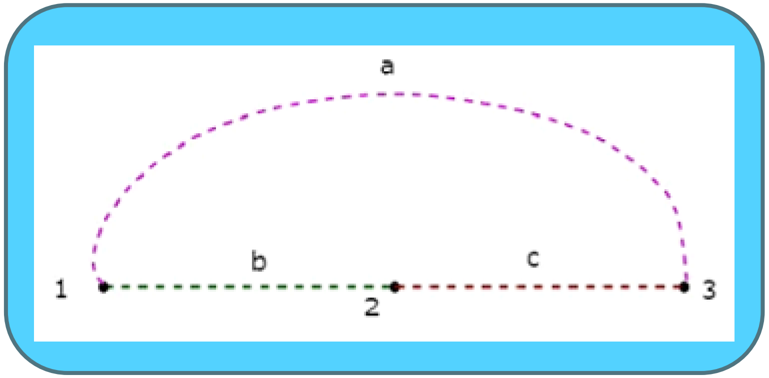
This connected subgraph contains all the four nodes of the given graph and there is no loop. Hence, it is a **Tree**.

This Tree has only three branches out of six branches of given graph. Because, if we consider even single branch of the remaining branches of the graph, then there will be a loop in the above connected subgraph. Then, the resultant connected subgraph will not be a Tree.

From the above Tree, we can conclude that the **number of branches** that are present in a Tree should be equal to ***n* - 1** where 'n' is the number of nodes of the given graph.

Co-Tree

$$V = \frac{W}{Q}\ (Volts)$$



$$I = \frac{Q}{T}\ (\text{Amperes})$$

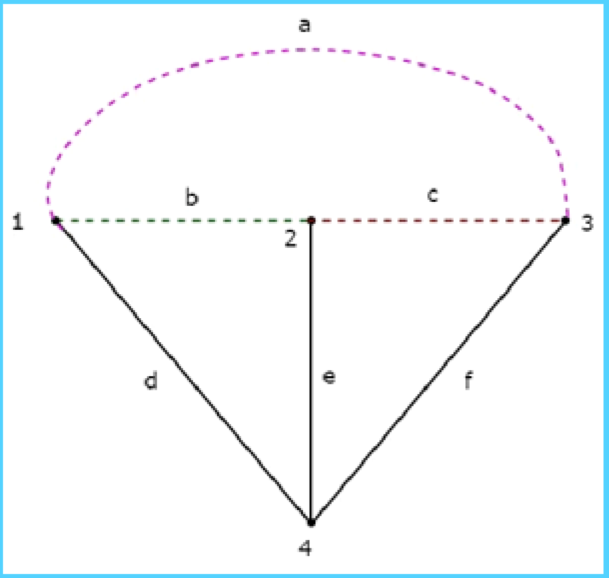
l = Number of links.
b =Number of branches present in a given graph.
N=*N*umber of nodes present in a given graph.

This Co-Tree has only three nodes instead of four nodes of the given graph, because Node 4 is isolated from the above Co-Tree. Therefore, the Co-Tree need not be a connected subgraph. This Co-Tree has three branches and they form a loop.

The number of branches that are present in a co-tree will be equal to the difference between the number of branches of a given graph and the number of twigs.

original Graph

If we combine a Tree and its corresponding Co-Tree, then we will get the **original graph**



Incidence Matrix

An Incidence Matrix represents the graph of a given electric circuit or network. Hence, it is possible to draw the graph of that same electric circuit or network from the incidence matrix. the connecting of branches to a node is called as incidence.

Incidence matrix is a representation of concepts of kirchoff's voltage law and kirchoff's current law applied to a network.

Incidence matrix is represented with the letter A.

It is also called as node to branch incidence matrix or node incidence matrix.

Incidence Matrix

If there are ‘n’ nodes and ‘b’ branches are present in a directed graph, then the incidence matrix will have ‘n’ rows and ‘b’ columns. Here, rows and columns are corresponding to the nodes and branches of a directed graph. Hence, the order of incidence matrix will be $n \times b$.

The elements of incidence matrix will be having one of these three values, +1, -1 and 0.

If the branch current is entering towards a selected node, then the value of the element will be +1.

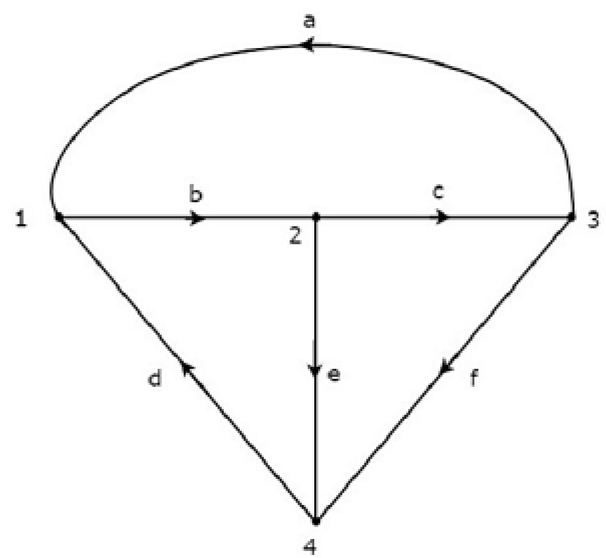
If the branch current is leaving from a selected node, then the value of the element will be -1.

If the branch current neither enters at a selected node nor leaves from a selected node, then the value of element will be 0.

Incidence Matrix

Example

Consider the following directed graph



Four Nodes

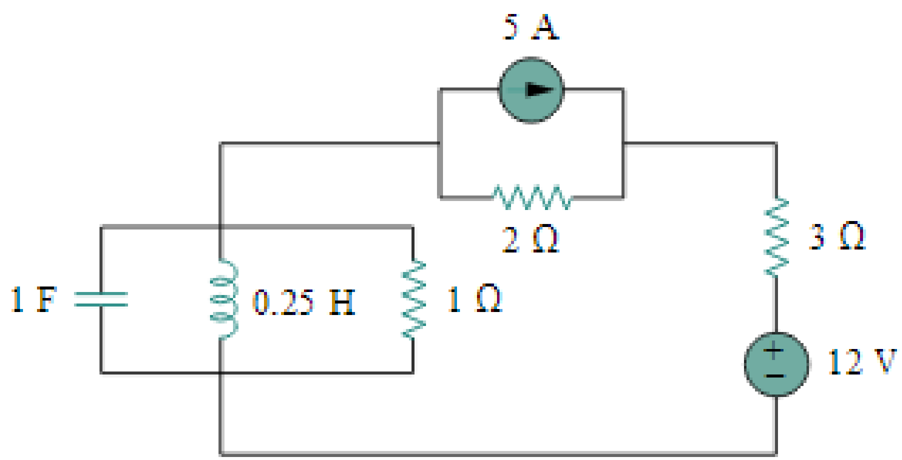
Six Branches

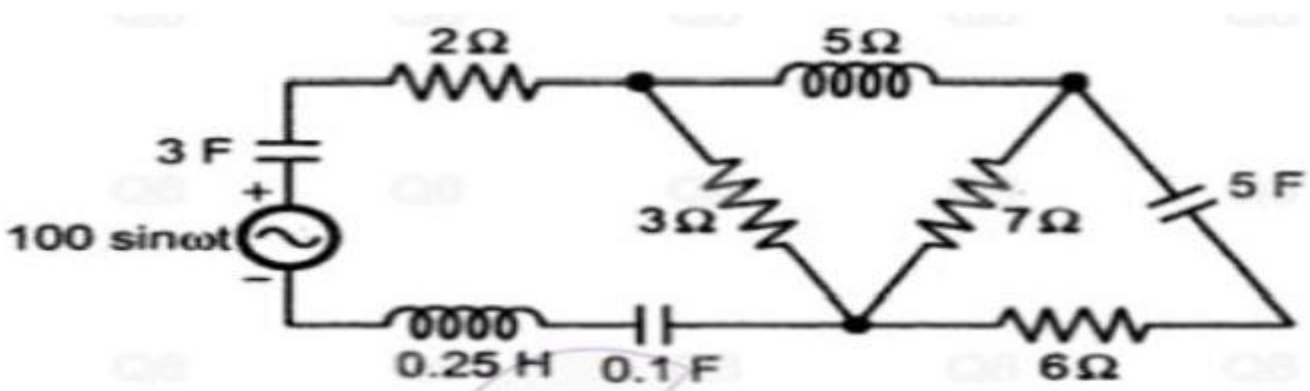
The incidence matrix corresponding to the directed graph will be

$\mathbf{p} = \frac{dw}{dt}$ (w

$$A = \begin{bmatrix} 1 & -1 & 0 & 1 & 0 & 0 \\ 0 & 1 & -1 & 0 & 1 & 0 \\ -1 & 0 & 1 & 0 & 0 & -1 \\ 0 & 0 & 0 & -1 & 1 & 1 \end{bmatrix}$$

Incidence Matrix

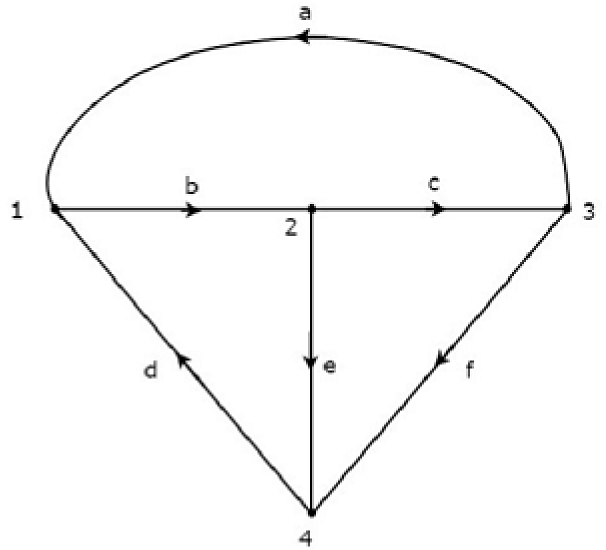




Incidence Matrix

Example

Consider the following directed graph



Four Nodes

Six Branches

Incidence Matrix is represented with the letter A.

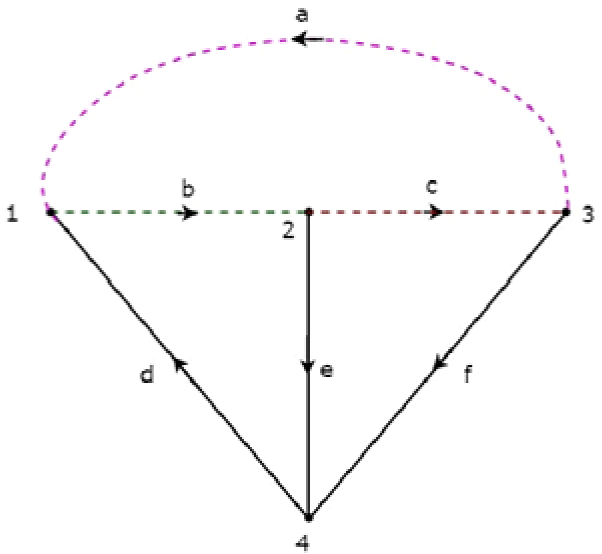
The order of incidence matrix will be N × B.

$$A = \begin{bmatrix} 1 & -1 & 0 & 1 & 0 & 0 \\ 0 & 1 & -1 & 0 & 1 & 0 \\ -1 & 0 & 1 & 0 & 0 & -1 \\ 0 & 0 & 0 & -1 & 1 & 1 \end{bmatrix}$$

Basic Tie set Matrices

Example

Consider the following directed graph



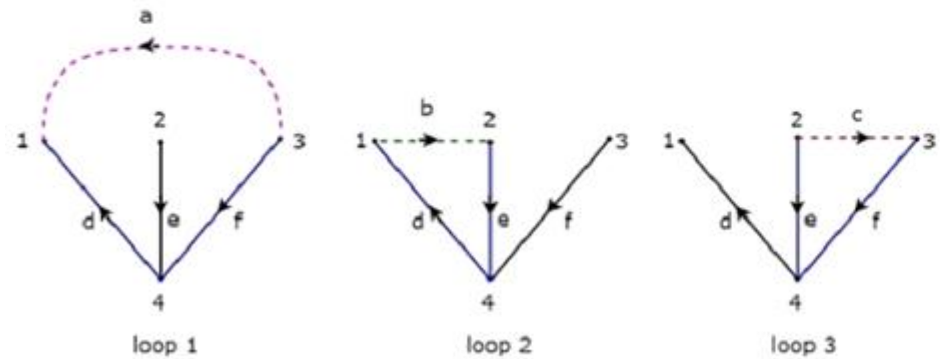
Four Nodes **Six Branches**

Three Trees T=N-1

Three Links L=B-N+1

Basic Tie set Matrices is represented with the letter B.

The order of incidence matrix will be L × B.

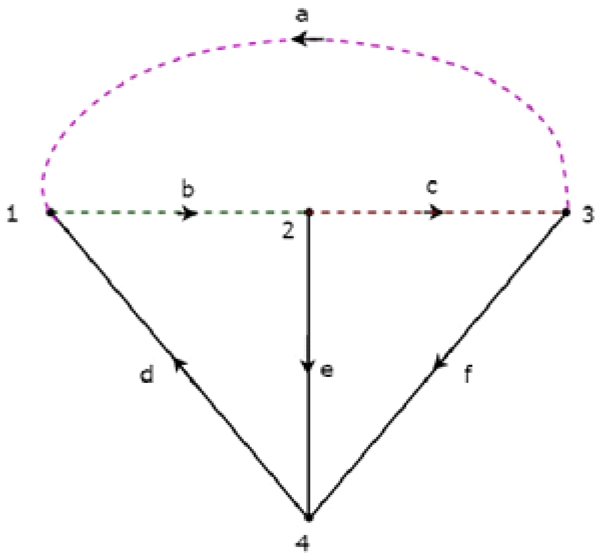


$$B = \begin{bmatrix} 1 & 0 & 0 & -1 & 0 & -1 \\ 0 & 1 & 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & -1 & 1 \end{bmatrix}$$

Basic cut set Matrices

Example

Consider the following directed graph



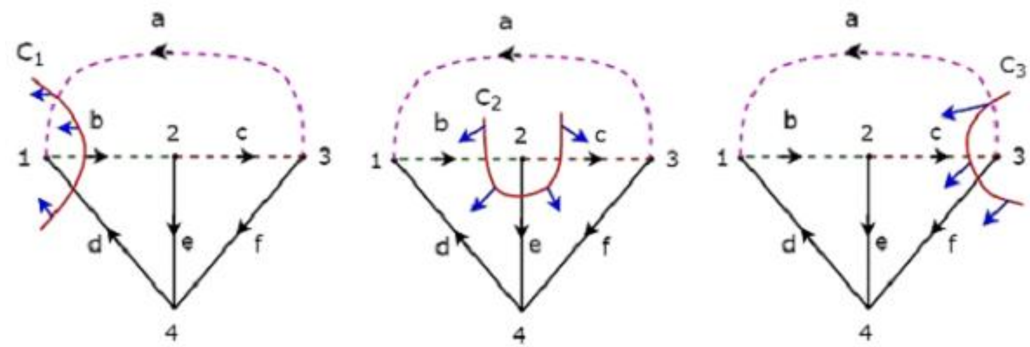
Four Nodes **Six Branches**

Three Trees T=N-1

Three Links L=B-N+1

Basic Tie set Matrices is represented with the letter C.

The order of incidence matrix will be T × B.



$$C = \begin{bmatrix} 1 & -1 & 0 & 1 & 0 & 0 \\ 0 & -1 & 1 & 0 & 1 & 0 \\ 1 & 0 & -1 & 0 & 0 & 1 \end{bmatrix}$$

Duality and Dual Networks

It is interesting to know how systems relate to one another. How a mechanical system can be modelled as an electrical system and observed. The concept of duality in electrical circuits is of great importance. Two phenomena are said to be dual if they can be expressed by same form of mathematical equations. This topic is usually covered under the network topology or graph theory.

