1. Active passive elements, unilateral bilateral elements, linear non linear elements.
2. KCL, KVL, nodal,mesh,thevenin, norton, superposition, max power transfer
3. Source conversation, star delta conversation
4. Current division & voltage division
5. R,L,C CIRCUIT

# DC NETWORKS

→ Ohm's law
→ KCL, KVL
→ Network Reduction theorem → (Thevnings, Norton's)
→ Superposition, M.P.T theorem.

## Ohms Law :-

According to ohms law the potential difference across any two point of the conductor, will be directly propotional to the current flowing through it.

$V \propto I$
$V = IR$

## KVL :-

(mesh analysis)

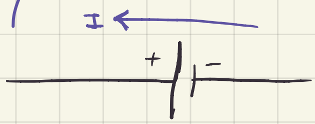
According to the Kirchoff's voltage law. In any closed circuit or mesh, the algebric sum of all the emfs and voltage drops will be zero.

Principal of conservation, energy given = energy consumed.
∴ net supply voltage = net voltage drop

Hence $\Sigma \mathcal{E}mf_1 + \Sigma IR = 0$

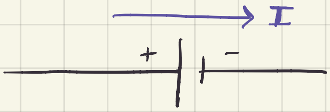
↳ $\Sigma IR = -\Sigma Emf$

a) Rise in Potential




rise in potential
(+ve)

b) Drop in Potential



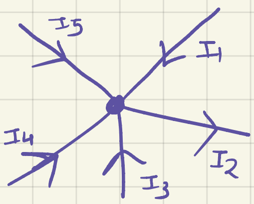

drop in potential (-ve)
potential Drop

## KCL :-

(nodal analysis)

According to Kirchoff's current law, The algebraic sum of all the currents meeting at a point on a junction will be zero.

$\Sigma I = 0$

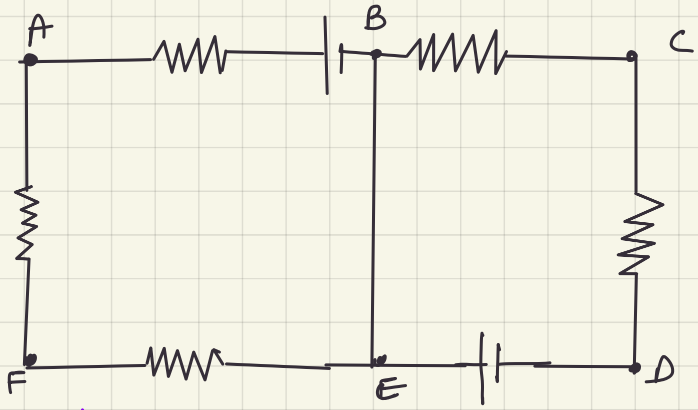


# KVL : Mesh Analysis Method

- Difference between mesh & loop

Closed path through which electric current flows. There can't be any other loop / circuit inside it.

There can be various loop inside loop.




Number of mesh ⟹ 2 (ABEF, BCDE)

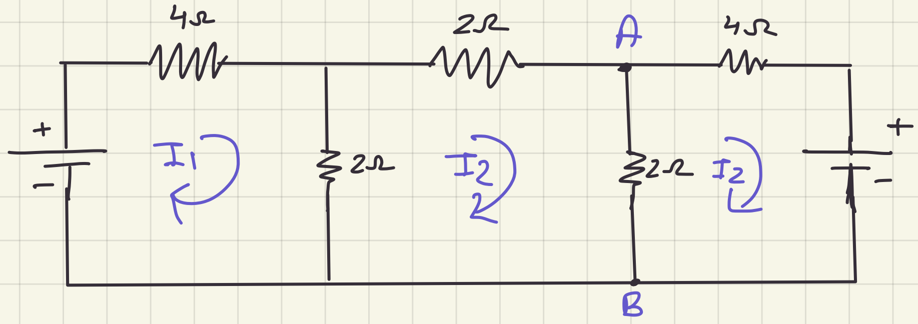
Number of loop ⟹ 3 (including the whole circuit).
(ABEF, BCDE, ACDF)

# Type of Questions.

1) Type 1 : Voltage sources + Resistance
2) Type 2 :- Voltage source + Resistance + Current Source (outer loop).
3) Type 3 :- Voltage source + Resistance + Current Source (inner loop (shared with 2 mesh).)

# Type 1 : Voltage, Resistance

Q1. Calculate the current in branch AB of 2Ω resistance for the given circuit using mesh analysis method.




Soln:- step1:- Identify number of mesh

↳ There are 3 mesh.

step2:- Decide the direction of loop (current)

↳ Clockwise current, $I_1, I_2, I_3$

step3:- Form the equations for each mesh.

↳ Here we will get 3 equations,

* Current of wires between 2 mesh.
⇒ The calculating mesh's current is taken greater always than the other ones'.

We Know $\Sigma Emf + \Sigma IR = 0$

Applying KVL in mesh ①:-

$$10 - I_1 \cdot 4 - 4(I_1 - I_2) = 0$$
$$\Rightarrow 10 - 4I_1 - 4I_1 - 4I_2 = 0$$
$$\Rightarrow 10 - 8I_1 - 4I_2 = 0 \longrightarrow ①$$

Applying KVL in mesh ②:-

$$\Rightarrow -4(I_2 - I_1) - 2(I_2) - 2(I_2 - I_3) = 0$$
$$\Rightarrow -8I_2 + 4I_1 - I_3 = 0$$
$$\Rightarrow 4I_1 - 8I_2 - I_3 = 0 \longrightarrow ②$$

Applying KVL in mesh ③:-

$$\Rightarrow -20 - 2(I_3 - I_2) - 4(I_3) = 0$$
$$\Rightarrow 2I_2 - 6I_3 = 20 \longrightarrow ③$$

Solving ① ② ③

$I_1 = 1.093\ A$

$I_2 = -0.312\ A$

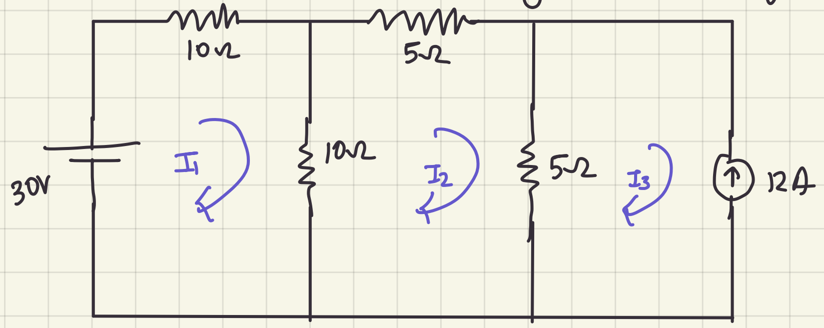
$I_3 = -3.437\ A$

• Therfore resultant current in AB is.

$$I_{AB} = I_2 - I_3$$
$$= -0.312 + 3.437$$
$$I_{AB} = -3.125\ A$$

# Type-2: Voltage Source + Resistance + Current Sources (outer loop)

Q. Find the current in AB Branch using mesh analysis:-




Soln:- 1) There are 3 meshes

2) $I_1, I_2, I_3$ in clockwise direction in 3 mesh

3) forming KVL equation for,

applying KVL in mesh ①

$\Rightarrow 30 - 10I_1 - 10(I_1 - I_2) = 0$

$\Rightarrow 30 - 20I_1 + 10I_2 = 0$ ——— ①

applying KVL in mesh ②

$\Rightarrow 10I_1 - 20I_2 + 5I_3 = 0$ ——— ②

applying KVL in mesh ③

$\Rightarrow I_3 = -12\ A$ (The value of current is already given, which is opposite to the assumed direction, so it's negative.)

→ ③

Solving ①, ②, ③

$I_1 = 0\ A$

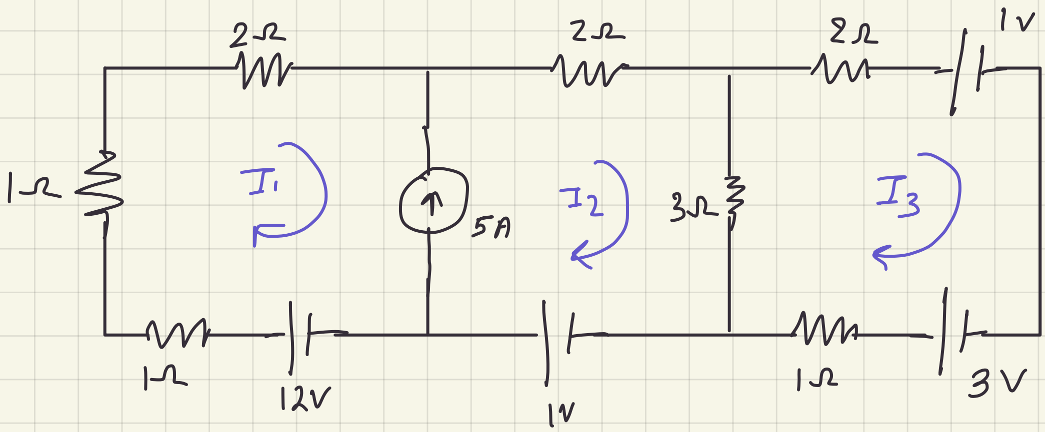
$I_2 = -3\ A$

$I_3 = -12\ A$

∴ Branch in AB

$I_{AB} = I_2 = -3A$

# Type-3: Voltage + Resistance + Current Source (Inside)



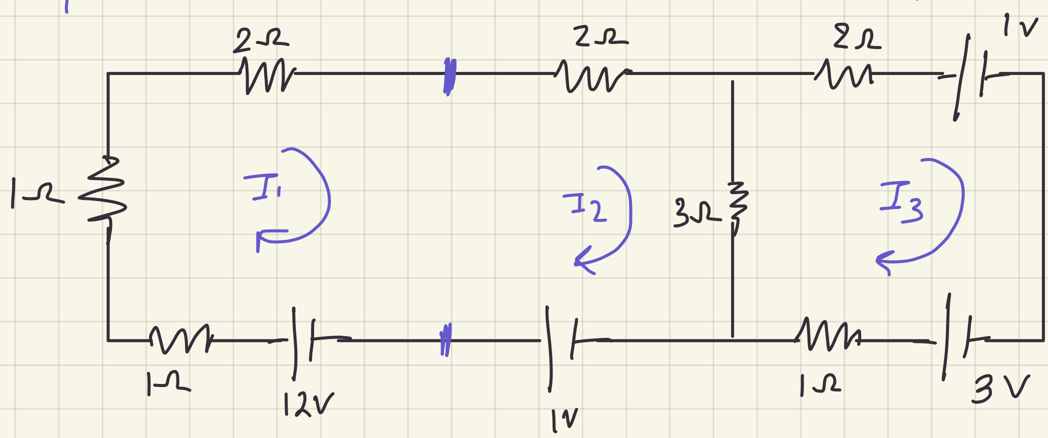

Soln :- Supermesh Method

Form eq. of current source first.