Principle of Duality:

Principle of duality in context of electrical networks states that

A dual of a relationship is one in which current and voltage are interchangeable

Two networks are dual to each other if one has mesh equation numerically identical to others node equation

Duality and Dual Networks

List of Dual Pairs:

For evaluating a dual network, you should follow these points

- ❖ The number of meshes in a network is equal to number of nodes in its dual network
- ❖ The impedance of a branch common to two meshes must be equal to admittance between two nodes in the dual network
- ❖ Voltage source common to both loops must be replaced by a current source between two nodes
- ❖ Open switch in a network is replaced by a closed switch in its dual network or vice versa

Duality and Dual Networks

S.No	Elements	Dual Elements
1	Voltage (v) V = IR	Current (i) I = VG
2	Short Circuit	Open Circuit
3	Series	Parallel
4	Norton	Thevenin
5	Resistance (R)	Conductance (G)
6	Impedance	Admittance
7	KVL	KCL
8	Capacitance	Inductance

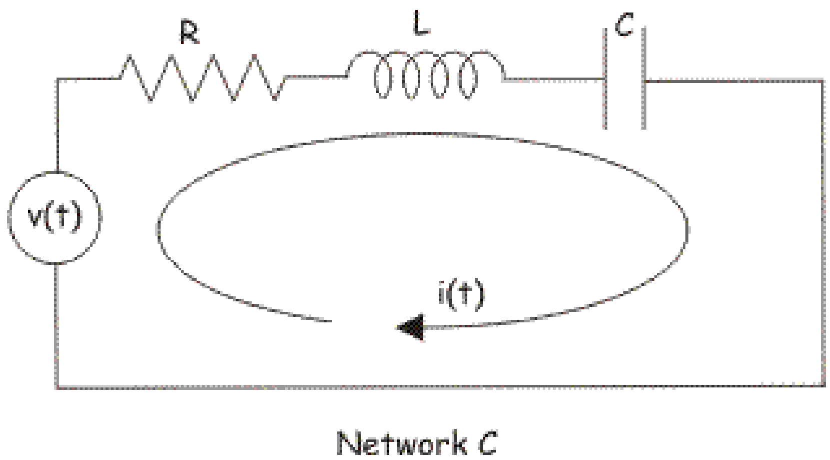
Duality and Dual Networks

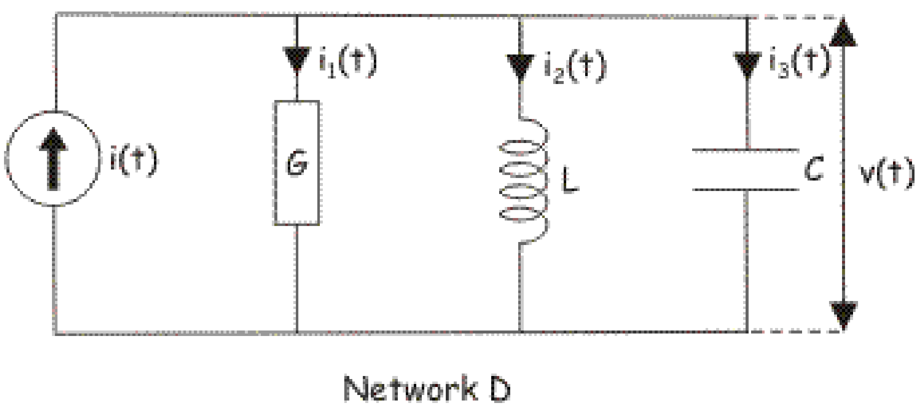
Formation of Dual Networks:

The principle of duality is applicable to planar circuits only. Carefully read the points stated below, follow each step and draw the dual circuit

- Place a dot within each loop, these dots will become nodes of the dual network
- Place a dot outside of the network, this dot will be the ground/datum node of the dual network
- Carefully draw lines between nodes such that each line cuts only one element
- If an element exclusively present in a loop, then connect the dual element in between node and ground/datum node
- If an element is common in between two loops, then dual element is placed in between two nodes
- Branch containing active source, consider as a separate branch
- Now to determine polarity of voltage source and direction of current sources, consider voltage source producing clockwise current in a loop. Its dual current source will have a current direction from ground to non-reference node

Duality and Dual Networks





Problems

Draw the graph from incident matrix and write cut-set matrix

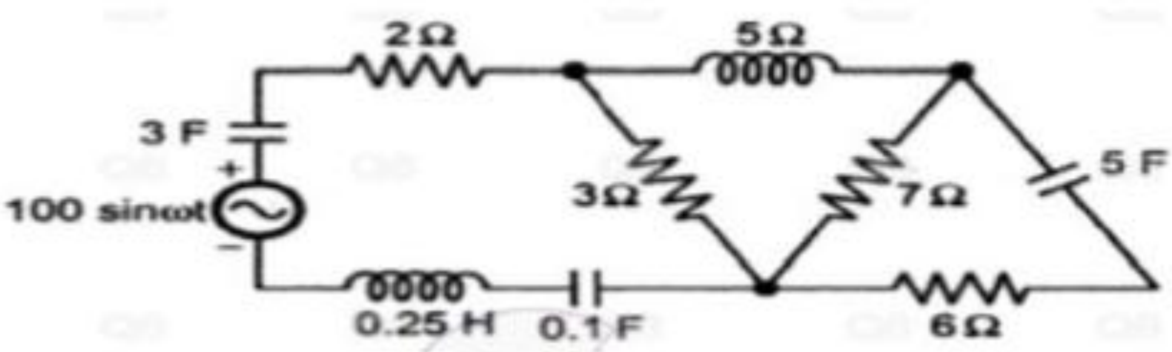
1	0	0	0	-1
-1	-1	-1	0	0
0	0	1	-1	0
0	1	0	1	1

Draw the following

i. Graph

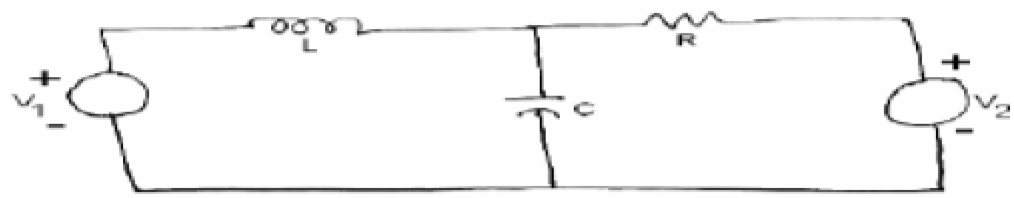
ii. Tree

iii. Dual network of figure shown below.

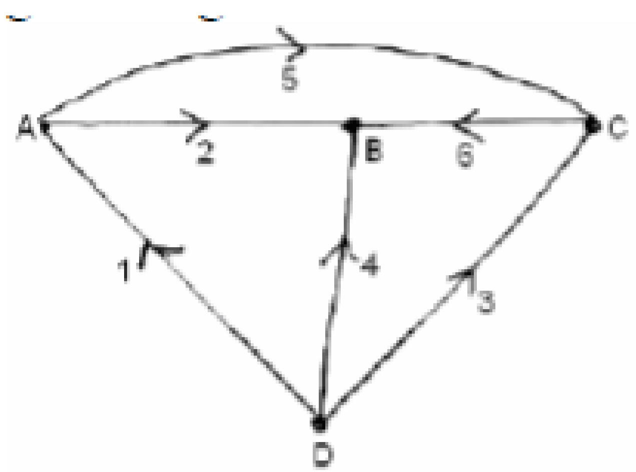


Problems

Explain the principal of duality and draw the dual network.

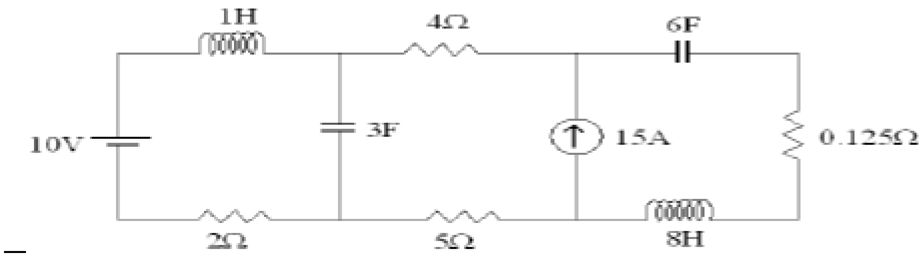


Determine the branch voltages using cut-set matrix.



Problems

Develop the fundamental tie-set matrix for the circuit shown in figure.

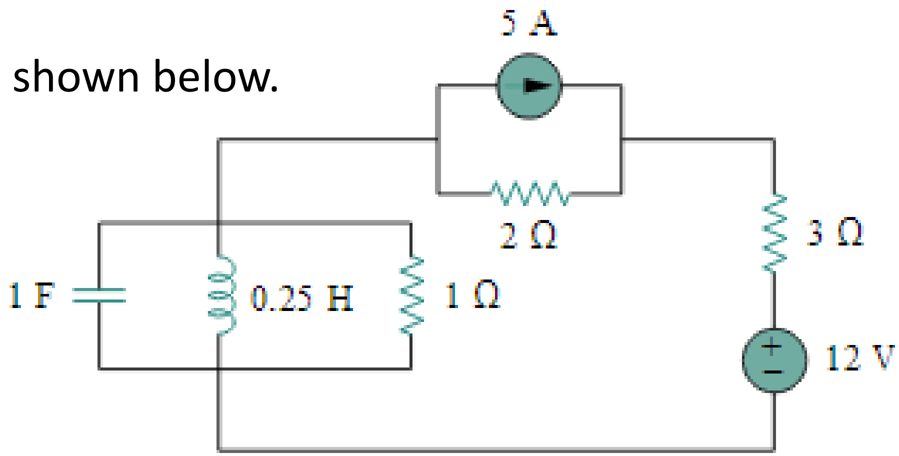


Draw the following

i. Graph

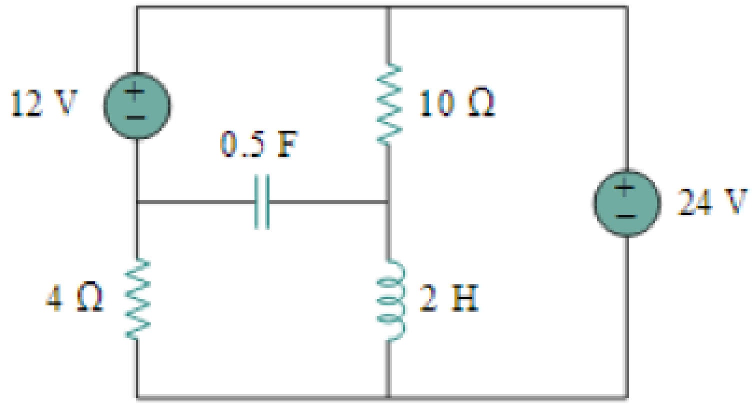
ii. Tree

iii. Dual network of figure shown below.

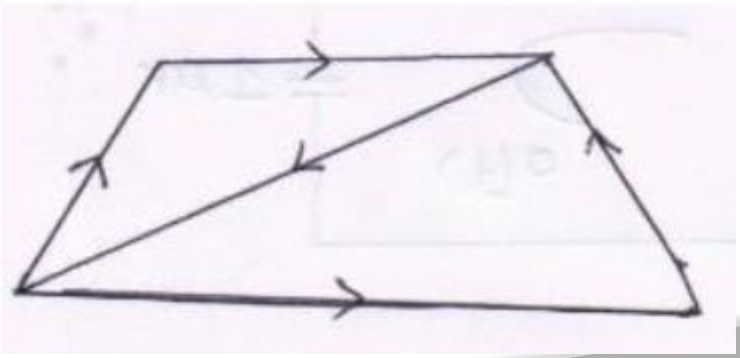


Problems

Explain the principal of duality and draw the dual network.

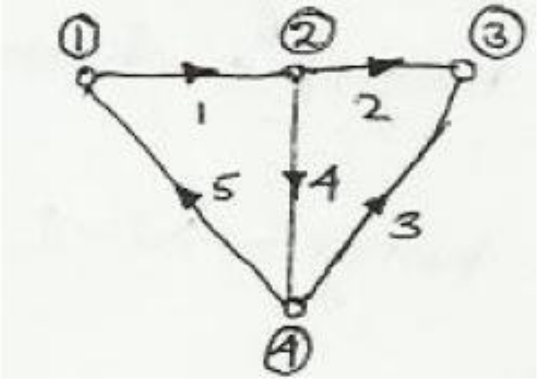


Determine the branch voltages using cut-set matrix.



Problems

Develop the fundamental tie-set matrix for the circuit shown in figure.

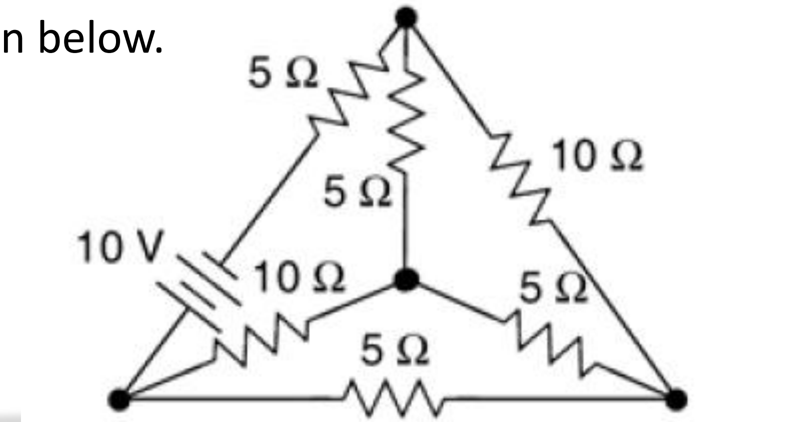


Draw the following

i. Graph

ii. Tree

iii. Dual network of figure shown below.



SINGLE PHASE AC CIRCUITS AND RESONANCE

Course Outcomes

CLOs	Course Learning Outcome
CLO 7	Identify the alternating quantities with it instantaneous, average and root mean square values.
CLO 8	Demonstrate the impression of reactance, susceptance, impedance and admittance in estimating power of AC circuits.
CLO 9	Demonstrate the concept of power, real, reactive and complex power, power factor of AC circuits.
CLO 10	Design the series and parallel RLC for the required bandwidth, resonant frequency and quality factor.

Single phase AC circuits

AC Circuit : The path for the flow of alternating current is called an AC Circuit. The alternating current (AC) is used for domestic and industrial purposes. In an AC circuit, the value of the magnitude and the direction of current and voltages is not constant, it changes at a regular interval of time. It travels as a sinusoidal wave completing one cycle as half positive and half negative cycle and is a function of time (t) or angle (θ=wt).

In DC Circuit, the opposition to the flow of current is the only resistance of the circuit whereas the opposition to the flow of current in the AC circuit is because of resistance (R), Inductive Reactance ($X_L = 2\pi f L$) and capacitive reactance ($X_C = \frac{1}{2\pi f C}$) of the circuit.

Single phase AC circuits

In AC Circuit, the current and voltages are represented by magnitude and direction. The alternating quantity may or may not be in phase with each other depending upon the various parameters of the circuit like resistance, inductance, and capacitance. The sinusoidal alternating quantities are voltage and current which varies according to the sine of angle θ.

For the generation of electric power, in all over the world the sinusoidal voltage and current are selected because of the following reasons are given below.

- The sinusoidal voltage and current produce low iron and copper losses in the transformer and rotating electrical machines, which in turns improves the efficiency of the AC machines.
- They offer less interference to the nearby communication system.
- They produce less disturbance in the electrical circuit.

Single phase AC circuits

The various terms which are frequently used in an AC Circuit are

- Alternating Voltage and Current in an AC Circuit:

The voltage that changes its polarity and magnitude at regular interval of time is called an alternating voltage. Similarly the direction of the current is changed and the magnitude of current changes with time it is called alternating current.

- Amplitude (or) Peak Value: The maximum positive or negative value attained by an alternating quantity in one complete cycle is called Amplitude or peak value or maximum value. The maximum value of voltage and current is represented by Em or Vm and Im respectively.

- Alternation: One half cycle is termed as alternation. An alternation span is of 180 degrees electrical.

- Cycle: When one set of positive and negative values completes by an alternating quantity or it goes through 360 degrees electrical, it is said to have one complete Cycle.

Single phase AC circuits

Instantaneous Value: The value of voltage or current at any instant of time is called an instantaneous value. It is denoted by (i or e).

Frequency: The number of cycles made per second by an alternating quantity is called frequency. It is measured in cycle per second (s) or hertz (Hz) and is denoted by (f).

Time Period: The time taken in seconds by a voltage or a current to complete one cycle is called Time Period. It is denoted by (T).

Wave Form: The shape obtained by plotting the instantaneous values of an alternating quantity such as voltage and current along the y axis and the time (t) or angle (θ=wt) along the x axis is called waveform.

Peat to Peak Value: The peak to peak value of sine wave is the value from the positive to negative peak.