- $I_2 - I_1 = 5$ — (1)

( Since the resultant is in direction of $I_2$ )
$\therefore I_2 > I_1$

- For Supermesh - we can write the combined equation as—




$\Rightarrow -1I_1 - 1I_1 - 2I_1 - 2I_2 - 3(I_2 - I_3) + 1 + 2 = 0$

$\Rightarrow -4I_1 - 5I_2 + 3I_3 + 3 = 0$ —— (2)

- Applying KVL in mesh (3)

$0I_1 + 3I_2 - 6I_3 = -2$ —— (3)

$\therefore I_1 =$
$I_2 =$
$I_3 =$

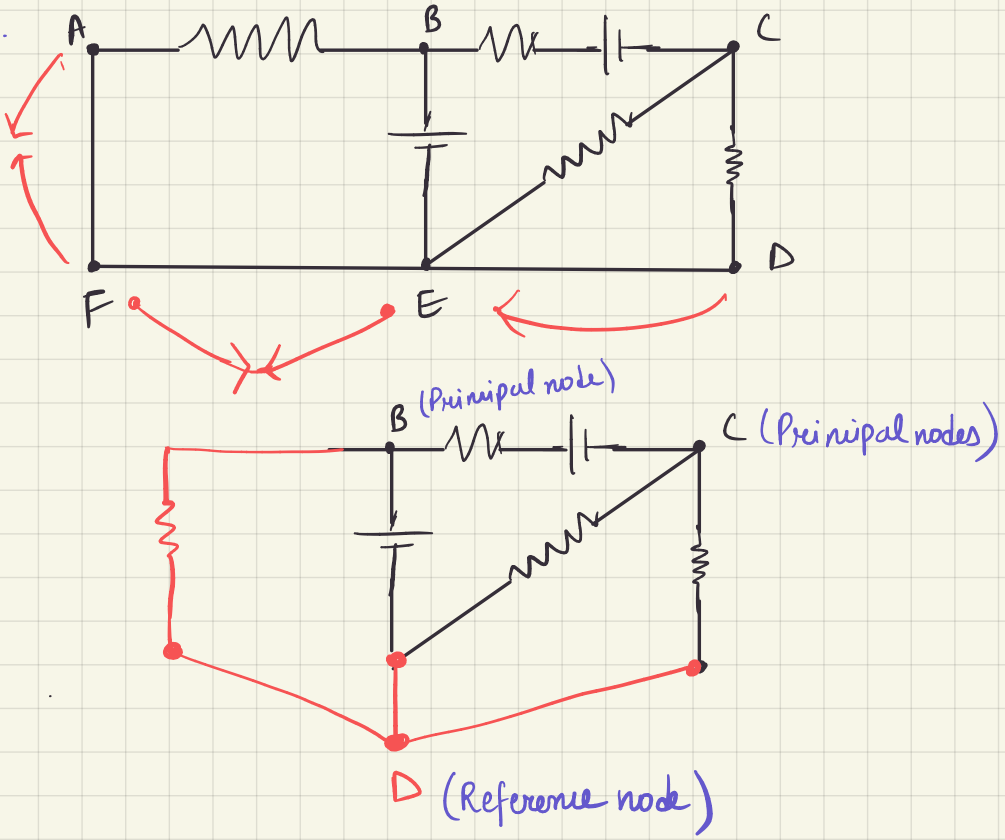
# KCL : Nodal Analysis Method

- Difference between Junction & node

A junction is a point in a circuit where 3 or more than 3 branches combine / divide.

It is a point where 2 or more than 2 branches combine. (only combine) not divide.

Eg.




## STEPS –

1) Identify the principal nodes or junctions present in the network.

2) Assign junction potential on each junction with respect to the assigned reference junction having value $V_0 = 0V$

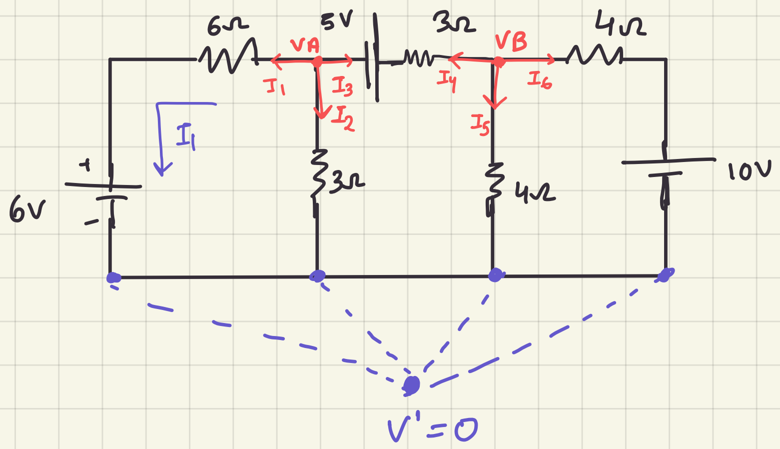
3) Assuming all the currents in outgoing direction from each junction, form KCL eq.

4) Solve the equations to calculate the value of junctions potentials.

5) Using individual junction potential find the value of required electrical quantity.

# Type-1 :- Voltage Source + Resistance

Q1. Find the current in 3Ω resistor using KCL.




● → Junction

Soln:- Applying KCL at junction A:-

$\Rightarrow I_1 + I_2 + I_3 = 0$

$\Rightarrow \frac{V_A - V_0 - 6}{6} + \frac{V_A - V_0}{3} + \frac{V_A - V_B + 5}{2} = 0$

$\Rightarrow \frac{V_A - V_0 - 6 + 2V_A - 2V_0 + 3V_A - 3V_B + 15}{6} = 0$

$\Rightarrow 6V_A - 3V_B = -9$ —— (1)

Applying KCL in junction 2:-

$\Rightarrow I_4 + I_5 + I_6 = 0$

$\Rightarrow \frac{V_B - V_A - 5}{2} + \frac{V_B - V_0}{4} + \frac{V_B - V_0 - 10}{4} = 0$

$\Rightarrow 2V_B - 2V_A - 10 + V_B - V_0 + V_B - V_0 - 10 = 0$

$\Rightarrow -2V_A + 4V_B = 20$ —— (2)

Solving (1) & (2)

$V_A = 1.333\,V$

$V_B = 5.666\,V$

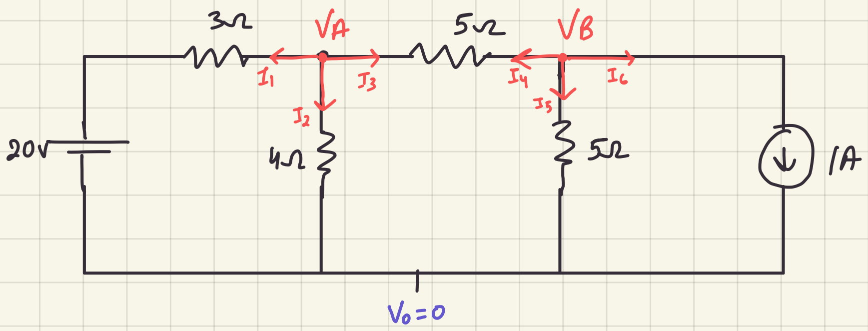
∴ Current through 3Ω resistor, ⇒ $I_2$ current.

$I_2 = \frac{V_A - V_0}{3} = \frac{V_A}{3} = \frac{1.333}{3}$

$I_{(3\Omega)} = 0.44A$

# Type - 2 : Voltage Source + Resistance + Current Source

Q2. Using nodal analysis find the current in $4\Omega$ branch.




Soln:- Applying KCL at junction A,

$$I_1 + I_2 + I_3 = 0$$

$$\Rightarrow \frac{V_A - V_0 - 20}{3} + \frac{V_A - V_0}{4} + \frac{V_A - V_B}{5} = 0$$

$$\Rightarrow \frac{20V_A - 400 + 15V_A + 12V_A - 12V_B}{60} = 0$$

$$\Rightarrow 47V_A - 12V_B = 400 \quad \text{--- (1)}$$

Applying KCL in junction B,

$$\Rightarrow I_4 + I_5 + I_6 = 0$$

$$\Rightarrow \frac{V_B - V_A}{5} + \frac{V_B - V_0}{5} + 1 = 0$$

$$\Rightarrow V_B - V_A + V_B + 5 = 0$$

$$\Rightarrow -V_A + 2V_B = -5 \quad \text{--- (2)}$$

Solving eq. (1) & (2)

$V_A = 9.02V$

$V_B = 2.012 V$

$$I_{4\Omega} = I_2 = \frac{V_A - V_0}{4} = \frac{9.02}{4} = 2.255A$$

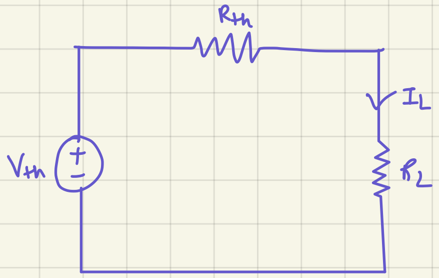
$I_{4\Omega} = 2.55 A$

# Thevenin's Theorem

- It is a network reduction theorem.
- It reduce the complexity of the circuit
- It simplify the circuit.

- According to the thevning's theorem, any linear bilateral network irrespective of its complexities can be redued into a Thevening's equivalent circuit having the Thevenin's open circuit voltage '$V_{th}$' in series with the Thevenin's equivalent resistance '$R_{th}$' along with load resistor $R_L$.

$$\boxed{I_L = \frac{V_{th}}{R_{th} + R_L}}$$




$V_{th}$ = Thevning voltage / open circuit voltale
$R_{th}$ = Thevning resistance
$R_L$ = Load Resistance (to be calulated / To find ?)
$I_L$ = load Current.

## Steps:-

1) Identify the load resistor $R_L$

2) Remove the load resistor and calulate the open circuit potential across two open ends. This will be thevning's equivalent voltage $V_{th}$.

3) Again remove the load resistor and replace all the active sources by their internal resistor

4) Calulate the equivalent resistance across the open ends. This will be the thevning's equivalent resistance $R_{th}$.

5) Draw the Thevenin's equivalent for given network.

6) Calulate the load Current $I_L$ by using the identity

$$\boxed{I_L = \frac{V_{th}}{R_{th} + R_L}}$$

limitations

Thevenin's theorem cannot be applied to a network which contains non linear impedance

cannot calculate the power consumed internally or efficiency of a circuit

1) Draw the given circuit

2) Ground the circuit.

3) Theving → Inmuare resistane.

4) Replace the load restane → any voltage

Main voltage → remove.

5) $\frac{V}{I} = \frac{10}{259.26} = R_{th} = 38.57 \Rightarrow R_{th}$

6) Make the equivalent circuit of thevning

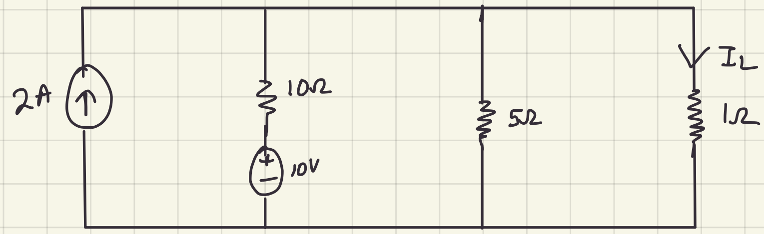
$V_{th}$ → 2nd circuit → when resistane is made high.

voltage through load branch.

$R_{th} = \frac{30V}{2.903A} = 10.334$

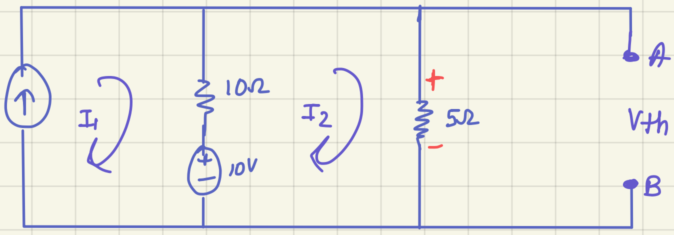
$R_{th} = \frac{60}{1.424A} = 42.134$

Q1. Find the current through 1Ω resistor in the given circuit using Thevenin's theorem.




Soln – • $R_L = 1\Omega$

• Removing $R_L$ we get ⇒




• Applying mesh analysis

For mesh ①

$$\Rightarrow \underline{I_1 = 2A}$$

For mesh ②

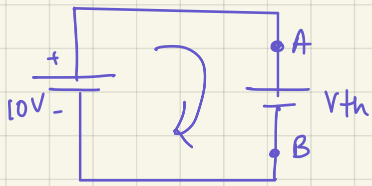
$$\Rightarrow 10 - 10(I_2 - I_1) - 5I_2 = 0$$

$$\Rightarrow -15I_2 + 10I_1 = -10$$

$$\Rightarrow -15I_2 = -30$$

$$\Rightarrow \underline{I_2 = 2\text{ Amp}}$$

• Drawing the equivalent circuit.



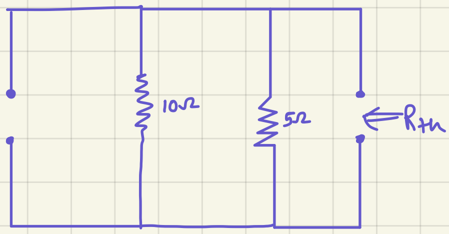

$$\Rightarrow -V_{th} + 10 = 0$$

$$\Rightarrow \boxed{V_{th} = 10V}$$

• Active sources will get replaced by internal sources.

⇒ voltage source : 0Ω (resistance) → short circuit

⇒ current source : ∞ (infinite resistance) → open circuit



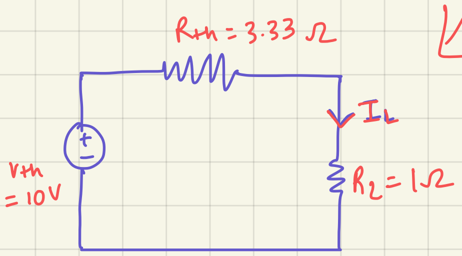

∴ Removing $R_L$ and replacing

$$\Rightarrow 10 \parallel 5$$

$$\Rightarrow \frac{10 \times 5}{10+5} = \frac{50}{15} = 3.33\,\Omega$$

$$\Rightarrow R_{th} = 3.333\,\Omega$$

•




$$I_L = \frac{V_{th}}{R_{th} + R_L}$$

$$= \frac{10}{3.33+1} = \frac{10}{4.33} = 2.309$$

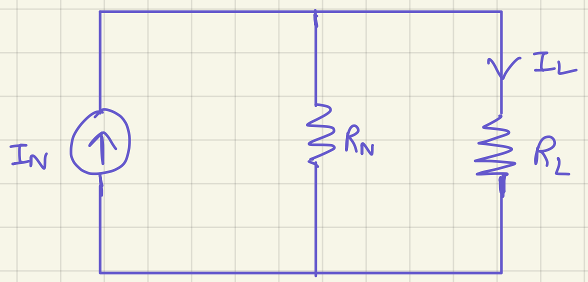
$$I_L = 2.309 \text{ Amp}$$

# NORTON'S THEOREM

- It is a network reduction theorem.
- It redue the complexity of the circuit
- It simplify the circuit.

- According to Norton's theorem, Any linear bilateral network irrespective of its complexities can be reduced into a Norton's equivalent circuit having a Norton's short circuit current '$I_N$' in parallel with Norton's equivalent resistane $R_N$ in parallel with load resistor $R_L$.

$$\boxed{I_L = \frac{I_N R_N}{R_L + R_N}}$$




## Steps:-

1) Identify the load resistor $R_L$
2) Replace $R_L$ with a short circuit branch
3) The current flowing through this short circuit branch will be the Norton's current $I_N$.
4) Remove $R_L$ and replace all the active sources by their internal resistance.
5) The equivalent resistance across the two open will be the Norton's resistance $R_N$
6) Draw the norton's equivalent circuit.
7) Calculate $I_L$ using the Identity.

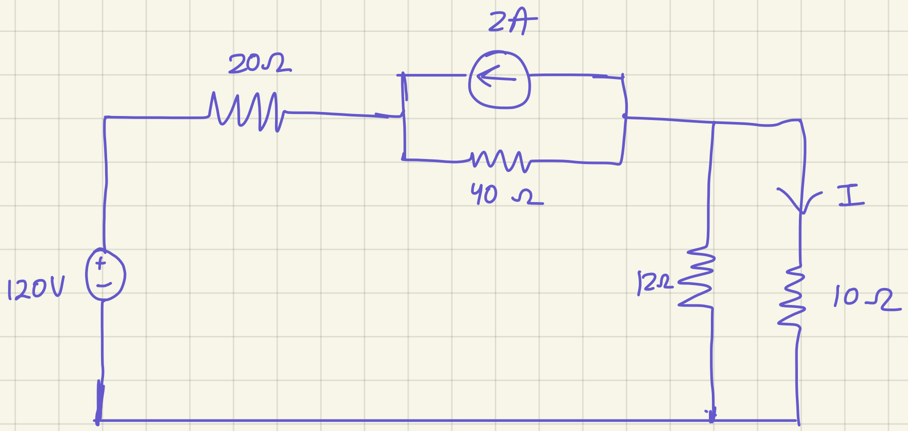
$$\boxed{I_L = \frac{I_N R_N}{R_N + R_L}}$$

IN → norton current → current sore
IN → 2nd circuit → negligible vale.

$R_N \rightarrow \frac{20}{680.85} = \frac{\text{2nd circuit (2nd last)}}{\text{Calulate}}$

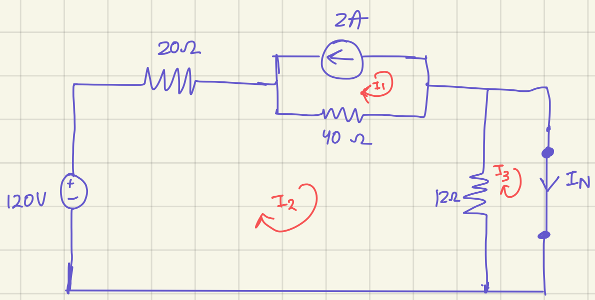
$\Rightarrow \frac{60}{1.424}$ IDC = $\boxed{\text{2nd circuit. load current}}$

Q. Find the current $I$ in the given circuit using Norton's Theorem.




Soln:- $R_L = 10\,\Omega$

Replacing the load resistor with a short circuit branch




mesh 1: $I_1 = -2A$ —— ①

mesh 2: $-72I_2 + 40I_1 + 12I_3 = -120$

$-72I_2 + 12I_3 = -40$ —— ②

mesh 3: $-12I_3 + 12I_2 = 0$ —— ③

Solving ①②③

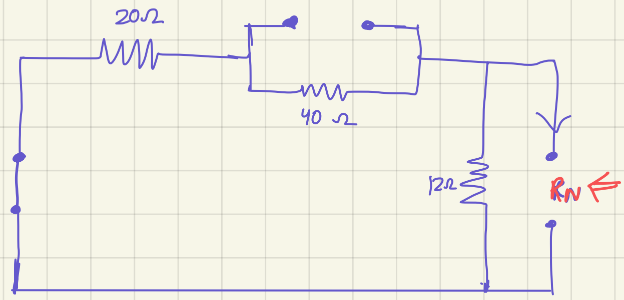
$I_1 = -2A$

$I_2 = 0.666\ A$

$I_3 = 0$

- $I_N = I_2 = 0.666\ A$ ⟶ Nortons current

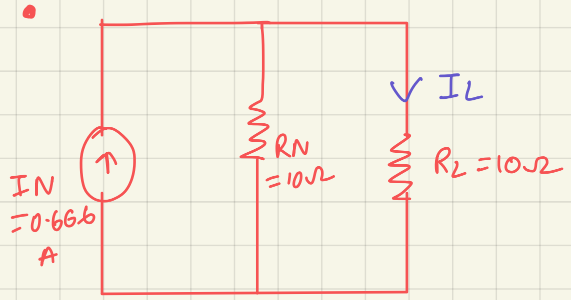
- Removing $R_L$ and replacing all the active sources by their internal resistance.




- $R_N = (20+40) \parallel 12$

$= \frac{60 \times 12}{60+12}$

$R_N = 10\,\Omega$

- 


$I_L = \frac{I_N R_N}{R_N + R_L}$

$= \frac{0.666 \times 10}{10 + 10}$

$\boxed{I_L = 0.333\,A}$

# Superposition Theorem

- According to the SPT, in any linear bilateral multi source network; the current or voltage across any branch can be calculated by taking the algebric sum of values calculated by taking one source at a time and replacing the other active sources by their internal resistances.

## Steps

1) Identify the branch and quantity to be calculated along with the presence of more than 1 active source.

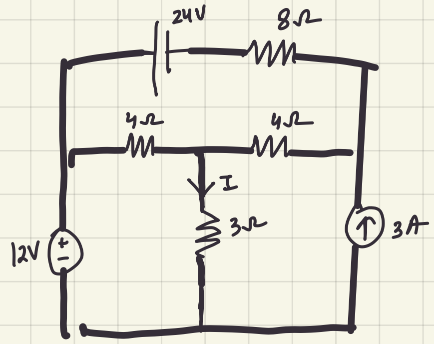
2) Consider any 1 active source and replace the remaining by their internal resistances.