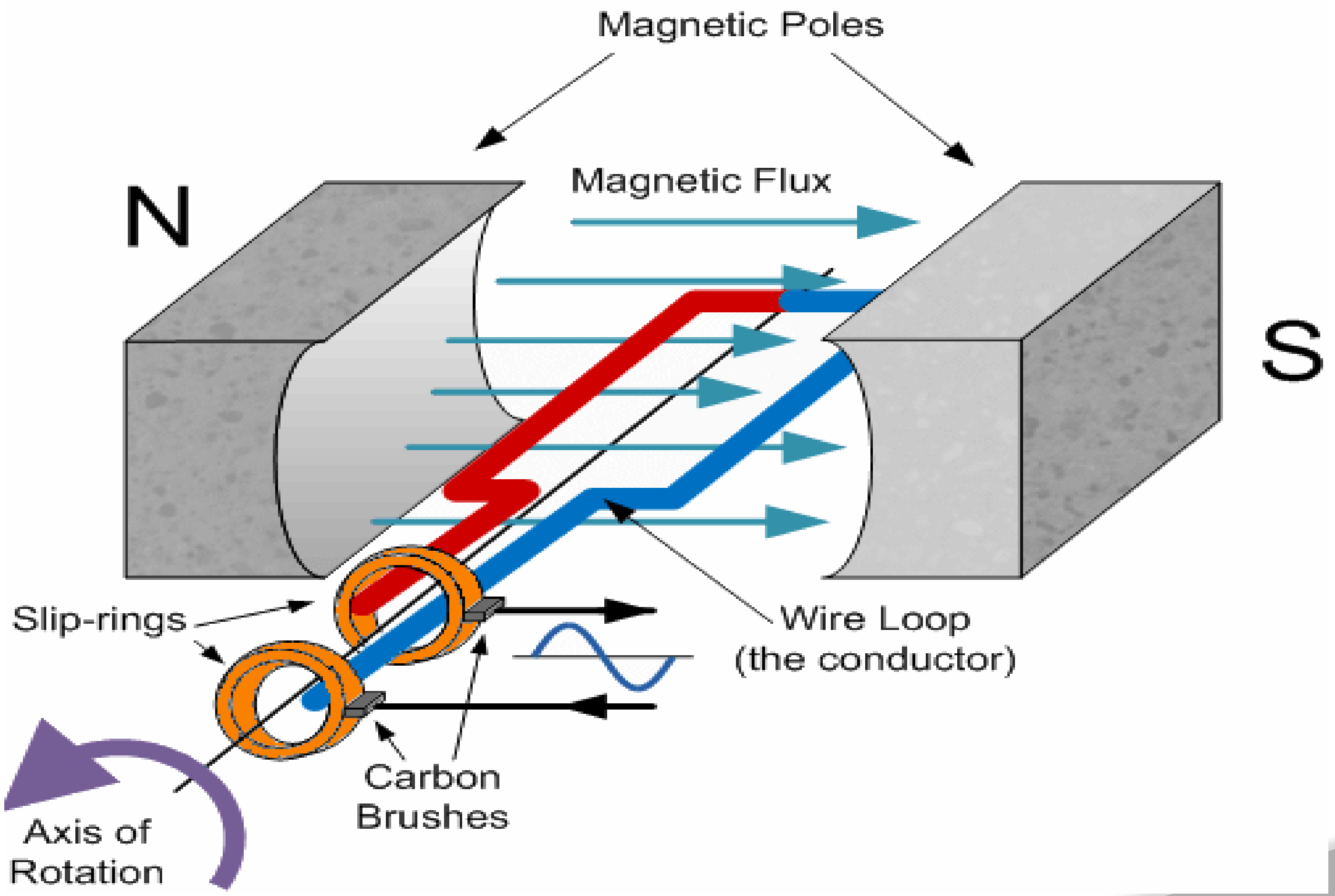
Representation of Alternating Quantities

If this single wire conductor is moved or rotated within a stationary magnetic field, an “EMF”, (Electro-Motive Force) is induced within the conductor due to the movement of the conductor through the magnetic flux.

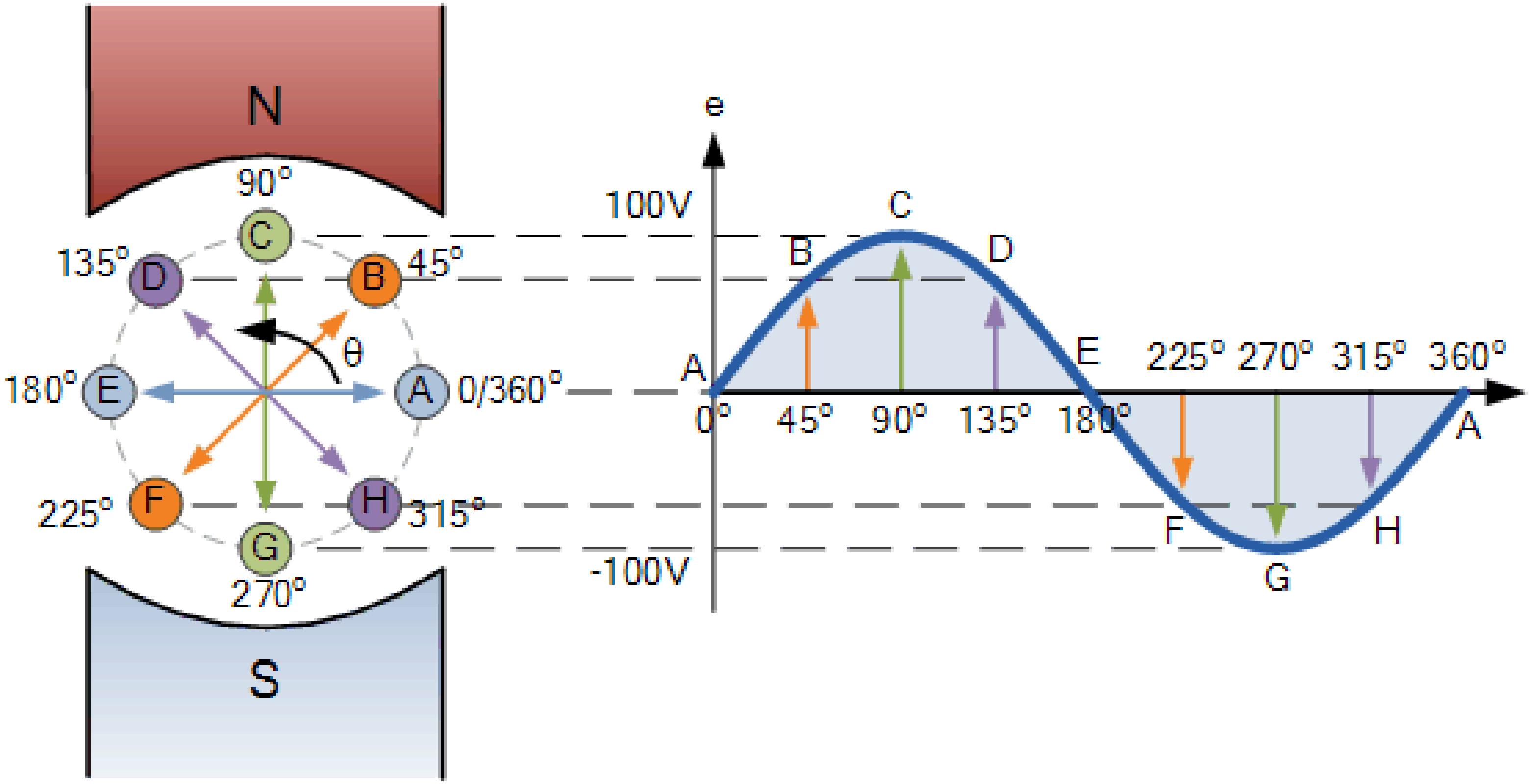
From this we can see that a relationship exists between Electricity and Magnetism giving us, as Michael Faraday discovered the effect of “Electromagnetic Induction” and it is this basic principal that electrical machines and generators use to generate a Sinusoidal Waveform for our mains supply.

An AC generator uses the principal of Faraday’s electromagnetic induction to convert a mechanical energy such as rotation, into electrical energy, a Sinusoidal Waveform. A simple generator consists of a pair of permanent magnets producing a fixed magnetic field between a north and a south pole. Inside this magnetic field is a single rectangular loop of wire that can be rotated around a fixed axis allowing it to cut the magnetic flux at various angles.

Representation of Alternating Quantities



Representation of Alternating Quantities



$$\frac{V_S}{R_S} = I + \frac{V_L}{R_S}$$

Representation of Alternating Quantities

As the coil rotates anticlockwise around the central axis which is perpendicular to the magnetic field, the wire loop cuts the lines of magnetic force set up between the north and south poles at different angles as the loop rotates. The amount of induced EMF in the loop at any instant of time is proportional to the angle of rotation of the wire loop.

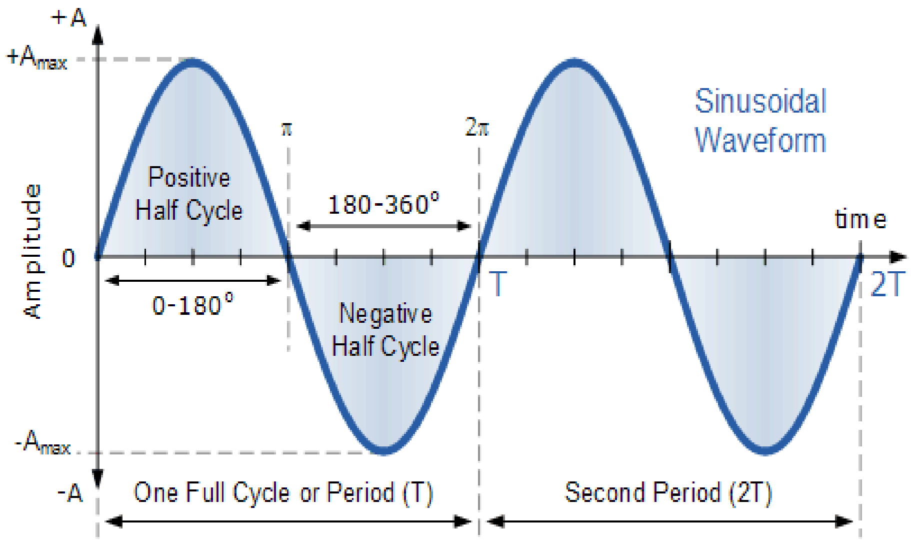
As this wire loop rotates, electrons in the wire flow in one direction around the loop. Now when the wire loop has rotated past the 180 point and moves across the magnetic lines of force in the opposite direction, the electrons in the wire loop change and flow in the opposite direction. Then the direction of the electron movement determines the polarity of the induced voltage.

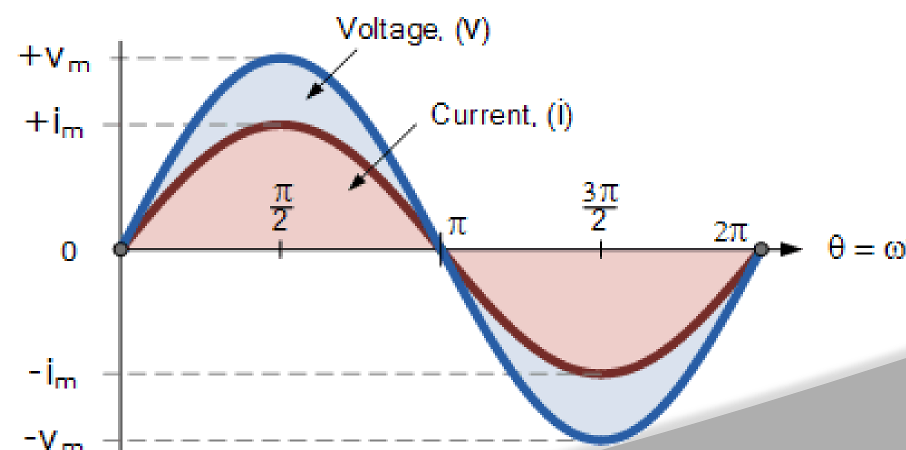
So we can see that when the loop or coil physically rotates one complete revolution, or 360, one full sinusoidal waveform is produced with one cycle of the waveform being produced for each revolution of the coil. As the coil rotates within the magnetic field, the electrical connections are made to the coil by means of carbon brushes and slip-rings which are used to transfer the electrical current induced in the coil.

Representation of Alternating Quantities

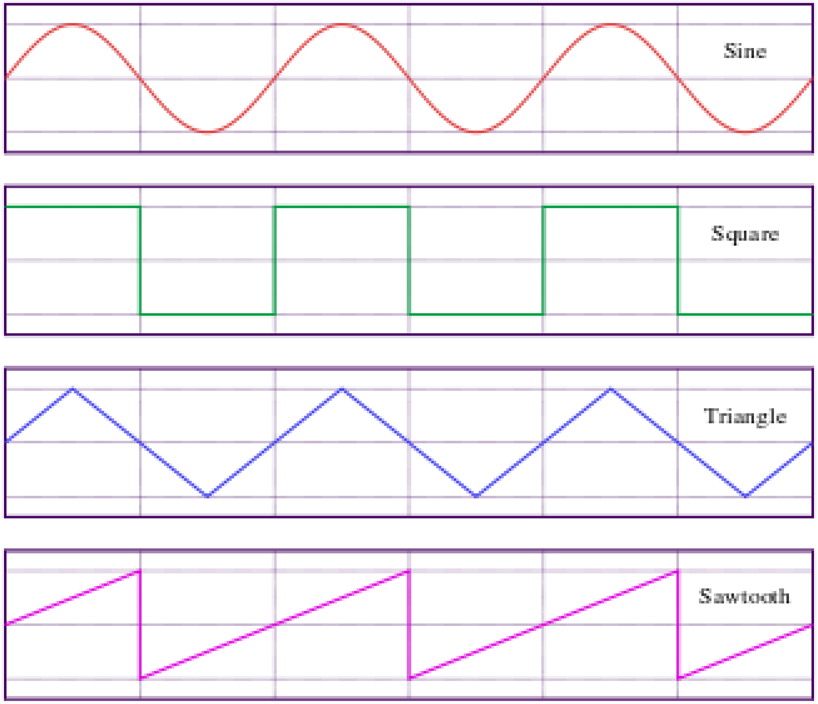
The amount of EMF induced into a coil cutting the magnetic lines of force is determined by the following three factors.

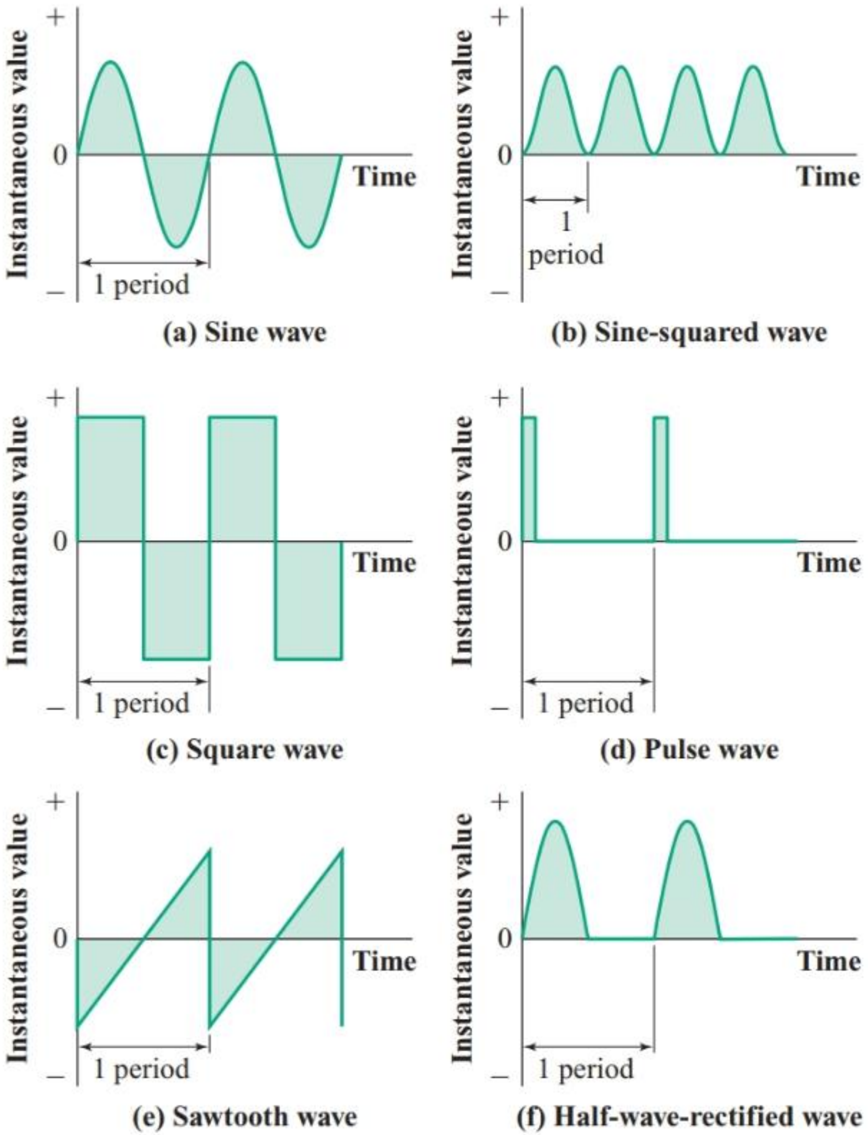
- Speed – the speed at which the coil rotates inside the magnetic field.
- Strength – the strength of the magnetic field.
- Length – the length of the coil or conductor passing through the magnetic field.





Different Periodic Waveforms





Average Value

Average voltage, as the name indicates, is the average of instantaneous voltages that are chosen at appropriately timed intervals in the half cycle of the wave could be sinusoidal, Triangular, trapezoidal or any other shape. Average value represents the quotient of the area under AC wave form with respect to time. It is also known as DC Value.