3) Calculate the required electrical quantity for that particular sources.

4) Repeat the last 2 steps for all the active sources

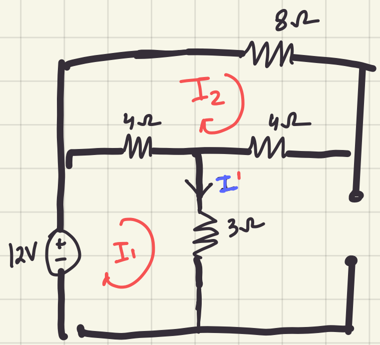
5) Algebric sum of all these individual values will be the final value of required electrical quantity for all the sources working together.

Q1. For the given circuit using the super position theorem calculate I.




There are 3 active sources in the given network.

- Taking 12V source and replacing all the other active sources by their internal resistances.




Mesh 1 : $-7I_1 + 4I_2 = -12$ —— (1)

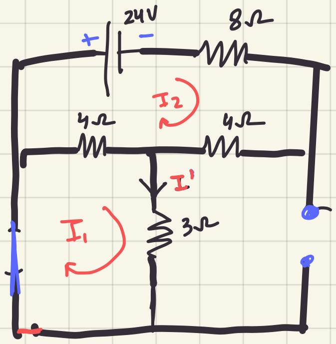
Mesh 2 : $-16I_2 + 4I_1 = 0$ —— (2)

Solving (1) & (2)

$\Rightarrow I_1 = 2A$

$\Rightarrow I_2 = 0.5A$

$\therefore I'_{(12V)} = 2A$



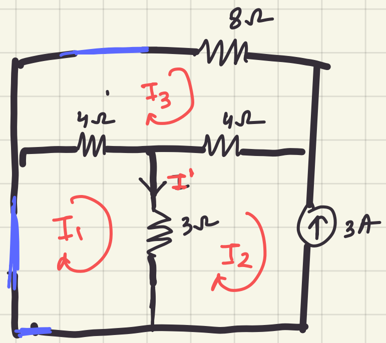

- Taking 24V source and replacing all the other active sources by their internal resistances.

Mesh 1: $-7I_1 + 4I_2 = 0$ —(1)
Mesh 2: $-16I_2 + 4I_1 = 24$ —(2)

Solving (1) & (2)

$I_1 = -1A$
$I_2 = -1.75A$

$\therefore \boxed{I'_{(24V)} = -1A}$




- Taking 3A source and replacing all the other active sources by their internal resistances

Mesh 1: $-7I_1 + 3I_2 + 4I_3 = 0$
Mesh 3: $-4I_1 - 4I_2 - 16I_3 = 0$
Mesh 2: $I_2 = -3$ Amp

Solving $I_1 = -2$ Amp
$I_2 = -3$ Amp
$I_3 = -1.25$ Amp.

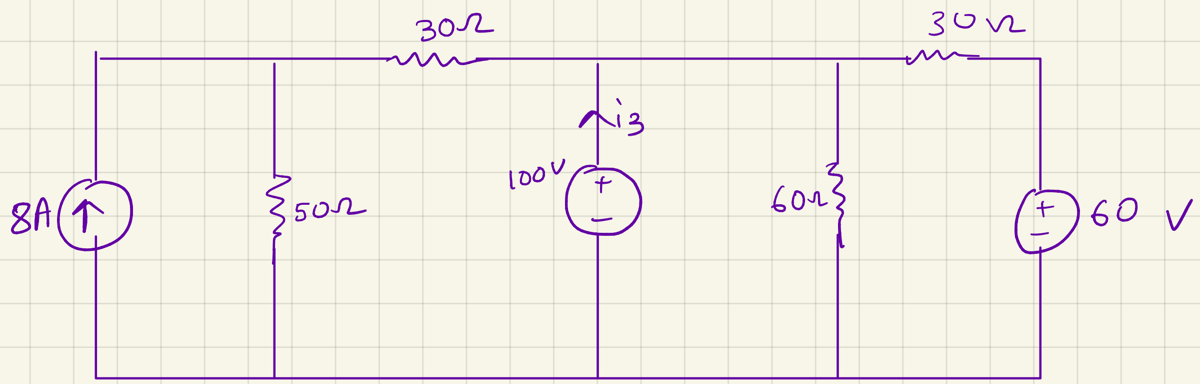
$I'_{(3A)} = I_1 - I_2 = -2 - (-3)$
$= 1$ amp

$I'_{(3A)} = 1$ (amp)

As per Superposition theorem,

$I_T = I_{(12V)} + I_{(24V)} + I_{(3A)}$
$= 2 - 1 + 1$

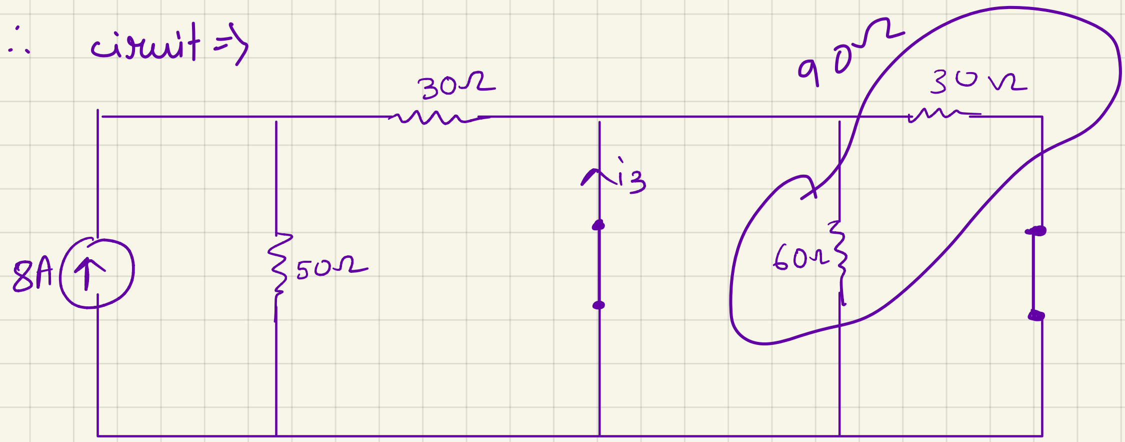
$\boxed{I_T = 2 \text{ Amp}}$



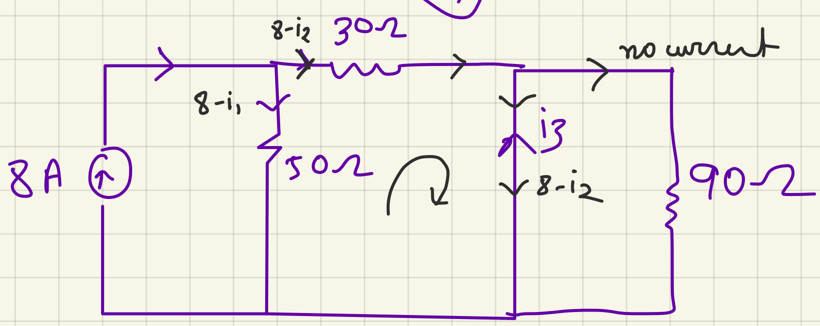

$i_3 = ?$

Step 1: lets assume only 8A current source is acting.
∴ other sources are deactivated

∴ circuit ⇒

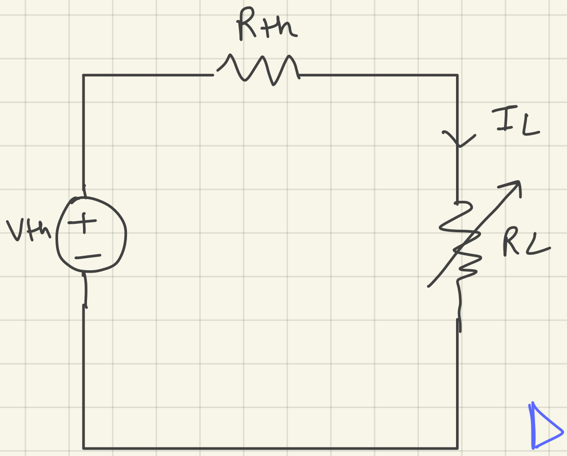



⇓



# Maximum Power Transfer Theorem

According to the maximum power transfer theorem the condition for minimum power flow through load resistor $R_L$ can be achieved when the load resistor equals to the Thevenins' equivalent resistance of the circuit.




Power through $R_L$ : $P = I_L^2 R_L$

- $I_L = \dfrac{V_{th}}{R_{th}+R_L}$

$$\therefore \quad P = \left(\frac{V_{th}}{R_{th}+R_L}\right)^2 R_L \quad \text{——— (2)}$$

Differentiating the above eqn with $R_L$ and equating it to zero.

$$\frac{dP}{dR_L} = V_{th}^2 \left[\frac{(R_{th}+R_L)^2 - 2R_L(R_{th}+R_L)}{(R_{th}+R_L)^4}\right] = 0$$

$$\Rightarrow R_{th}^2 - R_L^2 = 0$$

$$\Rightarrow \boxed{R_L = R_{th}} \quad \text{——— (3)}$$

**CONDITION**

when the load resistance is equal to peak resistance then peak amount power we will get.

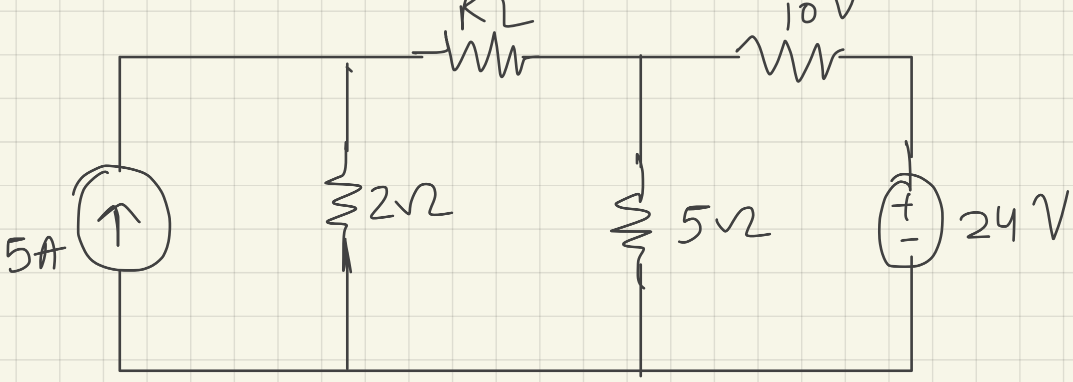
Now putting the value of $R_L = R_{th}$ in eq (2)

$$\therefore \quad P_{max} = \frac{V_{th}^2}{(R_{th}+R_{th})^2} \cdot R_{th}$$

$$= \frac{V_{th}^2}{4R_{th}^{\cancel{2}}} \cdot \cancel{R_{th}}$$

$$P_{max.} = \frac{V_{th}^2}{4R_{th}} \longrightarrow \text{Amount of max Power transfered.}$$

Q1. In the given network find the value of $R_L$, which will absorb the maximum power from the source. Also find the maximum power.



# R, C, L

- Resistance → Same phase
- Capacitor → Current lead by 90° (CCL) → potential lag.

$$\mathcal{E} = \mathcal{E}_0 \sin\omega t$$

$$i = \frac{\mathcal{E}_0}{\frac{1}{\omega C}} \sin\left(\omega t + \frac{\pi}{2}\right)$$

$\frac{1}{\omega C}$ → capacitive reactance

→ $\boxed{X_C = \frac{1}{\omega C}}$ $\Omega$ → unit

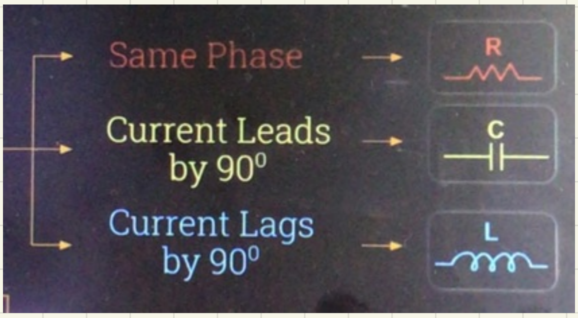
- Inductor → Potential lead by 90° (IPL) → current lag.

→ $\mathcal{E} = \mathcal{E}_0 \sin(\omega t)$

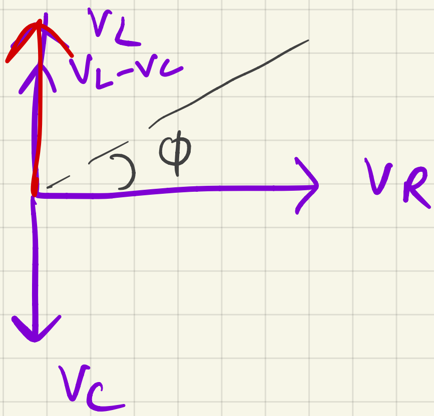
→ $i = \frac{\mathcal{E}_0}{\omega L} \sin\left(\omega t - \frac{\pi}{2}\right)$

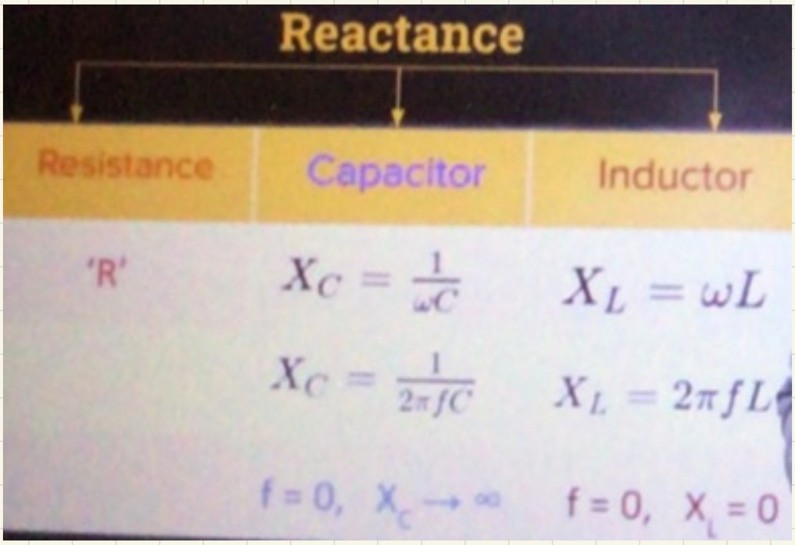
$\omega L$ → Inductive reactance

$$\boxed{X_L = \omega L}$$




→ LCR circuit



Reactance

| Resistance | Capacitor | Inductor |
|---|---|---|
| 'R' | $X_C = \frac{1}{\omega C}$ | $X_L = \omega L$ |
| | $X_C = \frac{1}{2\pi f C}$ | $X_L = 2\pi f L$ |
| | $f = 0,\ X_C \to \infty$ | $f = 0,\ X_L = 0$ |

$$\tan\phi = \frac{X_C - X_L}{R}$$

$$\tan\phi = \frac{V_L - V_C}{V_R}$$

- Impedence — $\sqrt{R^2+(X_L-X_C)^2}$

↳ min when $X_L = X_C$ : when resonance.

When resonance occurs, $X_L = X_C \Rightarrow Z = R$

then, current becomes maximum.

i.e $$\boxed{i_0 = \frac{\mathcal{E}_0}{\sqrt{R^2+\cancel{(X_L-X_C)^2}}}}$$ ($\to 0$)

Now, $X_L = X_C$

$$\Rightarrow \omega L = \frac{1}{\omega C}$$

$$\Rightarrow \boxed{\omega = \frac{1}{\sqrt{LC}}}$$

The effective resistance in an electric circuit or component of an are the combined networks of ohmic resistance and reactance is called impedance

- **Power factor** – Power consumed by any circuit

Denoted by $\cos\phi$.

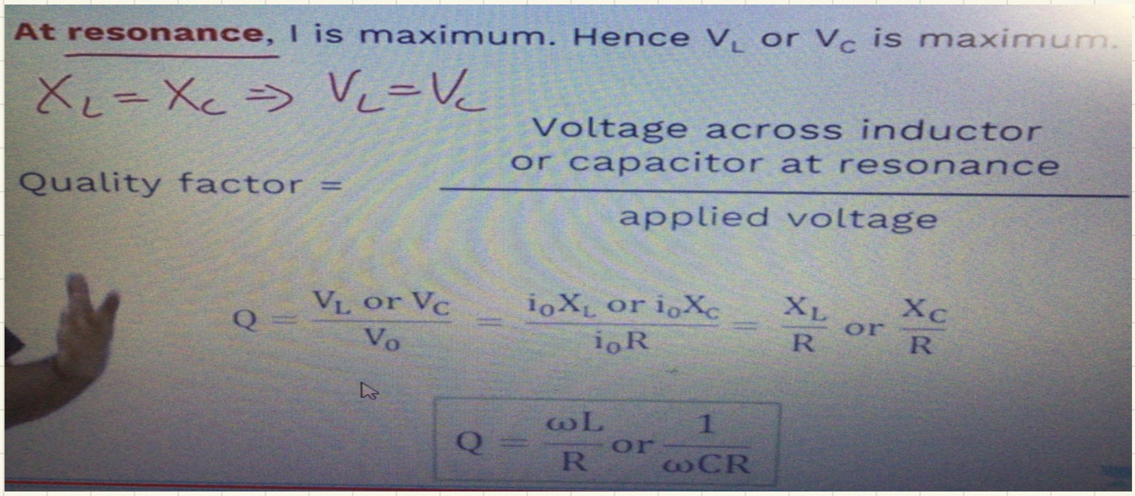
$$\cos\phi = \frac{R}{Z} < 1$$

$$\cos\phi = \frac{\text{Resistance}}{\text{Impedence}}$$

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

- **Quality factor** – It determines the sharpness of a frequency

$$\boxed{Q = \frac{\omega_0 L}{R}} \rightarrow \frac{X_L}{R} \rightarrow \frac{\text{Inductance Reactance}}{\text{resistance}} \rightarrow \text{Dimension less.}$$




- In series resonance, impedence of circuit is minimum and $(Z = R)$

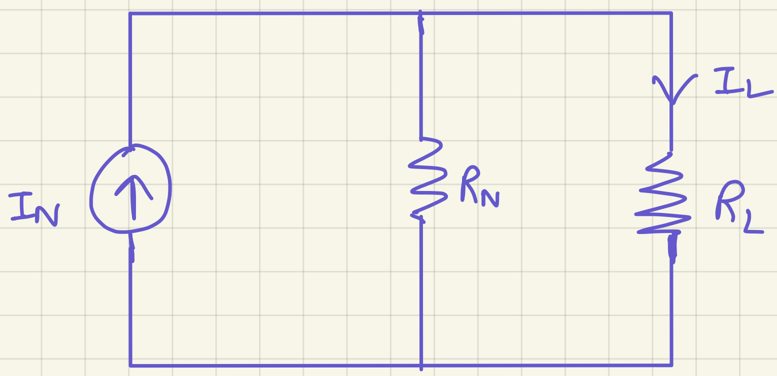
Current is maximum.

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

# NORTON

- According to Norton's theorem, Any linear bilateral network irrespective of its complexities can be reduced into a Norton's equivalent circuit having a Norton's short circuit current '$I_N$' in parallel with Norton's equivalent resistance $R_N$ in parallel with load resistor $R_L$.

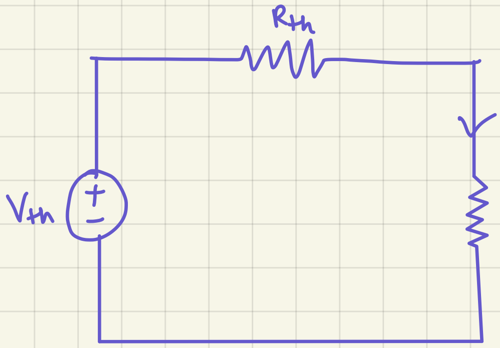
$$\boxed{I_L = \frac{I_N R_N}{R_L + R_N}}$$




# Thevning

- According to the thevning's theorem, any linear bilateral network irrespective of its complexities can be redued into a Thevening's equivalent circuit having the Thevenin's open circuit voltage '$V_{th}$' in series with the Thevenin's equivalent resistance '$R_{th}$' along with load resistor $R_L$.

$$\boxed{I_L = \frac{V_{th}}{R_{th} + R_L}}$$




$V_{th}$ = Thevning voltage / open circuit voltale
$R_{th}$ = Thevning resistance
$R_L$ = Load Resistance (to be calulated / To find ?)
$I_L$ = load Current.