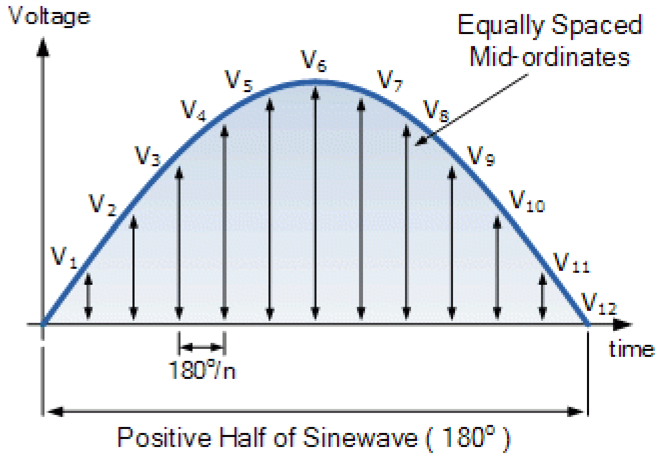
1. Average value is defines as that constant value, which produces the same amount of flux in case of voltage or same amount of charge in case of current as produced by alternating voltage or current when both are applied to the same circuit for the same period.
2. The average value of voltage is the average of all the instantaneous values during one complete cycle. They are actually dc values.
3. The average value is the amount of voltage that would be indicated by a DC voltmeter if it were connected across the load resistor.

Instantaneous value (either voltage or current) of an alternating waveform is the value at any particular instant of time. The voltage of a waveform at a given instant in time is called "Instantaneous voltage".

Instantaneous voltage = Maximum voltage x sin θ

Average Value for Periodic Wave

The average value of an alternating wave (both sinusoidal and non sinusoidal) can be determined graphically by taking the arithmetic mean of the ordinates at equal internals over a half cycle of the wave.



$$I_s R_s = V_s + \frac{I_L}{R_s}$$

The average value of periodic function f(t)

$$V_s = IR_s + V_L$$

RMS Value for Periodic Wave

While calculating Root Mean Square (RMS) value of alternating quantity heat energy produced by constant voltage. RMS value of an ac voltage is defined as that constant voltage, which produce the same amount of heat energy as produced by AC voltage, when both are applied to the same circuit for the same period.

The RMS value of an AC is considerable importance in practice because the ammeters and voltammeters record the RMS value of current and voltage, respectively.

The average power dissipated in the resistor in the interval is

$$V_s = IR_s$$

$$P = I^2R$$

$$V_{R_1}$$

The RMS value of periodic function f(t)

$$v = \frac{dw}{dq}\ (Volts)$$

Therefore, RMS value of AC is

$$V = \frac{W}{Q}\ (Volts)$$

Form Factor and Pear Factor

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

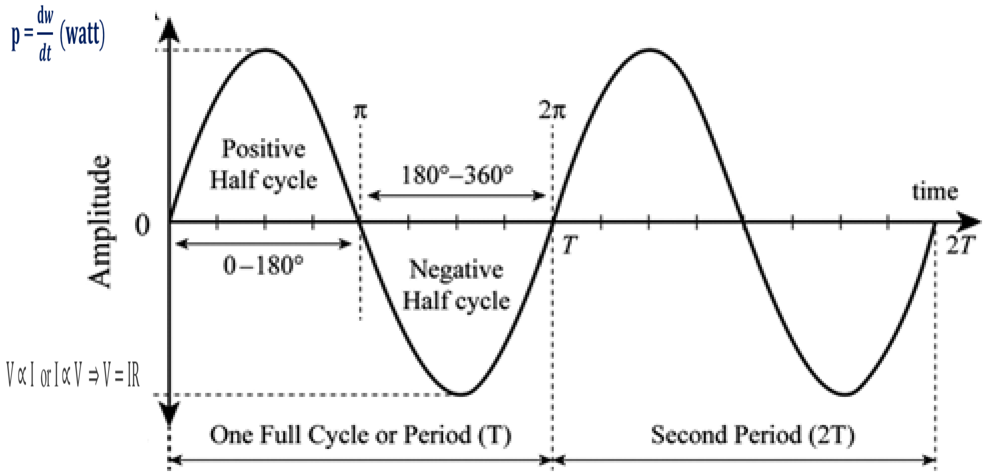
$$\mathbf{I} = \frac{Q}{T} \text{ (Amperes)}$$

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

$$\mathbf{v} = \frac{dq}{dt} \text{ (Amperes)}$$

INTRODUCTION TO AC CIRCUITS

Average Value, RMS Value, form Factor and Peak Factor for Sinusoidal Wave



$$I_s = V_s \frac{R_1+R_2}{R_1 R_2}$$

$$I_1 = I_S \frac{R_2}{R_1+R_2}$$

$$I_2 = I_S \frac{R_1}{R_1+R_2}$$

$$I_N = I_S \frac{R_T}{R_1+R_2}$$

$$I_1 = \frac{V_s}{R_1}$$

$$I_s = \frac{V_s}{R_T}$$

$$R_T = \frac{R_1 R_2}{R_1 + R_2}$$

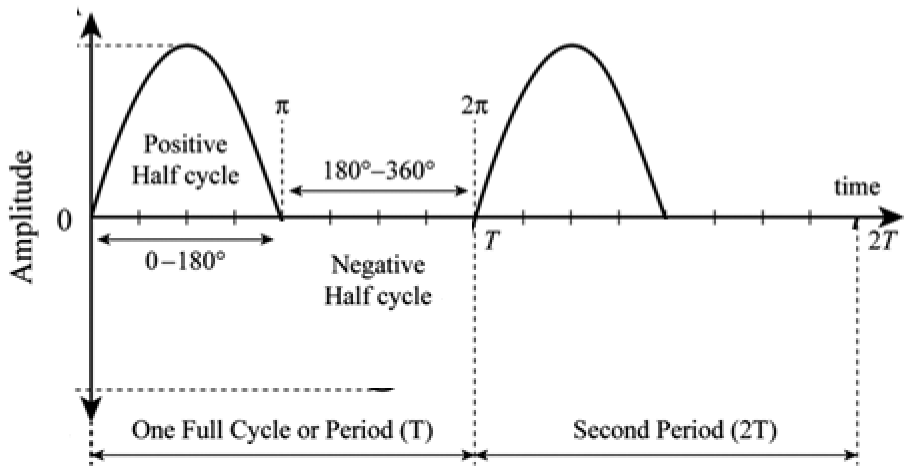
$$I_2 = \frac{V_s}{R_2}$$

$$F_{RMS} = \sqrt{\frac{1}{T}\int_0^T f(t)^2\, dt}$$

$$I_s = \frac{V_s}{\frac{R_1 R_2}{R_1 + R_2}}$$

$$I_s = I_1 R_1 \frac{R_1+R_2}{R_1 R_2}$$

Average Value, RMS Value, form Factor and Peak Factor for Half Sinusoidal Wave



At X//Y $R_1 + R_2$

At X//Z $R_1 + R_3$

At X//Y $\frac{R_c(R_a+R_b)}{R_a+R_b+R_c}$

At Y//Z $\frac{R_a(R_c+R_b)}{R_a+R_b+R_c}$

At X//Z $\frac{R_b(R_c+R_a)}{R_a+R_b+R_c}$

$$I_s = \frac{V_s}{R_T}$$

$$F_{RMS} = \sqrt{\frac{1}{T}\int_0^T f(t)^2\, dt}$$

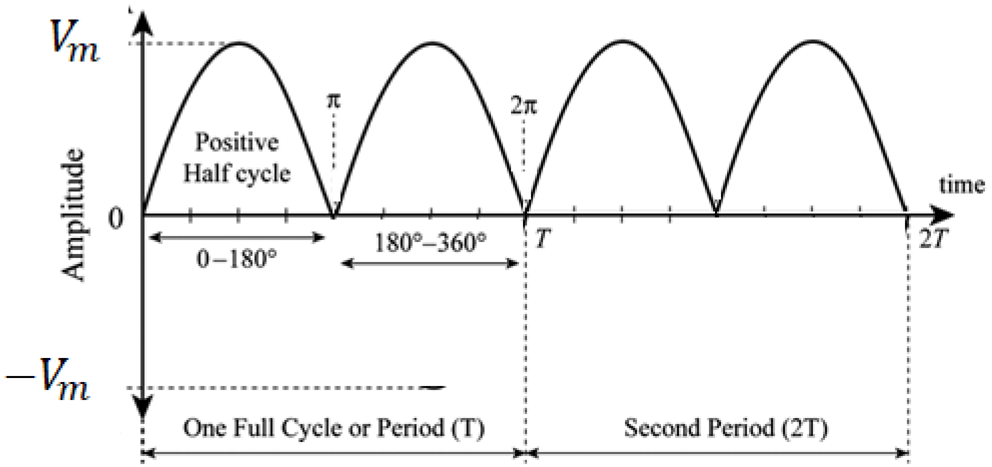
Time period T= 2π *but* (π to 2π) *the value of* $V(t) = 0$

$$V_{Avg} = \frac{1}{2\pi}\int_0^{\pi} V_m \sin(\theta)\, d\theta$$

At Y//Z $R_2 + R_3$

INTRODUCTION TO AC CIRCUITS

Average Value, RMS Value, form Factor and Peak Factor for Full Sinusoidal Wave



$$I_s = V_s \frac{R_1+R_2}{R_1 R_2}$$

$$I_1 = I_S \frac{R_2}{R_1+R_2}$$

$$I_2 = I_S \frac{R_1}{R_1+R_2}$$

$$I_N = I_S \frac{R_T}{R_1+R_2}$$

$$I_1 = \frac{V_S}{R_1}$$

$$I_S = \frac{V_S}{R_T}$$

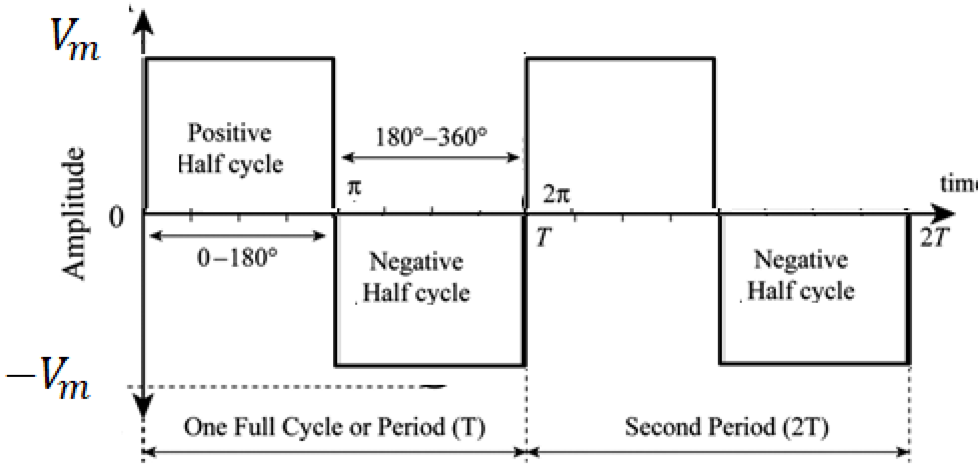
$$F_{RMS} = \sqrt{\frac{1}{T}\int_0^T f(t)^2\,dt}$$

$$R_2 + R_3 = \frac{R_a(R_c + R_b)}{R_a + R_b + R_c} \quad (2)$$

$$I_2 = \frac{V_S}{R_2}$$

$$R_1 + R_3 = \frac{R_b(R_c + R_a)}{R_a + R_b + R_c} \quad (3)$$

Average Value, RMS Value, form Factor and Peak Factor for square Wave



$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c}$$

$$R_2 = \frac{R_a R_c}{R_a + R_b + R_c}$$

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

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

implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses.

Resistance : Resistance is nothing but this property of resisting the flow of electrons or the current. The unit of resistance is **ohm** (Ω) . One ohm is equal to volt per ampere.

From Ohm's law, we have seen that $R = \frac{V}{I}$

$$I_s = \frac{V_s}{R_T}$$

$$F_{RMS} = \sqrt{\frac{1}{T}\int_0^T f(t)^2\, dt}$$

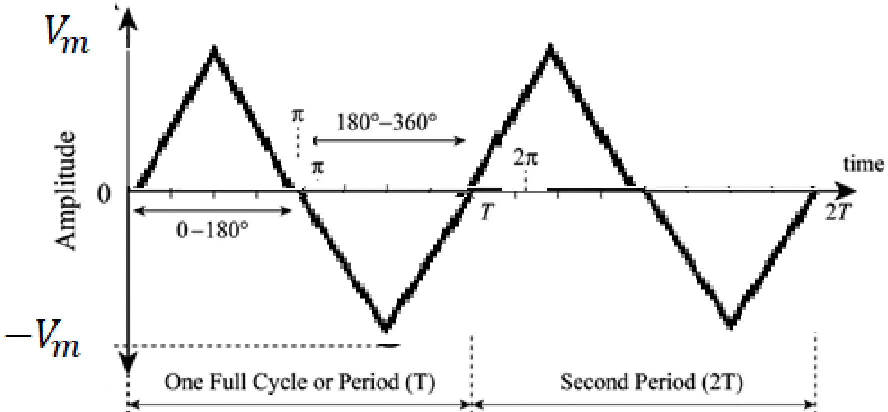
$$V = IR$$

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

$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$$

$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$$

Average Value, RMS Value, form Factor and Peak Factor for Triangular Wave



$$R_1 * R_2 + R_2 * R_3 + R_1 * R_3 = \frac{(R_bR_c)(R_aR_c)}{(R_a+R_b+R_c)^2} + \frac{(R_aR_c)(R_aR_b)}{(R_a+R_b+R_c)^2} + \frac{(R_bR_c)(R_aR_b)}{(R_a+R_b+R_c)^2}$$

$$R_1 * R_2 + R_2 * R_3 + R_1 * R_3 = \frac{(R_aR_bR_c)(R_a+R_b+R_c)}{(R_a+R_b+R_c)^2}$$

$$R_1 * R_2 + R_2 * R_3 + R_1 * R_3 = \frac{(R_aR_bR_c)}{(R_a+R_b+R_c)}$$

$$R_1 * R_2 + R_2 * R_3 + R_1 * R_3 = \frac{(R_aR_bR_c)}{(R_a+R_b+R_c)}$$

$$but\ R_1 = \frac{R_bR_c}{R_a+R_b+R_c} \qquad C = \frac{\varepsilon_0 A}{d}$$

$$\text{Energy} = \frac{1}{2}Cv^2$$

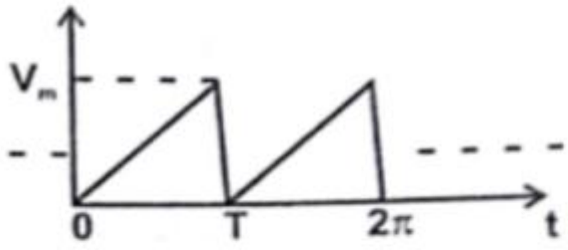
$$R_1 * R_3 = \frac{(R_bR_c)(R_aR_b)}{(R_a+R_b+R_c)^2}$$

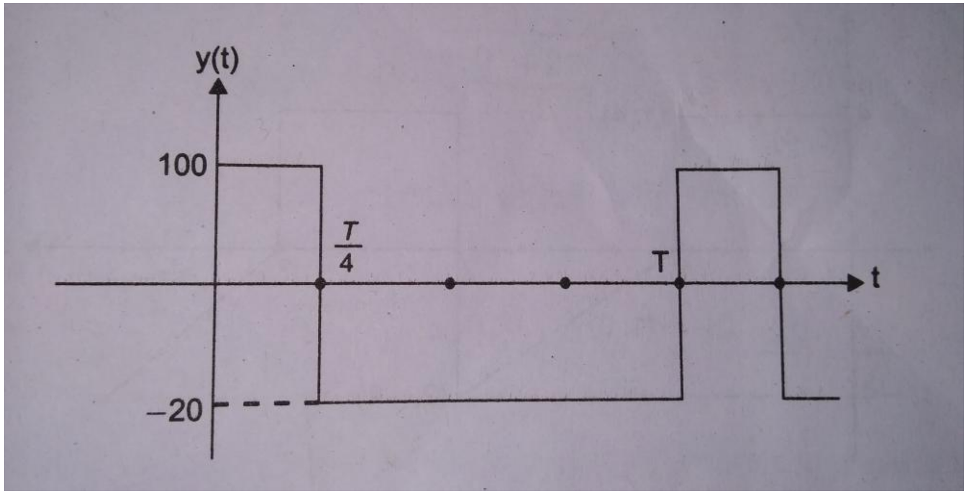
quation $(R_1)*(R_2)$ + Equation $(R_2)*(R_3)$ + Equation $(R_1)*(R_3)$

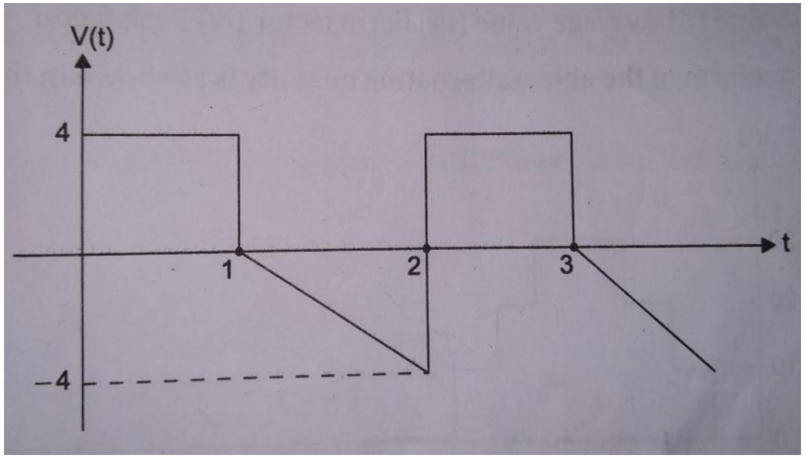
Equation $(R_1)*(R_3)$

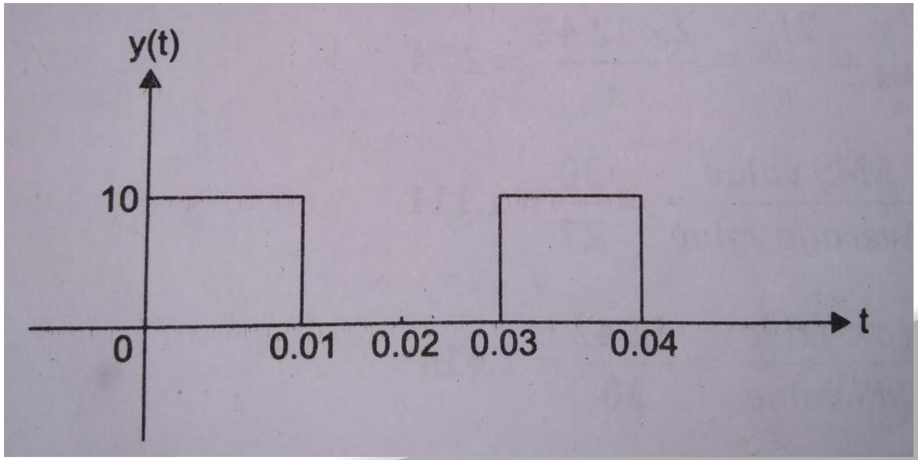
$$R_1 * R_2 + R_2 * R_3 + R_1 * R_3 = \frac{(R_bR_c)(R_aR_c) + (R_aR_c)(R_aR_b) + (R_bR_c)(R_aR_b)}{(R_a+R_b+R_c)^2}$$

Average Value, RMS Value, form Factor and Peak Factor for the given Wave





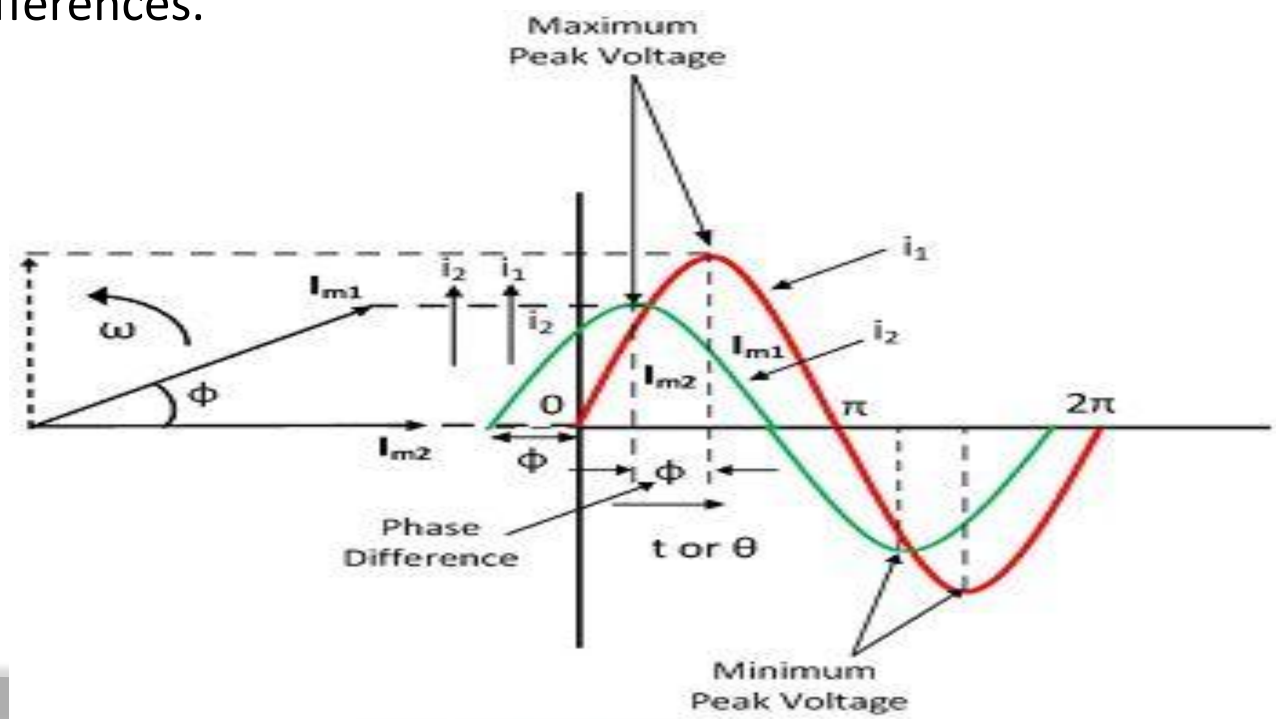




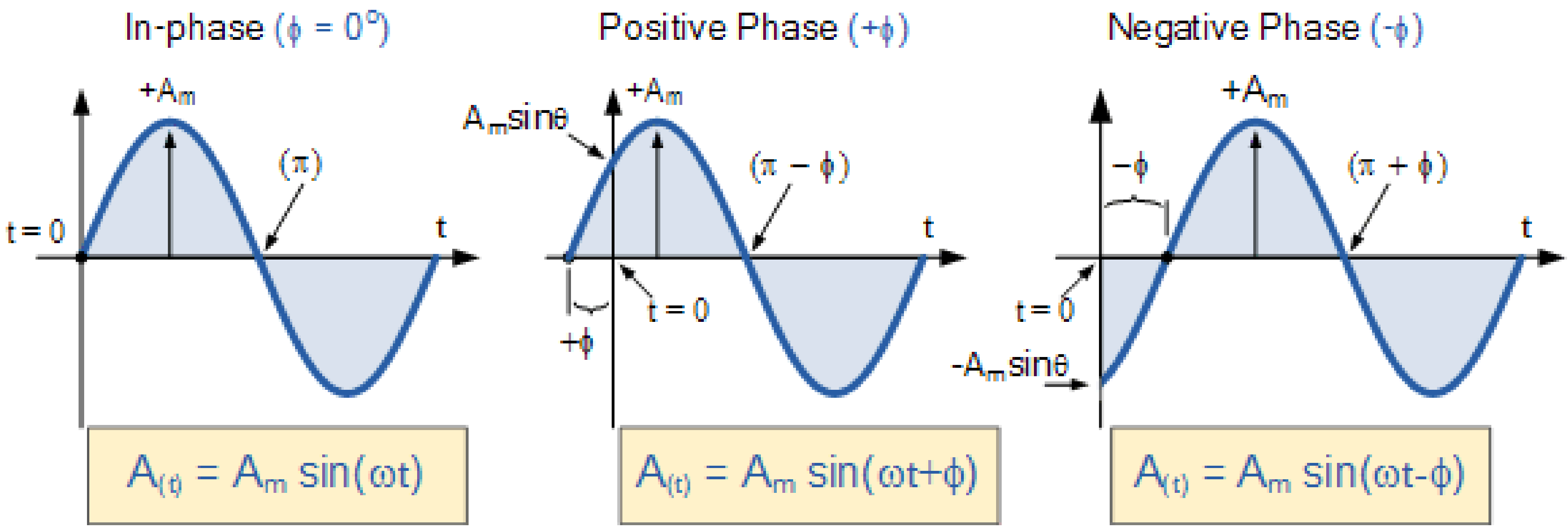
Phase and phase difference

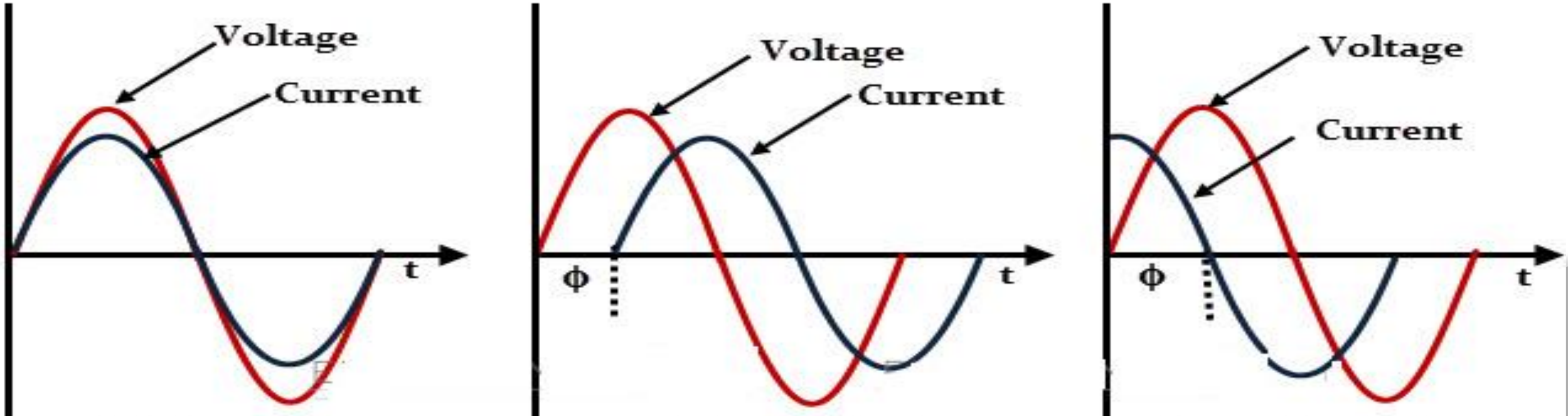
The phase difference between the two electrical quantities is defined as the angular phase difference between the maximum possible value of the two alternating quantities having the same frequency.

In other words, the two alternating quantities have phase difference when they have the same frequency, but they attain their zero value at the different instant. The angle between zero points of two alternating quantities is called angle of phase differences.



Phase and phase difference





Resistive circuit
$\phi = 0$, Unity Power factor

Inductive circuit
Lagging Power factor

Capacitive circuit
Leading Power factor

j Notation

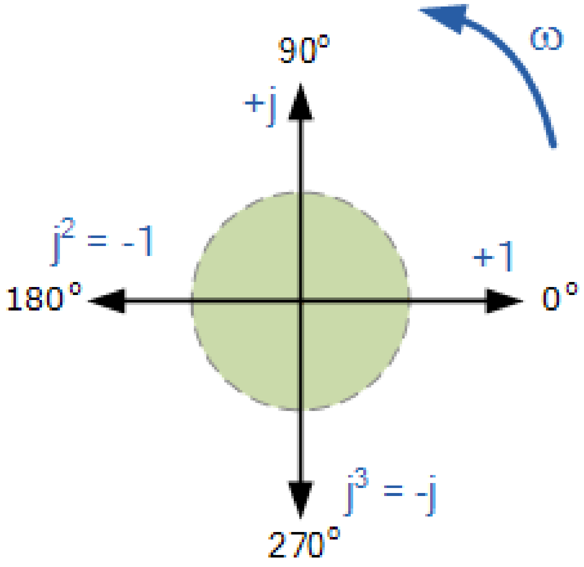
Calculate the equivalent resistance R_{ab}

$$90^0 \text{ rotation:} \quad j^1 = \sqrt{-1} = +j$$

$$180^0 \text{ rotation:} \quad j^2 = \left(\sqrt{-1}\right)^2 = -1$$

$$270^0 \text{ rotation:} \quad j^3 = \left(\sqrt{-1}\right)^3 = -j$$

$$360^0 \text{ rotation:} \quad j^4 = \left(\sqrt{-1}\right)^4 = +1$$



Representation of Rectangular and Polar Forms

Sinusoids are easily expressed in terms of phasors, which are more convenient to work with the sine and cosine functions. Phasors in the complex form can be represented polar and rectangular forms.

Rectangular or Cartesian or Complex Form : $z = x \pm jy$

Polar form : $z = \mathrm{r}\angle \pm \theta$

Trigonometrical Form : $z = \mathrm{r}(cos\theta \pm jsin\theta)$

Exponential : $z = re^{\pm j\theta}$

Representation of Rectangular and Polar Forms

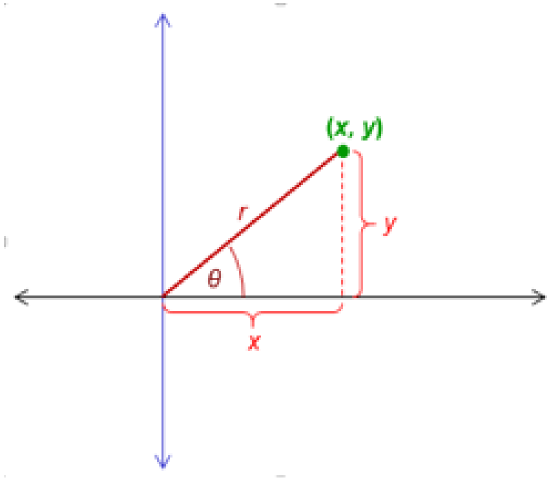
Rectangular Coordinates: (x, y) ⟷ Polar Coordinates: (r, θ)

Convert from rectangular to polar coordinates

$$r = \sqrt{x^2 + y^2} \qquad \theta = \tan^{-1}\frac{y}{x}$$

Convert from polar to rectangular coordinates

$$x = r\cos\theta \qquad y = r\sin\theta$$



Concept of Reactance, Impedance, Susceptance and Admittance.

In electric and electronic systems, **reactance** is the opposition of a circuit element to a change in current or voltage, due to that element's inductance or capacitance.

Reactance is measured in **Ohm's but is given the symbol "X"** to distinguish it from a purely resistive "R" value and as the component in question is an inductor, the reactance of an inductor is called **Inductive Reactance**, (X_L) and is measured in Ohms.

As the capacitor charges or discharges, a current flows through it which is restricted by the internal impedance of the capacitor. This internal impedance is commonly known as **Capacitive Reactance** and is given the symbol (X_C) in Ohms.

Concept of reactance, impedance, susceptance and admittance.

The impedance is defined as the ratio of sinusoidal voltage to the sinusoidal current. It is also defined as the total opposition offered to the flow of sinusoidal current. Hence the impedance is measured in OHMS.

The real part of the impedance is resistance and the imaginary part is reactance.

The mesh or nodal equations are to be solved for finding loop currents or node voltages using Matrix form known as Inspection Method. These equations are algebraic equations of form [A][X]=[B], where [X] is unknown values. The Cramer's rule is a simple method used for solving these equations. It is also known as Method of Determinations. Consider the Equations

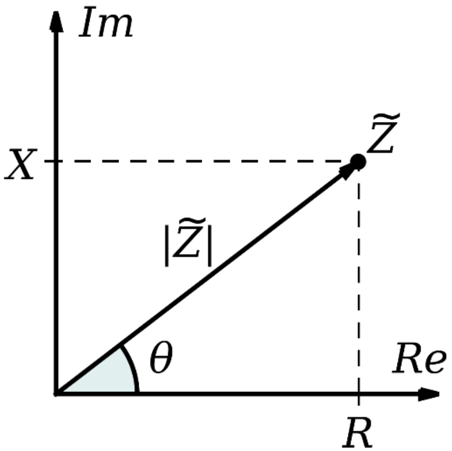
$$A_1X + B_1Y + C_1Z = D_1$$
$$A_2X + B_2Y + C_2Z = D_2$$
$$A_3X + B_3Y + C_3Z = D_3$$

The above equations can be written matrix form as

$$\begin{bmatrix} A_1 & B_1 & C_1 \\ A_2 & B_2 & C_2 \\ A_3 & B_3 & C_3 \end{bmatrix}\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} D_1 \\ D_2 \\ D_3 \end{bmatrix}$$

Using Cramer's rule $X = \frac{|\Delta_1|}{|\Delta|}$; $Y = \frac{|\Delta_2|}{|\Delta|}$; $Z = \frac{|\Delta_3|}{|\Delta|}$

$$\Delta = \begin{bmatrix} A_1 & B_1 & C_1 \\ A_2 & B_2 & C_2 \\ A_3 & B_3 & C_3 \end{bmatrix};\ \Delta_1 = \begin{bmatrix} D_1 & B_1 & C_1 \\ D_2 & B_2 & C_2 \\ D_3 & B_3 & C_3 \end{bmatrix};\ \Delta_2 = \begin{bmatrix} A_1 & D_1 & C_1 \\ A_2 & D_2 & C_2 \\ A_3 & D_3 & C_3 \end{bmatrix}\ \Delta_3 = \begin{bmatrix} A_1 & B_1 & D_1 \\ A_2 & B_2 & D_2 \\ A_3 & B_3 & D_3 \end{bmatrix}$$



Impedance for series Resistive and Capacitive :

$$Z = R - jX_C \ or\ Z = \sqrt{R^2 + X_C^2}\ \angle \tan^{-1}\left(\frac{X_C}{R}\right)$$

Impedance for series Resistive, Inductive and Capacitive :

$$Z = R + j(X_L - X_C) or\ Z = \sqrt{R^2 + X^2}\ \angle \tan^{-1}\left(\frac{X}{R}\right)$$

Concept of Reactance, Impedance, Susceptance and Admittance.