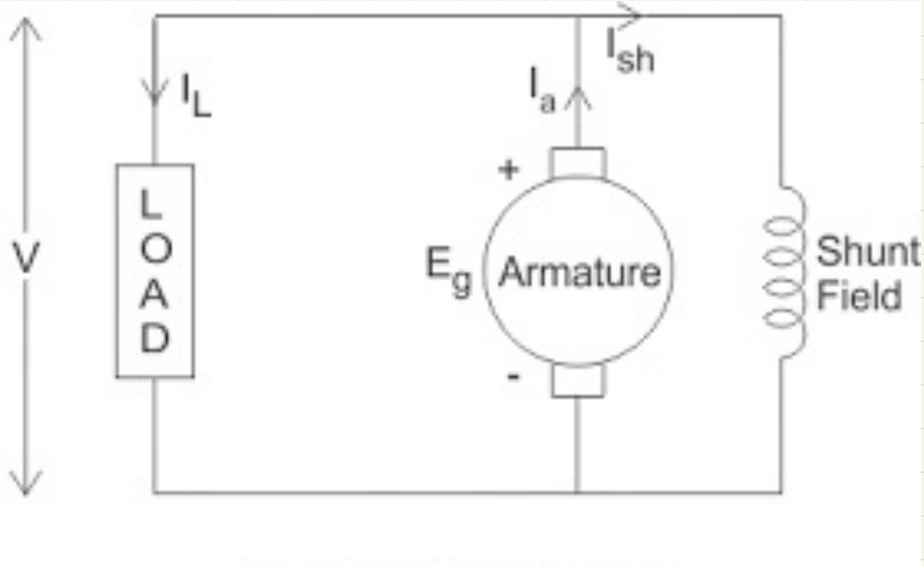
# SUPERPOSITION THEOREM

- According to the SPT, in any linear bilateral multi source network; the current or voltage across any branch can be calculated by taking the algebric sum of values calculated by taking one source at a time and replacing the other active sources by their internal resistances.

# Maximum Power Transfer Theorem

According to the maximum power transfer theorem the condition for minimum power flow through load resistor $R_L$ can be achieved when the load resistor equals to the Thevenins' equivalent resistance of the circuit.

- Shunt Generator Diagram



Shunt Wound Generator

- **_Why do you replace voltage sources with short circuits and current sources with open circuits in Thevenin's and Norton's theorem?_**

→ Voltage → Zero impedance → value is made zero to convert it into IDEAL voltage source

?

An ideal voltage source can produce whatever current it needs to keep its terminal voltage at specified value.

→ Current source → Zero → To make it ideal → ideal source has INFINITE Impedance which is open circuit

why ?

↳ It can produce whatever votage needs to flow through the specified current.

- unit of active power — KVA ampere

- Active power — true power perfor the real work

$$P \rightarrow I^2R$$

$$P = VI$$

$$P = (V_o \sin\omega t)\, I$$

- Form Factor $= \dfrac{I_{rms}}{I_{av}} = \underline{\underline{1.11}} = \dfrac{V_{rms}}{V_{aveage}}$

- Peak Factor $= \dfrac{I_m}{I_{rms}} = \dfrac{E_m}{E_{rms}}$

- India $\rightarrow$ 50 Hz $\rightarrow$ $\underline{\underline{230V}}$

- AVERAGE VALUE OF current/voltage

| | |
|---|---|
| In Full Cycle or Long Period | $\langle I \rangle = I_{avg} = I_{mean} = \bar{I} = \dfrac{\int_0^T I\,dt}{\int_0^T dt} = 0$ |
| In Half Cycle | $I_{avg} = I_{mean} = \bar{I} = \dfrac{\int_0^{T/2} I\,dt}{\int_0^{T/2} dt} = \dfrac{2I_0}{\pi} = 0.637 I_0$ |

$$I_{av} = \frac{2I_0}{\pi} = 0.637 I_0$$

$$V_{AV} = \frac{2V_0}{\pi} = 0.637 V_0$$

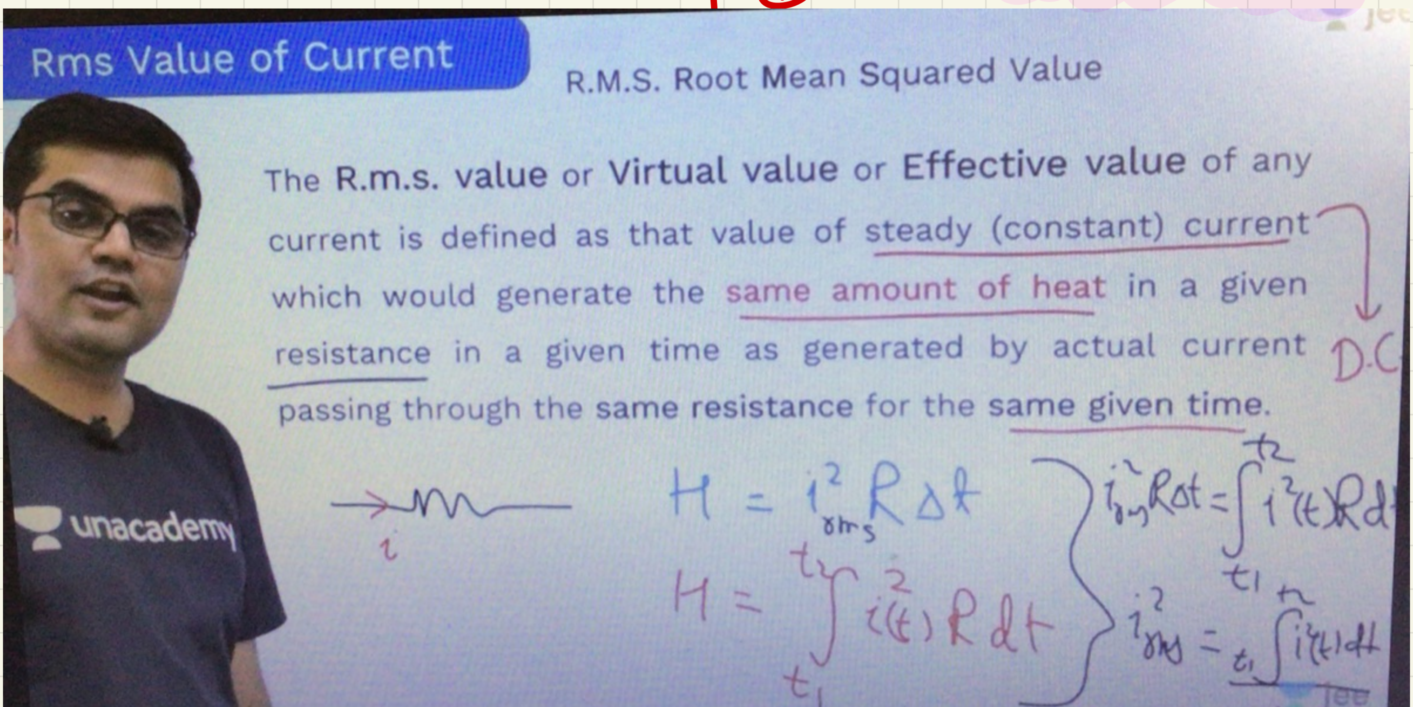
- RMS – It is the root of average value of $I^2$ over a time period.

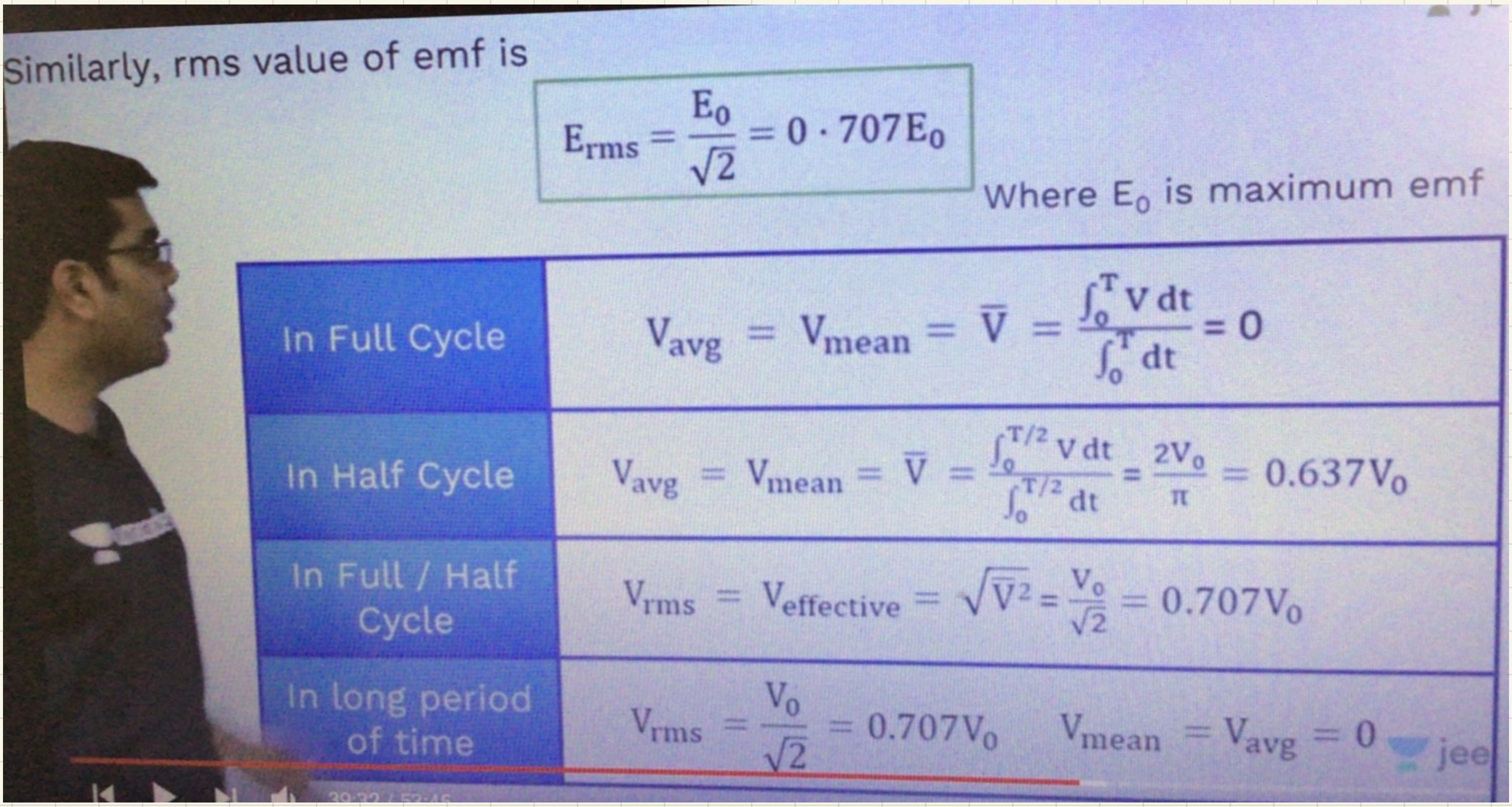
$$I_{rms} = \sqrt{\frac{\int_0^t I^2 dt}{\int^t dt}}$$