In parallel circuit the inverse of the parameters will be useful for analysis. The inverse of impedance is Admittance. It is also defined as the ratio of sinusoidal current to voltage.

hevenin's Theorem states that "Any linear bilateral network (AC or DC) ontaining several voltages, currents and resistances can be replaced by just one ingle voltage source (V_{th}) in series with a single resistance (R_{th}) connected cross the load". Where V_{th} or V_{oc} is the open circuited voltage measured etween the load terminals & R_{th} is the Thevenin's equivalent resistance neasured across the load when all the voltage sources are replaced by short ircuit and current sources are replaced by open circuit.

Conductance : $G = \frac{1}{R}$

teps to be followed in Thevenin's Theorem

. Remove that portion of the network across which the Thevenin's equivalent circuit is to be found.

I. Find the Thevenin's resistance R_{th}.
   - Remove the load resistance.
   - Replace all sources by their internal resistance (voltage sources are replaced by short circuit and current sources are replaced by open circuit)
   - Find the equivalent resistance R_{th}.

II. Find the Open Circuit Voltage V_{oc} or Thevenin's Voltage V_{th}
   - Remove the load resistance
   - Find the Thevenin's voltage V_{th} across the load terminal

Admittance for series Resistive, Inductive and Capacitive :

$$Y = G + j(B_L - B_C) \text{ or } Y = \sqrt{G^2 + B^2} \angle \tan^{-1}\left(\frac{B}{G}\right)$$

MODULE -IV

MAGNETIC CIRCUITS

Course Outcomes

CLOs	Course Learning Outcome
CLO 11	Analyze the steady state behavior of series and parallel RL, RC and RLC circuit with sinusoidal excitation.
CLO 12	Determine magnetic flux, reluctance, self and mutual inductance in the single coil and coupled coils magnetic circuits.
CLO 13	State the faraday’s laws of electromagnetic induction used in construction of magnetic Circuit.

Complex power analysis

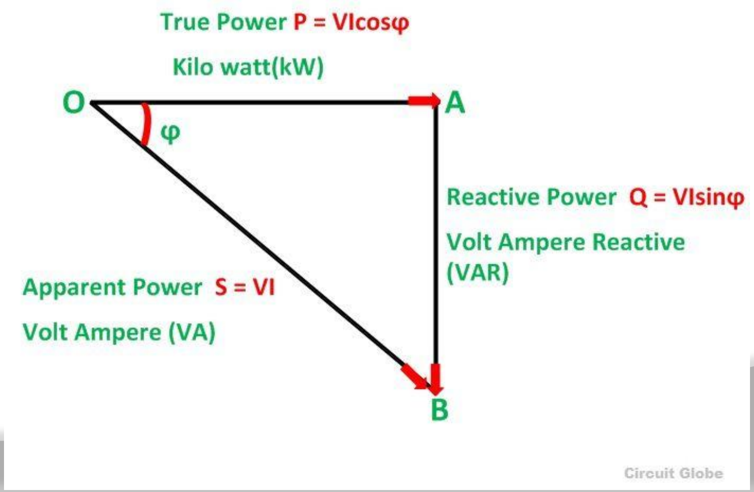
AC Circuit : The path for the flow of alternating current is called an AC Circuit. The alternating current (AC) is used for domestic and industrial purposes. In an AC circuit, the value of the magnitude and the direction of current and voltages is not constant, it changes at a regular interval of time. It travels as a sinusoidal wave completing one cycle as half positive and half negative cycle and is a function of time (t) or angle (θ=wt).

In DC Circuit, the opposition to the flow of current is the only resistance of the circuit whereas the opposition to the flow of current in the AC circuit is because of resistance (R), Inductive Reactance ($X_L = 2\pi f L$) and capacitive reactance ($X_C = \frac{1}{2\pi f C}$) of the circuit.

Complex power analysis

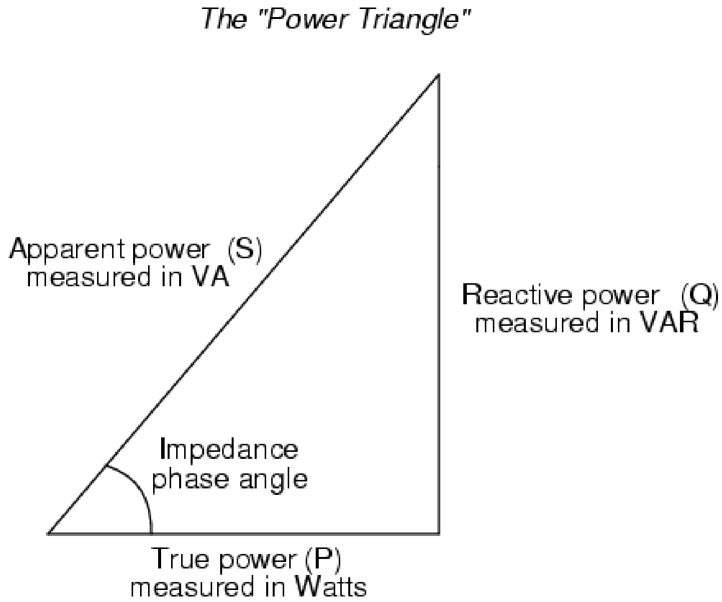
Power Triangle is the representation of a right-angle triangle showing the relation between active power, reactive power and apparent power. When each component of the current that is the active component (Icosφ) or the reactive component (Isinφ) is multiplied by the voltage V

The power which is consumed or utilized in an AC Circuit is called True power or **Active Power** or real power. It is measured in kilowatt (kW) or MW. The power which flows back and forth that means it moves in both the direction in the circuit or react upon it, is called **Reactive Power**. The reactive power is measured in kilovolt-ampere reactive (kVAR) or MVAR. The product of root mean square (RMS) value of voltage and current is known as **Apparent Power**. This power is measured in KVA or MVA.

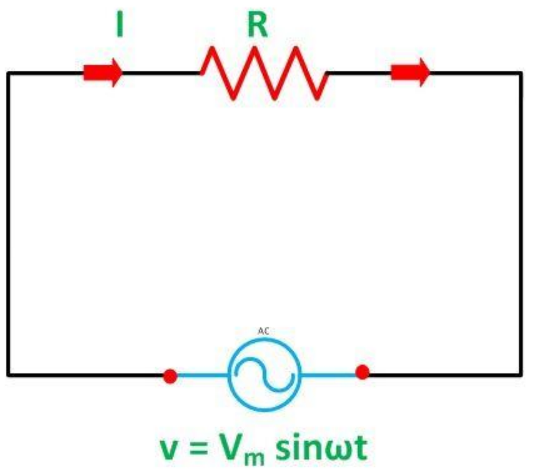


Power Factor

$$\frac{V_S}{R_S} = I + \frac{V_L}{R_S}$$



Single Phase AC circuits consisting of "R"



In an AC circuit, the ratio of voltage to current depends upon the supply frequency, phase angle, and phase difference. In an AC resistive circuit, the value of resistance of the resistor will be same irrespective of the supply frequency.

$$I_S = I + I_L \qquad I = \frac{Q}{T} \; ($$

$$V_S = IR_S + V_L \qquad v = \frac{dw}{dq} \; (Volts)$$

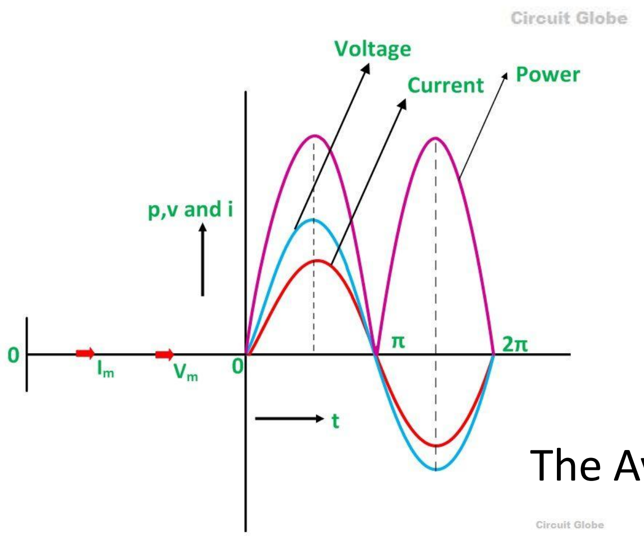
$$I_S R_S = V_S + \frac{I_L}{R_S}$$

$$V_S = IR_S$$

$$P = I^2 R \qquad V_{R1}$$

$$V = \frac{W}{Q} \; (Volts)$$

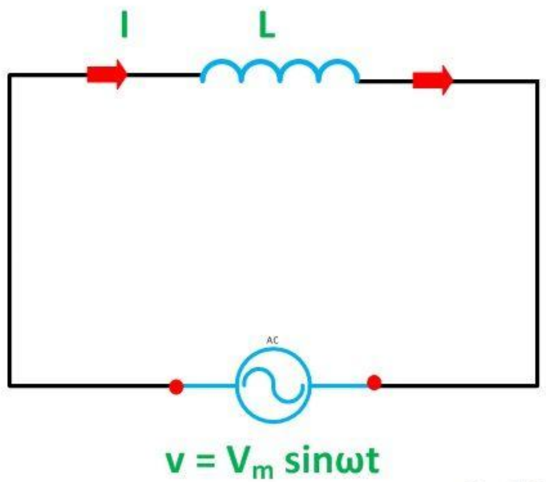
$$I_S = \frac{V_S}{R_S} + I_L$$



The Average power $I_S = \frac{V_S}{R_S}$

COMPLEX POWER ANALYSIS

Single Phase AC circuits consisting of "L"



The circuit which contains only inductance (L) and not any other quantities like resistance and capacitance in the Circuit is called a Pure inductive circuit. In this type of circuit, the current lags the voltage by an angle of 90 degrees.

$$I_S = I + I_L \qquad I_s = I_1 R_1 \frac{R_1+R_2}{R_1R_2}$$

$$I_s = \frac{V_s}{R_T} \qquad I_s = V_s \frac{R_1+R_2}{R_1R_2}$$

$$F_{RMS} = \sqrt{\frac{1}{T}\int_0^T f(t)^2\,dt}$$

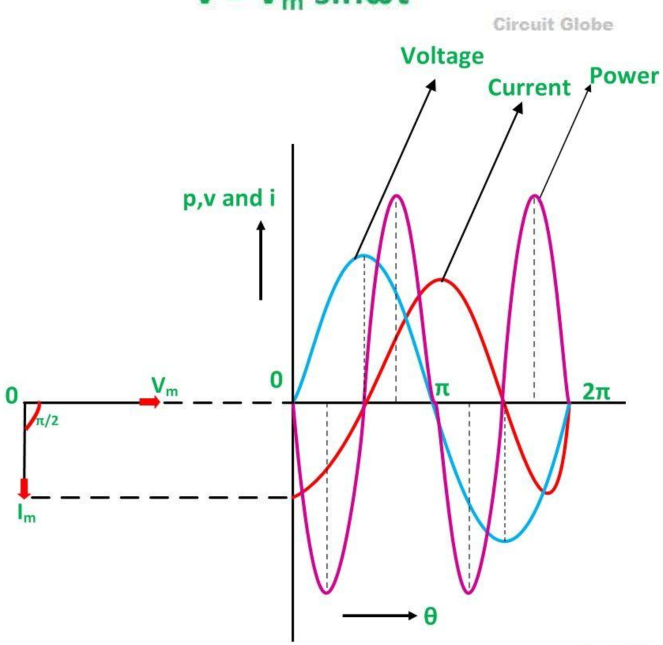
$$P = \frac{W}{T} = VI(\text{watt}) \qquad p = \frac{dw}{dt}\ (\text{watt})$$

$$V \propto I \text{ or } I \propto V \Rightarrow V = IR \qquad I_1 = \frac{V_s}{R_1}$$

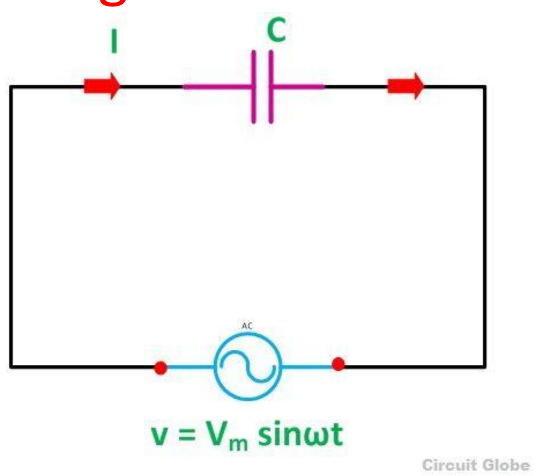
$$I_2 = \frac{V_s}{R_2}$$

$$R_T = \frac{R_1R_2}{R_1+R_2} \qquad I_1 = I_S \frac{R_2}{R_1+R_2}$$

The Average power $I_s = \frac{V_s}{\frac{R_1R_2}{R_1+R_2}}$



Single Phase AC circuits consisting of "C"



The circuit containing only a pure capacitor of capacitance C farads is known as a Pure Capacitor Circuit. In pure AC capacitor Circuit, the current leads the voltage by an angle of 90 degrees

$$V(t) = V_m \sin(wt) = V_m \sin(\theta)$$

At X//Y $R_1 + R_2$

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

Power factor = cos ϕ=0

$$I_N = I_S \frac{R_T}{R_1+R_2}$$

$$I(t) = CwtV_m(coswt)$$

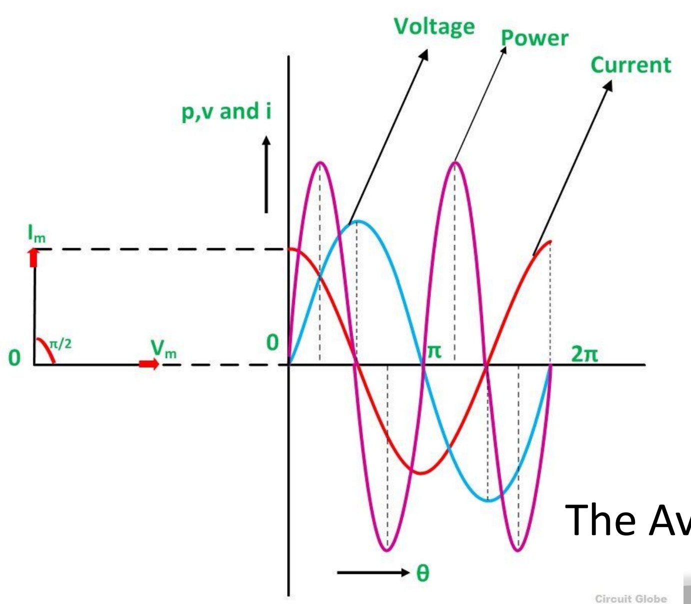
$$I(t) = \frac{V_m}{X_C} sin(wt + \frac{\pi}{2})$$

$$I(t) = I_m sin(wt + \frac{\pi}{2})$$

$$F_{RMS} = \sqrt{\frac{1}{T}\int_0^T f(t)^2\, dt}$$

$$V_{Avg} = \frac{1}{2\pi}\int_0^{\pi} V_m \sin(\theta)\, d\theta$$

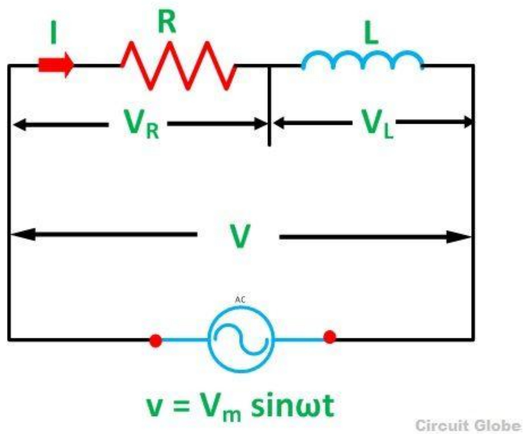
At Y//Z $R_2 + R_3$

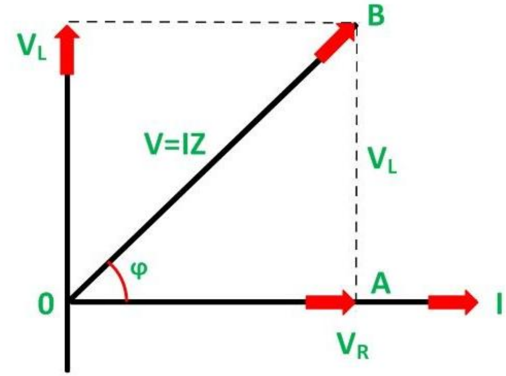


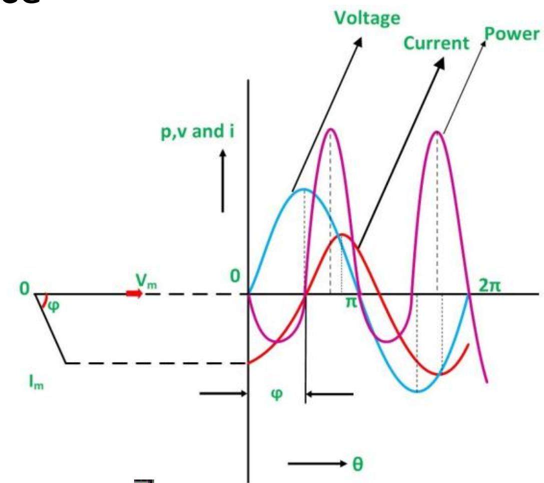
The Average power Time period T= 2π but (π to 2π) the value of V(t) = 0

Single Phase AC circuits consisting of Series "RL" circuit

Consider the RL series circuit excited by sinusoidal voltage source



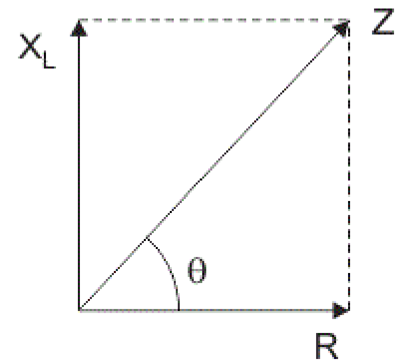




At X//Y $\frac{R_c(R_a+R_b)}{R_a+R_b+R_c}$

At Y//Z $\frac{R_a(R_c+R_b)}{R_a+R_b+R_c}$

At X//Z $\frac{R_b(R_c+R_a)}{R_a+R_b+R_c}$



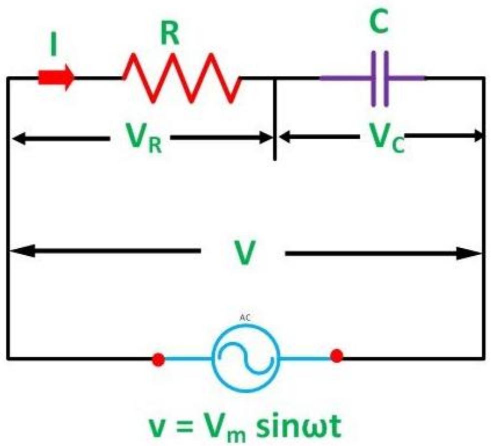
$$R_1 + R_2 = \frac{R_c(R_a + R_b)}{R_a + R_b + R_c} \qquad (1)$$

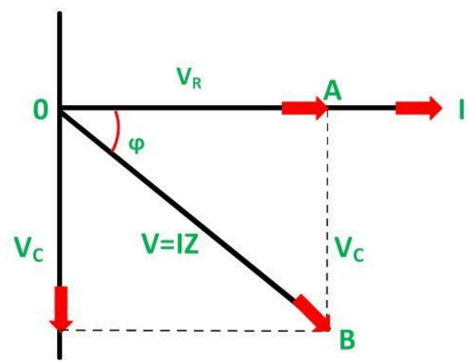
$$R_2 + R_3 = \frac{R_a(R_c + R_b)}{R_a + R_b + R_c} \qquad (2)$$

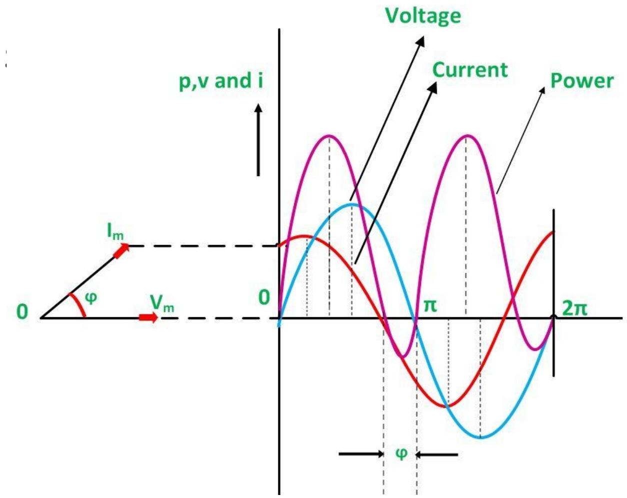
$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$$

Single Phase AC circuits consisting of Series “RC” circuit

Consider the RC series circuit excited by sinusoidal voltage

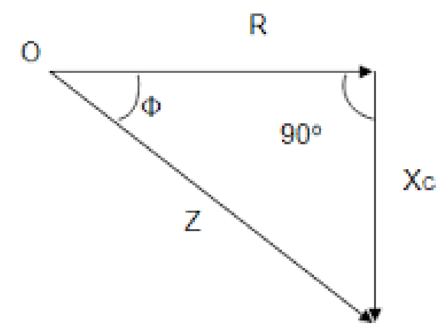






$V = IR$

At Y//Z $\frac{R_a(R_c+R}{R_a+R_b+}$



$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c}$$

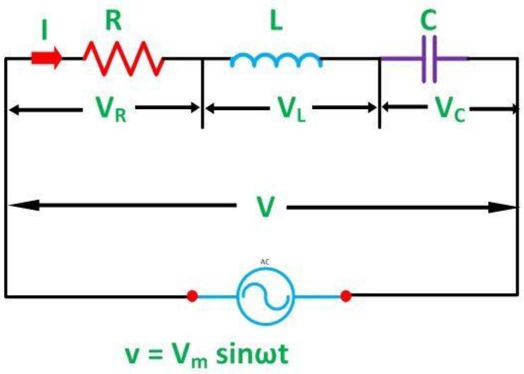
$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$$

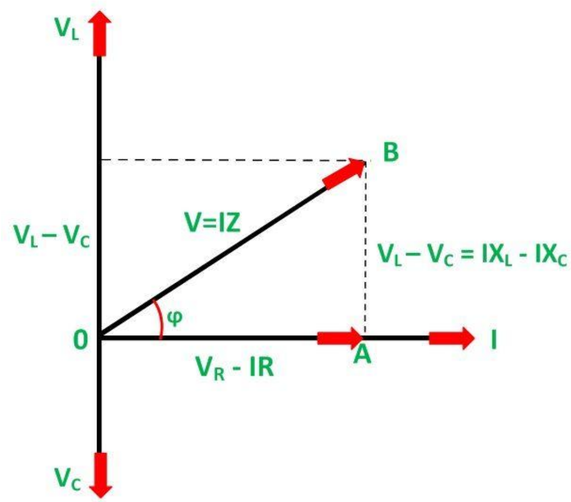
$$R_2 = \frac{R_a R_c}{R_a + R_b + R_c}$$

$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$$

Single Phase AC circuits consisting of Series “RLC” circuit

Consider the RLC series circuit excited by sinusoidal voltage source





$\text{Energy} = \frac{1}{2} C\imath$

$$R_1 * R_3 = \frac{(R_bR_c)(R_aR_b)}{(R_a+R_b+R_c)^2}$$

$$R_1 * R_2 + R_2 * R_3 + R_1 * R_3 = \frac{(R_aR_bR_c)}{(R_a+R_b+R_c)}$$

Equation $(R_1) * (R_3)$

Equation $(R_1) * (R_2)$ + Equation $(R_2) * (R_3)$+ Equation $(R_1) * (R_3)$

$$R_1 * R_2 + R_2 * R_3 + R_1 * R_3 = \frac{(R_bR_c)(R_aR_c)}{(R_a+R_b+R_c)^2} + \frac{(R_aR_c)(R_aR_b)}{(R_a+R_b+R_c)^2} + \frac{(R_bR_c)(R_aR_b)}{(R_a+R_b+R_c)^2}$$

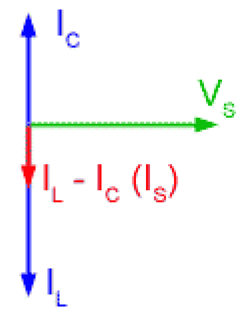
$$R_1 * R_2 + R_2 * R_3 + R_1 * R_3 = \frac{(R_bR_c)(R_aR_c)+(R_aR_c)(R_aR_b)+(R_bR_c)(R_aR_b)}{(R_a+R_b+R_c)^2}$$

COMPLEX POWER ANALYSIS

Single Phase AC circuits consisting of Series "RLC" circuit

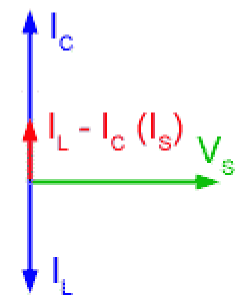
$$C = \frac{\varepsilon_0 A}{d}$$

$$R_1 * R_2 + R_2 * R_3 + R_1 * R_3 = \frac{(R_a R_b R_c)(R_a + R_b + R_c)}{(R_a + R_b + R_c)^2}$$

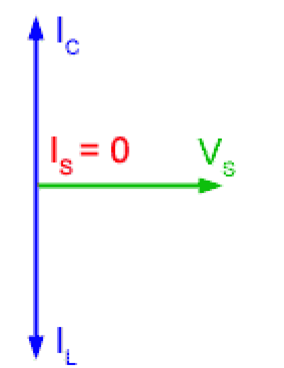


$$R_1 * R_2 + R_2 * R_3 + R_1 * R_3 = \frac{(R_a R_b R_c)}{(R_a + R_b + R_c)}$$

$$R_1 * R_2 + R_2 * R_3 + R_1 * R_3 = R_a \frac{(R_b R_c)}{(R_a + R_b + R_c)}$$



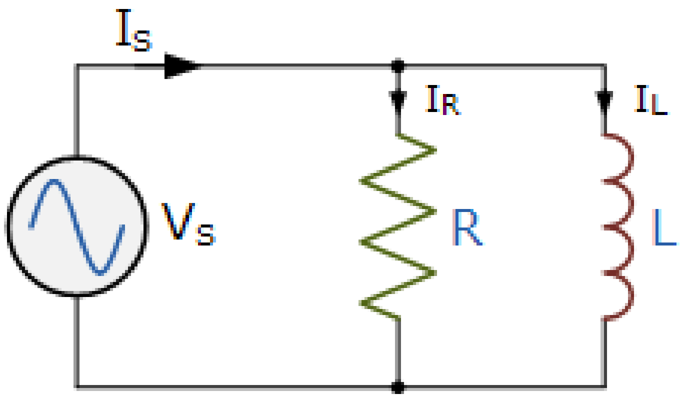
$$but\ R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$$

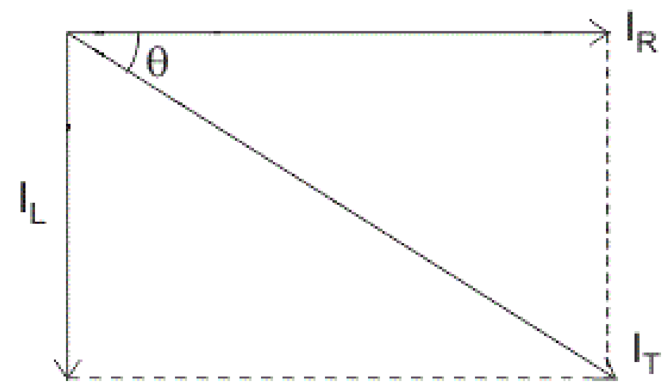


Behaves like a resistive circuit, this condition is called Resonance

COMPLEX POWER ANALYSIS

Single Phase AC circuits consisting of Parallel “RL” circuit





$$\frac{R_1 * R_2 + R_2 * R_3 + R_1 * R_3}{R_1} = I$$

$$\bar{I}_S\angle 0 = \bar{I}_R\angle 0 + \bar{I}_L\angle\text{-}90$$

$$I_S = I_R - jI_L$$

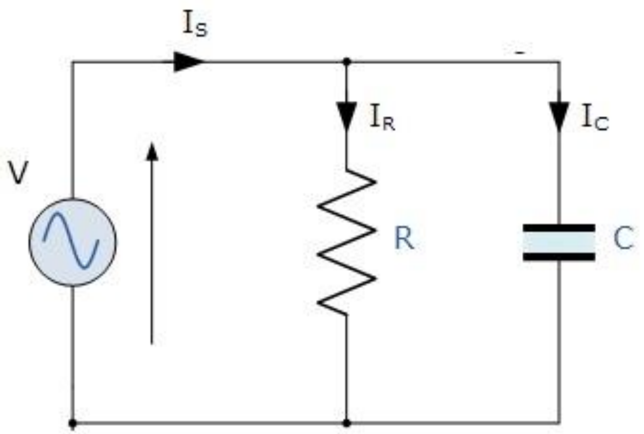
In parallel Voltages are same so $I_S = \dfrac{V_S}{Z}$

Calculate the equivalent

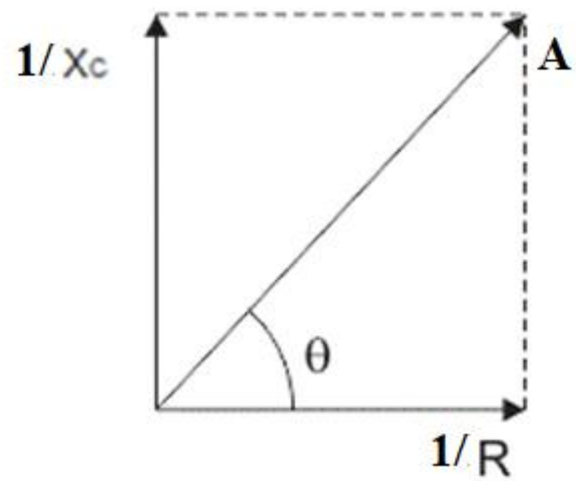
$$z = x \pm jy$$

$$z = r\angle \pm \theta$$

Single Phase AC circuits consisting of Parallel "RC" circuit



V_a



$$\bar{I}_S\angle 0 = \bar{I}_R\angle 0 + \bar{I}_C\angle 90$$

The mesh or nodal equations are to be solved for finding loop currents or node voltages using Matrix form known as Inspection Method. These equations are algebraic equations of form [A][X]=[B], where [X] is unknown values. The Cramer's rule is a simple method used for solving these equations. It is also known as Method of Determinations. Consider the Equations

$$A_1X + B_1Y + C_1Z = D_1$$
$$A_2X + B_2Y + C_2Z = D_2$$
$$A_3X + B_3Y + C_3Z = D_3$$

The above equations can be written matrix form as

$$\begin{bmatrix} A_1 & B_1 & C_1 \\ A_2 & B_2 & C_2 \\ A_3 & B_3 & C_3 \end{bmatrix}\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} D_1 \\ D_2 \\ D_3 \end{bmatrix}$$

Using Cramer's rule $X = \frac{|\Delta_1|}{|\Delta|}$; $Y = \frac{|\Delta_2|}{|\Delta|}$; $Z = \frac{|\Delta_3|}{|\Delta|}$

$\Delta = \begin{bmatrix} A_1 & B_1 & C_1 \\ \ldots \end{bmatrix}$; $\Delta_1 = \begin{bmatrix} D_1 & B_1 & C_1 \\ \ldots \end{bmatrix}$; $\Delta_2 = \begin{bmatrix} A_1 & D_1 & C_1 \\ \ldots \end{bmatrix}$; $\Delta_3 = \begin{bmatrix} A_1 & B_1 & D_1 \\ \ldots \end{bmatrix}$

In parallel Voltages are same so $I_S = \dfrac{V_S}{Z}$

Impedance for series Resistive and Capacitive :

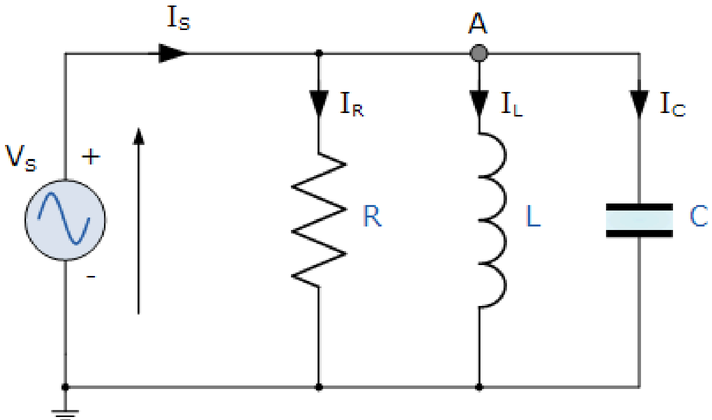
$$Z = R - jX_C \text{ or } Z = \sqrt{R^2 + X_C^2}\angle\tan^{-1}\left(\frac{X_C}{R}\right)$$

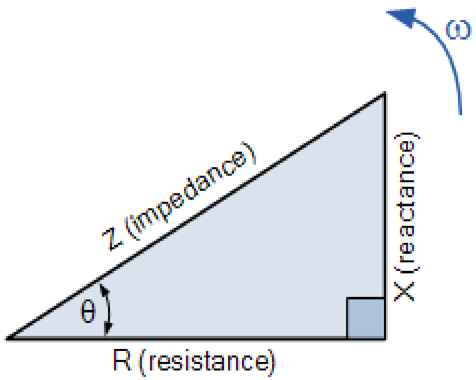
Impedance for series Resistive, Inductive and Capacitive :

$$Z = R + j(X_L - X_C) \text{ or } Z = \sqrt{R^2 + X^2}\angle\tan^{-1}\left(\frac{X}{R}\right)$$

Thevenin's Theorem states that "Any linear bilateral network (AC or DC) containing several voltages, currents and resistances can be replaced by just one single voltage source (V_{th}) in series with a single resistance (R_{th}) connected across the load". Where V_{th} or V_{oc} is the open circuited voltage measured between the load terminals & R_{th} is the Thevenin's equivalent resistance measured across the load when all the voltage sources are replaced by short circuit and current sources are replaced by open circuit.