½ cycle : $I_{rms}$

$$= \frac{I_0}{\sqrt{2}} = 0.707 I_0$$

$$\therefore I_{rms} = \frac{\text{Peak } I}{\sqrt{2}}$$



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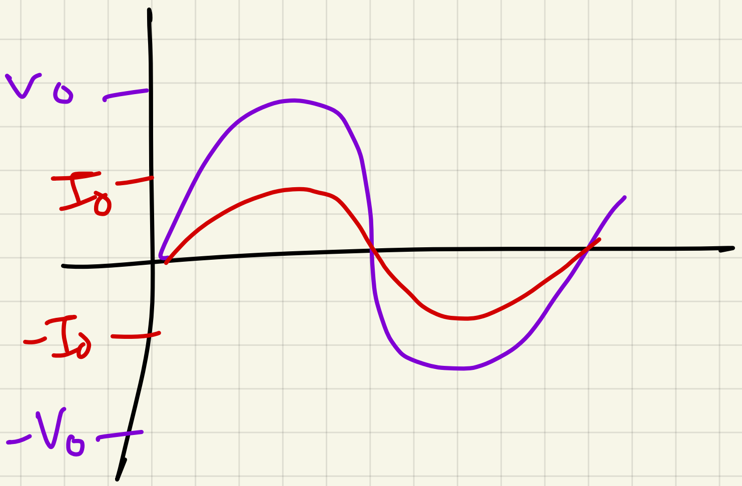
## Only resistive = same phase

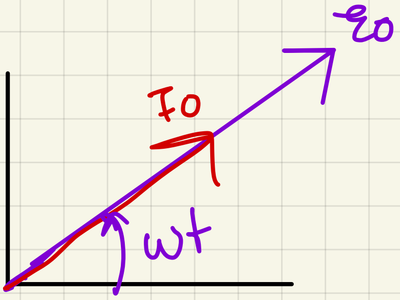



$$i_0 = \frac{\mathcal{E}_0}{R}$$

$$i = \frac{\mathcal{E}}{R}$$

$$\mathcal{E} = \mathcal{E}_0 \sin\omega t$$

$$i = i_0 \sin\omega t$$



# Only Inductive IPL

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

$I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$

$DC \Rightarrow \omega = 0$

$X_L = 0$

inductor offer zero resistance to DC

*A transformer may be defined as a static electric device that transfers electrical energy from one circuit to another circuit at the same frequency but with changed voltage (or current or both) through a magnetic circuit.*

EMF Equation:

$e = -N\,d\phi/dt$

$e = -2\pi f \phi_{max} N \cos \omega t$ V

$E_{max} = 2\pi f \phi_{max} N$ V

$E_{rms} = 4.44 \phi_{max} f N$ V

RMS value of voltage indued at primary, $E_1 = 4.44 \phi_{max} f N_1$ V.

RMS value of voltage indued at seconday, $E_2 = 4.44 \phi_{max} f N_2$ V

Type of Transformer (single phase)

i) Core type - Pg. 532

ii) Shell type - Pg. 532

* Lamination reduce eddy current loss

* Silicon steel reduces hysteresis loss.

- Tranformation Ratio $\Rightarrow \frac{E_1}{E_2} = \frac{N_1}{N_2}$ (Pg - 533)

  The ratio of primary voltage to secondary voltage is same as the ratio of primary winding turns to the seconday winding turns.

1) When $N_1 > N_2$ then $E_2 < E_1$
   step up transformer.

2) When $N_2 > N_1$ then $E_2 > E_1$
   then it's step down transformer

- Impedance Transformer

— impedance $Z_2$ is connected across the secondary winding at its output.

Pg - 534

12 ← Transform

12 – 12:20 3phase

12:20 – 30 ← AC
• RLC

30 – 40 – DC Network

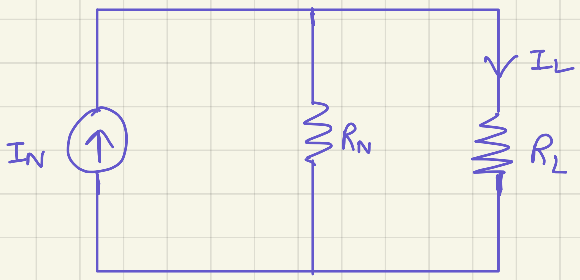
40 – 50 viva questions

# NORTON'S THEOREM

- It is a network reduction theorem.
- It reduce the complexity of the circuit
- It simplify the circuit.

- According to Norton's theorem, Any linear bilateral network irrespective of its complexities can be reduced into a Norton's equivalent circuit having a Norton's short circuit current '$I_N$' in parallel with Norton's equivalent resistance $R_N$ in parallel with load resistor $R_L$.

$$\boxed{I_L = \frac{I_N R_N}{R_L + R_N}}$$




# Steps :-

1) Identify the load resistor $R_L$
2) Replace $R_L$ with a short circuit branch
3) The current flowing through this short circuit branch will be the Norton's current $I_N$.
4) Remove $R_L$ and replace all the active sources by their internal resistance
5) The equivalent resistance across the two open will be the Norton's resistance $R_N$
) Draw the norton's equivalent circuit.

Calculate $I_L$ using the Identity.

$$\boxed{I_L = \frac{I_N R_N}{R_N + R_L}}$$

$I_N$ → norton current → current source
↘ 2nd circuit → negligible value.

$R_N$ → $\frac{20}{680.85}$ = $\frac{\text{2nd circuit (2nd last)}}{\text{Calculate}}$

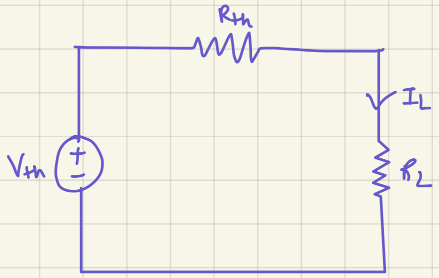
⇒ $\frac{60}{1.424}$ IDC = $\boxed{\text{2nd circuit. load current}}$

# Thevenin's Theorem

- It is a network reduction theorem.
- It redue the complexity of the ciruit
- It simplify the ciruuit.

- According to the thevning's theorem, any linear bilateral network irrespective of its complexities can be redued into a Thevening's equivalent cireuit having the Thevenin's open cirurit voltage '$V_{th}$' in series with the Thevenin's equivalent resistane '$R_{th}$' along with load resistor $R_L$.

$$\boxed{I_L = \frac{V_{th}}{R_{th} + R_L}}$$




$V_{th}$ = Thevning voltage / open ciruit voltale
$R_{th}$ = Thevning resistance
$R_L$ = Load Resistance (to be calulated / To find?)
$I_L$ = load Current.

## Steps:-

1) Identify the load resistor $R_L$

2) Remove the load resistor and calulate the open circuit potential across two open ends. This will be thevning's equivalent voltage $V_{th}$.

3) Again remove the load resistor and replace all the active sources by their internal resistor

4) Calulate the equivalent resistane across the open ends. This will be the thevning's equivalent resistance $R_{th}$.

5) Draw the Thevenin's equivalent for given network.

6) Calulate the load Current $I_L$ by using the identity

$$\boxed{I_L = \frac{V_{th}}{R_{th} + R_L}}$$

limitations

Thevenin's theorem cannot be applied to a network which contains non linear impedence

cannot calculate the power consumed internally or efficiency of a circuit

Rectifier – A rectifier is a device that converts an oscillating two-directional alternating current (AC) into a single-directional direct current (DC

A full wave same as half wave, but it allows unidirectional current through the load during the sinosuidal cycle.

Inverter – while an inverter converts DC to AC.

Filter

↳ A filter is a circuit capable of passing /amplifying certain frequencies while attenuating other frequencies.

Diode – A diode is defined as a two-terminal electronic component that only conducts current in one direction

Transformer – Defination

A transformer is a passive electrical device that transfers electrical energy from one electrical circuit to another, or multiple circuits.

Zener diode is a special type of diode designed to reliably allow current to flow "backwards" when a certain set reverse voltage, known as the Zener voltage

– Uses

A transformer is an electrical apparatus designed to convert alternating current from one voltage to another. It can be designed to "step up" or "step down" voltages and works on the magnetic induction principle.

## 4.2 CHARACTERISTICS OF NETWORK ELEMENTS

### 4.2.1 Linear and Non-linear Elements

A *linear element* shows linear characteristics of voltage vs current. Thus the parameters of linear elements remain constant (i.e., the parameters do not change with voltage or current applied to that element). Resistors, inductors and capacitors are linear elements.

On the other hand, for a *non-linear element*, the current passing through it does not change linearly with the linear change in applied voltage across it, at a particular temperature and frequency. In a non-linear element the parameters change with applied voltage and current changes. Semiconductor devices like diodes, transistors, thyristors, etc. are typical examples of non-linear elements. Ohm's law is not valid for non-linear elements.

*A network element is a component of a circuit having different characteristics like linear, non-linear, active or passive etc. and will be defined shortly.

# Difference between full wave & half wave

Full-wave rectification rectifies the negative component of the input voltage to a positive voltage, then converts it into DC (pulse current) utilizing a diode bridge configuration.

In contrast, half-wave rectification removes just the negative voltage component using a single diode before converting to DC.
Afterward, the waveform is smoothed by charging/discharging a capacitor, resulting in a clean DC signal.

## Bridge Rectifier

We can define bridge rectifiers as a type of full-wave rectifier that uses four or more diodes in a bridge circuit configuration to efficiently convert alternating (AC) current to a direct (DC) current.

**Copper loss** is the term often given to heat produced by electrical currents in the conductors of **transformer** windings, or other electrical devices.

which result from induced currents in adjacent components.

Lower current is passed at a higher voltage across the wires.
2. Thicker wires are used to reduce resistance (R) as R is inversely proportional to area of cross section of wire.

When the flux links with a closed circuit, an emf is induced in the circuit and the current flows, the value of the current depends upon the amount of emf around the circuit and the resistance of the circuit.

The eddy current loss is minimized by making the core with thin laminations.

Iron losses are caused by the alternating flux in the core of the transformer as this loss occurs in the core it is also known as Core loss. Iron loss is further divided into hysteresis and eddy current loss.

The iron or core losses can be minimized by using silicon steel material for the construction of the core of the transformer

The core of the transformer is subjected to an alternating magnetizing force, and for each cycle of emf, a hysteresis loop is traced out. Power is dissipated in the form of heat known as hysteresis loss

## Stray Loss

The occurrence of these stray losses is due to the presence of leakage field. The percentage of these losses are very small as compared to the iron and copper losses so they can be neglected.

## Dielectric Loss

Dielectric loss occurs in the insulating material of the transformer that is in the oil of the transformer, or in the solid insulations. When the oil gets deteriorated or the solid insulation gets damaged, or its quality decreases, and because of this, the efficiency of the transformer gets affected.

## What is Active Power: (P)

**Active Power** is the actual power which is really transferred to the load such as transformer, induction motors, generators etc and dissipated in the circuit.