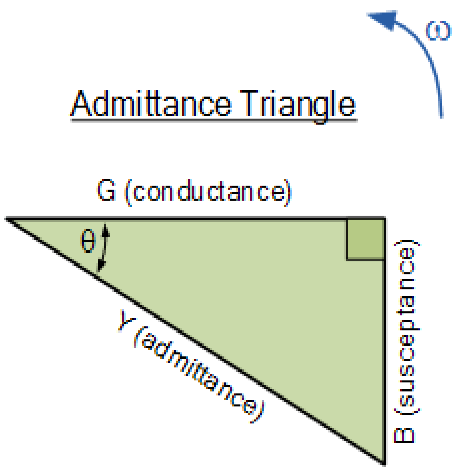
Single Phase AC circuits consisting of Parallel "RLC" circuit





Impedance Triangle

Admittance Triangle



Norton's Theorems states that "Any linear bilateral network (AC or DC) containing several voltages, currents and resistances can be replaced by just on single current source (I_N) in parallel with a single resistance (R_{th}) connected across the load". Where I_N or I_{sc} is the short-circuited current measured between the load terminals & R_{th} is the Norton's equivalent resistance measur across the load when all the voltage sources are replaced by short circuit and current sources are replaced by open circuit.

$$\bar{I}_S\angle 0 = \bar{I}_R\angle 0 + \bar{I}_L\angle\text{-}90 + \bar{I}_C\angle 90$$

Steps to be followed in Norton's Theorems

I. Remove that portion of the network across which the Norton's equivalent circuit is to be found.
II. Find the Norton's resistance R_{th}.
  - Remove the load resistance.
  - Replace all sources by their internal resistance (voltage sources are replaced by short circuit and current sources are replaced by open circuit)
  - Find the equivalent resistance R_{th}.
III. Find the Short Circuit Current I_{sc} or Norton's current I_N
  - Remove the load resistance
  - Find the Norton's current I_N across the load terminal

In parallel Voltages are same so $I_S = \dfrac{V_S}{Z}$

$$\frac{1}{Z} = \frac{1}{R} + j\left(-\frac{1}{X_L} + \frac{1}{X_C}\right)$$

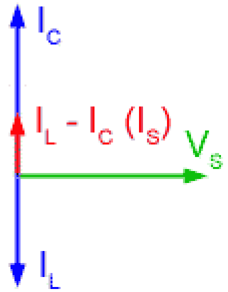
$$A = G + j(B_C - B_L) = \sqrt{G^2 + (B_C - B_L)^2}\angle\tan^{-1}\left(\frac{(B_C - B_L)}{G}\right)$$

$$A = Admitance = \frac{1}{Z};\ G = \ Conductance = \frac{1}{R};\ \ B_C = Susceptance = \frac{1}{(X_C - X_L)}$$

COMPLEX POWER ANALYSIS

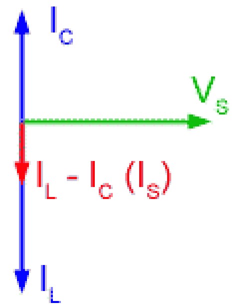
Single Phase AC circuits consisting of Parallel "RLC" circuit

Case(i): "X" is Positive i.e $B_C - B_L > 0$ or $B_C > B_L$



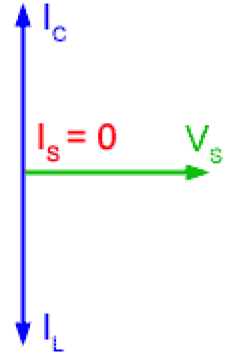
Current "I" Leads by ϕ

Case(ii): "X" is Positive i.e$B_C - B_L < 0$ or $B_C < B_L$



Current "I" lags by ϕ

Case(iii): "X" is Positive i.e$B_C - B_L = 0$ or $B_C = B_L$



Behaves like a resistive circuit, this condition is called Resonance

MODULE -V

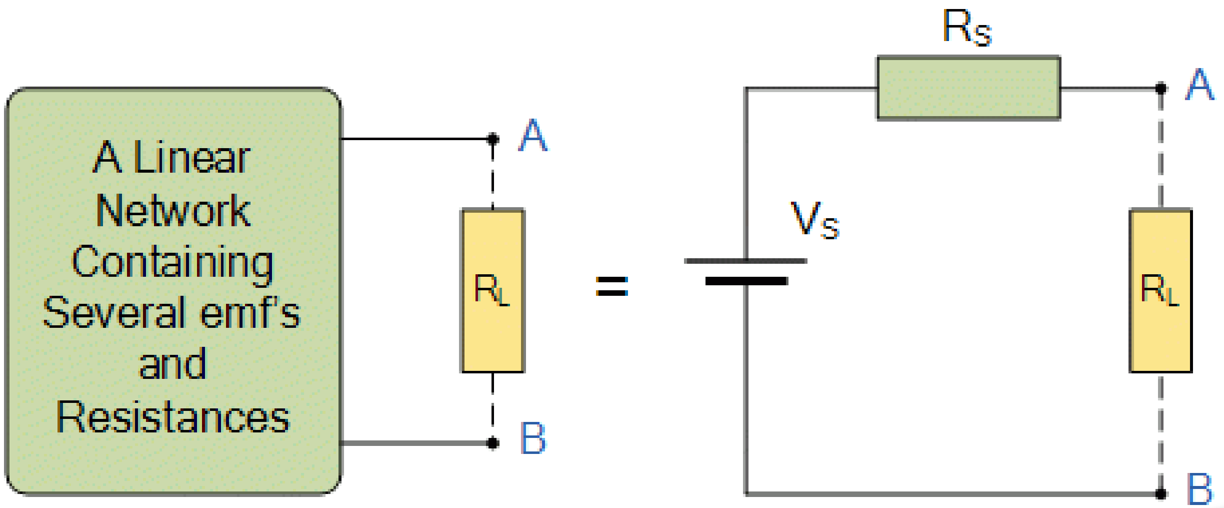
NETWORK THEOREMS (DC AND AC)

Course Outcomes

CLOs	Course Learning Outcome
CLO 14	Summarize the procedure of thevenin’s, norton’s and milliman’s theorems to reduce complex network into simple equivalent network.
CLO 15	Prove the law of conservation of energy, superposition principle, reciprocity and maximum power transfer condition for the electrical network with DC and AC excitation.

Thevenin's Theorems

Thevenin's Theorem states that "Any linear bilateral network (AC or DC) containing several voltages, currents and resistances can be replaced by just one single voltage source (V_{th}) in series with a single resistance (R_{th}) connected across the load". Where V_{th} or V_{oc} is the open circuited voltage measured between the load terminals & R_{th} is the Thevenin's equivalent resistance measured across the load when all the voltage sources are replaced by short circuit and current sources are replaced by open circuit.



Thevenin's Theorems

Steps to be followed in Thevenin's Theorem

I. Remove that portion of the network across which the Thevenin's equivalent circuit is to be found.

II. Find the Thevenin's resistance R_{th}.

- Remove the load resistance.
- Replace all sources by their internal resistance (voltage sources are replaced by short circuit and current sources are replaced by open circuit)
- Find the equivalent resistance R_{th}.

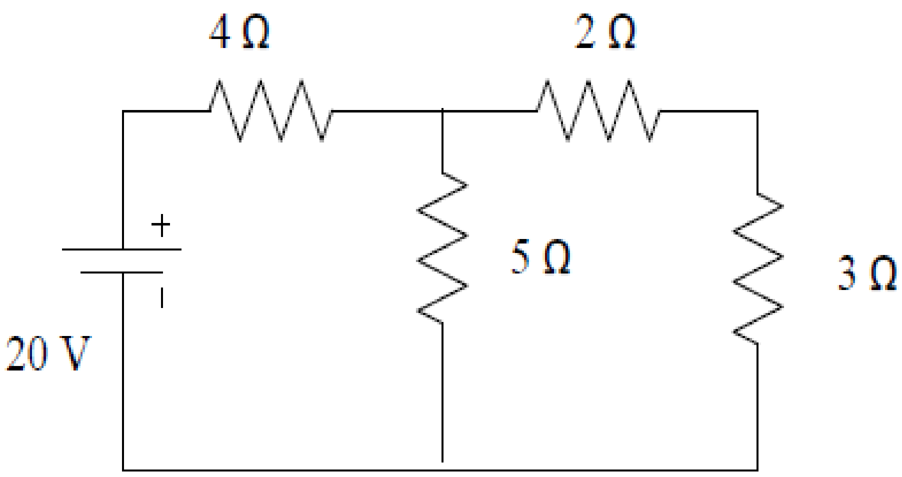
III. Find the Open Circuit Voltage V_{oc} or Thevenin's Voltage V_{th}

- Remove the load resistance
- Find the Thevenin's voltage V_{th} across the load terminal

IV. Draw the Thevenin's Equivalent circuit

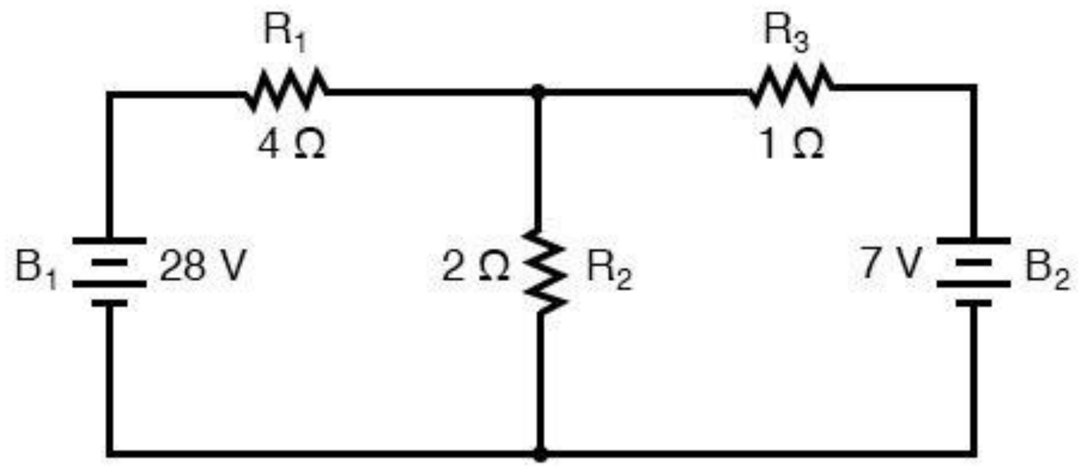
Thevenin’s Theorems

Calculate the current flowing through 3 ohms resistor using Thevenin’s Theorems.



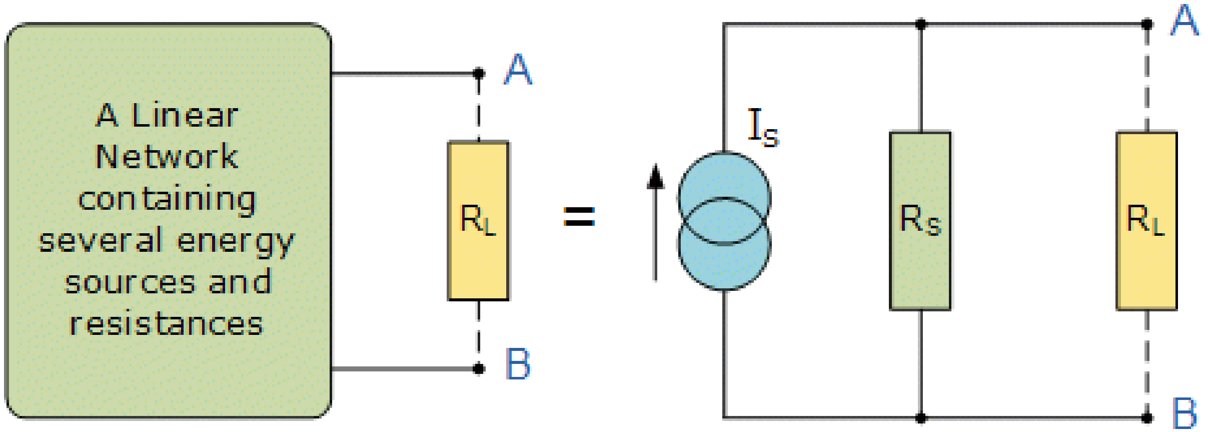
Thevenin's Theorems

Calculate the current flowing through 2 ohms resistor using Thevenin's Theorems.



Norton's Theorems

Norton's Theorems states that "Any linear bilateral network (AC or DC) containing several voltages, currents and resistances can be replaced by just one single current source (I_N) in parallel with a single resistance (R_{th}) connected across the load". Where I_N or I_{sc} is the short-circuited current measured between the load terminals & R_{th} is the Norton's equivalent resistance measured across the load when all the voltage sources are replaced by short circuit and current sources are replaced by open circuit.



Norton’s Theorems

Steps to be followed in Norton’s Theorems

I. Remove that portion of the network across which the Norton’s equivalent circuit is to be found.

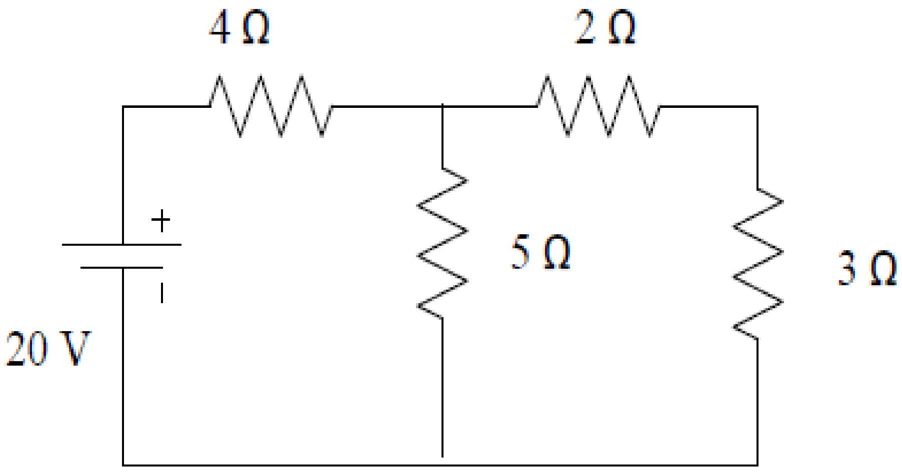
II. Find the Norton’s resistance $\mathrm{R_{th}}$.
   - Remove the load resistance.
   - Replace all sources by their internal resistance (voltage sources are replaced by short circuit and current sources are replaced by open circuit)
   - Find the equivalent resistance $\mathrm{R_{th}}$.

III. Find the Short Circuit Current I_{sc} or Norton’s current I_N
   - Remove the load resistance
   - Find the Norton’s current I_N across the load terminal

IV. Draw the Norton’s Equivalent circuit

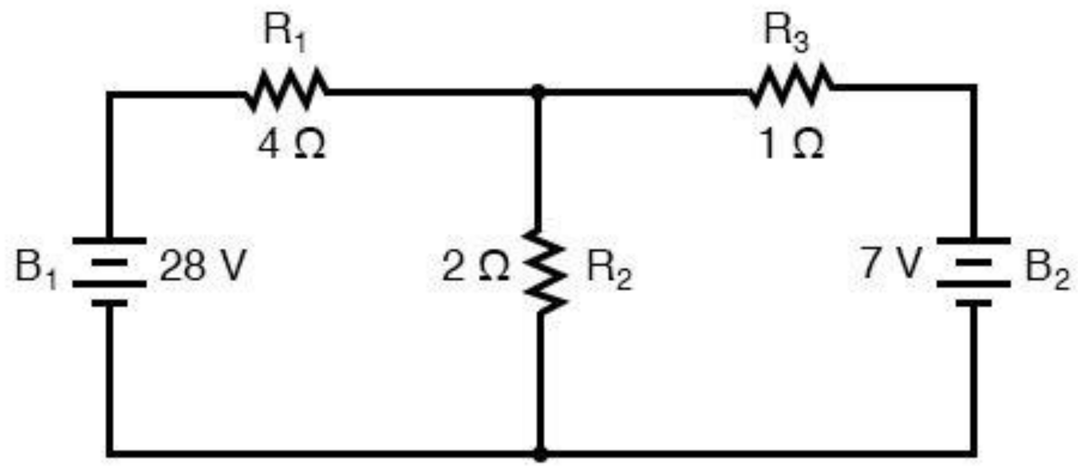
Norton's Theorems

Calculate the current flowing through 3 ohms resistor using Norton's Theorems.



Norton’s Theorems

Calculate the current flowing through 2 ohms resistor using Norton’s Theorems.




Thank you