**The unit of Real or Active power** is **Watt** where **1W = 1V x 1 A.** .

## What is Reactive Power: (Q)

Also known as (**Use-less Power**, **Watt less Power**)

The powers that continuously bounce back and forth between source and load is known as reactive Power (**Q**)

The unit of **Reactive Power is Volt-Ampere reactive** i.e. **VAR where 1 VAR = 1V x 1A.**

## What is Apparent Power: (S)

The **Product of voltage and current** if and only if the **phase angle differences** between current and voltage are ignored

**The unit of Apparent power (S) VA i.e. 1VA = 1V x 1A.**

## What is Complex Power ? (S = P+jQ or S=VI*)

The Complex sum of **Real Power** (**P**) and **Reactive Power** (**Q**) is known as **Complex Power** which can be expressed like **S = P+jQ** and measured in terms of **Volt Amps Reactive (generally in kVAR)**

Star connection

$$V_L = \sqrt{3}\, V_{ph}$$

$$I_L = I_{ph}$$

$$\text{Power} = \sqrt{3}\, I_L V_L \cos\theta$$

Delta Connection

$$V_L = V_{ph}$$

$$I_L = \sqrt{3}\, I_{ph}$$

Power

## What is Power Factor?

Power factor may be defined by three definitions and formals as follow.

You may also read: Is Reactive Power Useful?

**1). *The Cosine of angle between Current and Voltage is called Power Factor.***

**$P = VI \cos\theta$** *OR*

**$\cos\theta = P / V I$** *OR*

**$\cos\theta = kW / kVA$** *OR*

**$\cos\theta$ = True Power/ Apparent Power**

Where:

P = Power in Watts

V = Voltages in Volts

I = Current in Amperes

W = Real Power in Watts

VA = Apparent Power in Volt-Amperes or kVA

$\cos\theta$ = Power factor

**2). The ratio between Resistance and Impedance in AC Circuit is known**

**$\cos\theta = R/Z$**

Where:

R = Resistance in Ohms (Ω)

Z = Impedance (Resistance in AC circuits i.e. **$X_L$**, **$X_C$** and **R** known as **Inductive reactance**, **capacitive reactance** and **resistance** respectively) in Ohms (Ω)

$\cos\theta$ = Power factor

Impedance “Z” is the total resistance of AC Circuit i.e.

**$Z = \sqrt{[R^2 + (X_L + X_C)^2]}$**

Where:

$X_L = 2\pi f L$ … L is inductance in Henry

$X_C = 1/ 2\pi f C$ … C is capacitance in Farads

Related Post: Difference Between Active and Reactive Power

**3).*The ratio between Active Power and Apparent Power in volts-amperes is called power factor.***

**$\cos\theta$ = Active Power / Apparent Power**

**$\cos\theta = P / S$**

**$\cos\theta = kW / kVA$**

Where

kW = P = Real Power in kilo-Watts

kVA = S = Apparent Power in kilo-Volt-Amperes or Watts

$\cos\theta$ = Power factor

**Power Factor Formula in Three Phase AC Circuits**

**Power Factor $\cos\theta = P / \sqrt{3}\, V_L \times I_L$ … Line Current & Voltage**

**Power Factor $\cos\theta = P / \sqrt{3}\, V_P \times I_P$ … Phase Current & Voltage**

In **pure resistive circuit**, power factor is 1 due to zero phase angle difference (Φ) between current and voltage.

In **pure capacitive circuit**, power factor is leading due to the lagging VARs. i.e. Voltage is lagging 90° behind the current. In other words, Current is leading 90° from voltage (Current and voltage are 90° out of phase with each others, where current is leading and voltage is lagging).

In **pure inductive circuit**, power factor is lagging due to the leading VARs i.e. Voltage is leading 90° from current. In other words, Current is lagging begging 90° behind the voltage (Current and voltage are 90° out of phase with each, others where voltage is leading and current is lagging).

battery, transformer
semiconductor

### 4.2.2 Active and Passive Elements

resistor, inductor, thermistor
capacitor

If a circuit element has the capability of enhancing the energy level of an electric signal passing through it, it is called an *active element*, viz., a battery, a transformer, semiconductor devices, etc. Otherwise the element that simply allows the passage of the signal through it without enhancement is called *passive element* (viz., resistors, inductors, thermistors and capacitors). Passive elements do not have any intrinsic property of boosting an electric signal.

### 4.2.3 Unilateral and Bilateral Elements

If the magnitude of the current passing through an element is affected due to change in polarity of the applied voltage, the element is called a *unilateral element*. On the other hand if the current magnitude remains the same even if the polarity of the applied voltage is reversed, it is called a *bilateral element*. Unilateral elements offer varying impedances with variation in the magnitude or direction of flow of the current while bilateral elements offer same impedance irrespective of the magnitude or direction of flow of current. A resistor, an inductance and a capacitor, all are bilateral elements while diodes, transistors, etc. are unilateral elements.

### 4.10.2 Independent and Dependent Sources

The voltage or current sources which do not depend on any other quantity in the circuit (i.e the strength of voltage or current in the sources), and do not change for any change in the connected network, are called *independent sources*. Independent sources are represented by circles. An independent voltage source and an independent current source is shown in Fig. 4.74.1(a) and 4.74.1(b)

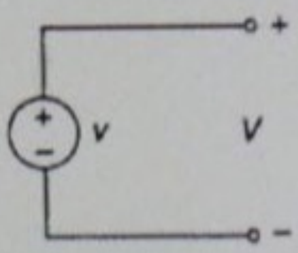



**Fig. 4.74-1(a)** *Independent voltage source*

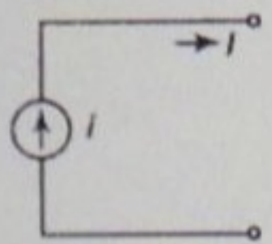



**Fig. 4.74-1(b)** *Independent current source*

A *dependent voltage or current source* is one which depend on some other quantity in the circuit (may be either voltage or current) i.e the strength of voltage or current changes in the source for any change in the connected network. Dependent sources are represented by diamond-shaped symbol. There are four possible

# R, C, L

- Resistance → Same phase
- Capacitor → Current lead by 90° (CCL) → potential lag.

$$\varepsilon = \varepsilon_0 \sin\omega t$$

$$i = \frac{\varepsilon_0}{\frac{1}{\omega C}} \sin\left(\omega t + \frac{\pi}{2}\right)$$

$\frac{1}{\omega C}$ → capacitive reactance

→ $\boxed{X_C = \frac{1}{\omega C}}$ $\Omega$ → unit

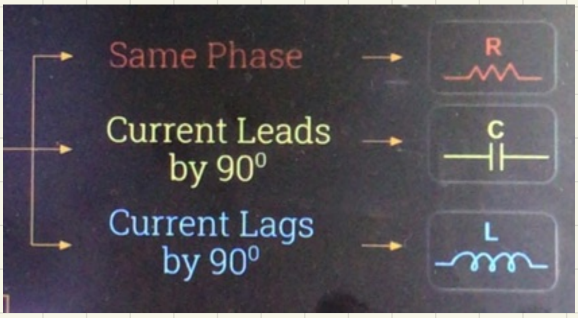
- Inductor → Potential lead by 90° (IPL) → current lag.

→ $\varepsilon = \varepsilon_0 \sin(\omega t)$

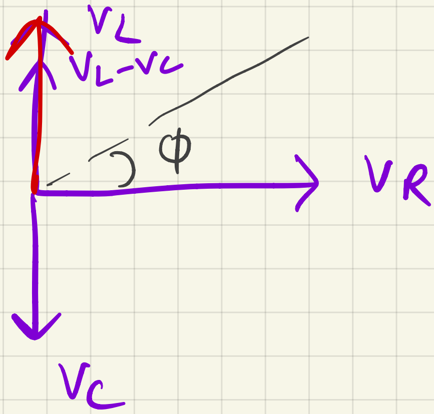
→ $i = \frac{\varepsilon_0}{\omega L} \sin\left(\omega t - \frac{\pi}{2}\right)$

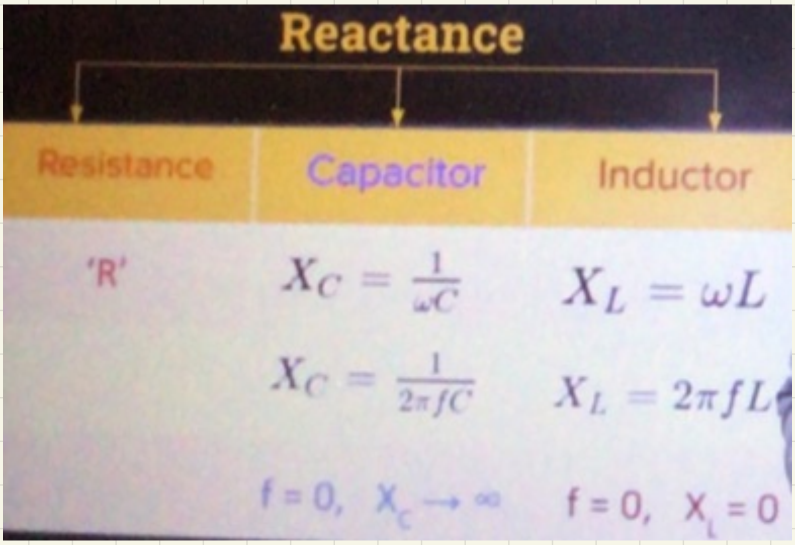
$\omega L$ → Inductive reactance

$$\boxed{X_L = \omega L}$$




→ LCR circuit



**Reactance**

| Resistance | Capacitor | Inductor |
|---|---|---|
| 'R' | $X_C = \frac{1}{\omega C}$ | $X_L = \omega L$ |
| | $X_C = \frac{1}{2\pi f C}$ | $X_L = 2\pi f L$ |
| | $f = 0,\ X_C \to \infty$ | $f = 0,\ X_L = 0$ |

$$\tan\phi = \frac{X_C - X_L}{R}$$

$$\tan\phi = \frac{V_L - V_C}{V_R}$$

- Impedence – $\sqrt{R^2+(X_L-X_C)^2}$

↳ min when $X_L = X_C$ : when resonance.

When resonance occurs, $X_L = X_C \Rightarrow Z = R$

then, current becomes maximum.

i.e $\boxed{i_0 = \dfrac{\varepsilon_0}{\sqrt{R^2+\cancel{(X_L-X_C)^2}}}}$ 0

Now, $X_L = X_C$

$$\Rightarrow \omega L = \frac{1}{\omega C}$$

$$\Rightarrow \boxed{\omega = \frac{1}{\sqrt{LC}}}$$

The effective resistance in an electric circuit or component of an are the combined networks of ohmic resistance and reactance is called impedance