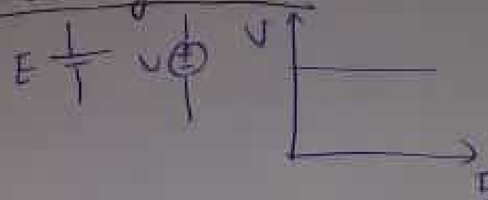
14/12/20

# Electrical Engineering
## Unit 1

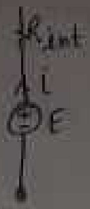
**Circuit**

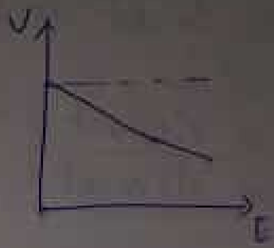
**Source** Voltage Source
Current Source

**Ideal voltage source** →



**Practical Voltage Source**



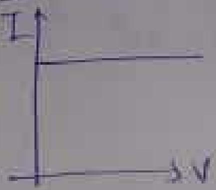


I ↑ V ↓ es

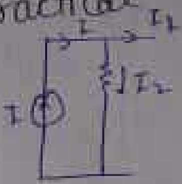
15/12/2020

**Current Source**

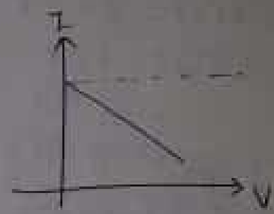
**Ideal**



**Practical**



$I_1 < I$



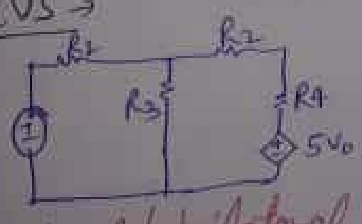
**Dependent Voltage / Current** → Also called Controlled Source

Voltage source

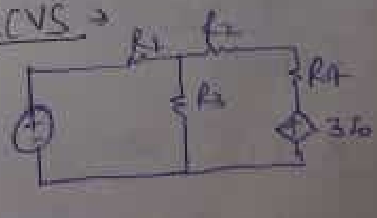
Current Source

1- Voltage Controlled Voltage Source (VCVS)
2- Current " " " (CCVS)
3- Voltage " Current " (VCCS)
4- Current " " " (CCCS)

① VCVS →



② CCVS →



**Unilatral / bilateral element** →

Unilatral → p-n junction, BJT

Bilateral → R, L, C,

⟹

## Active & Passive elements:-

If any element has Internal source or own energy source, then called active element (voltage source) & if it does not have energy source then called passive element.

**Active element:-** Voltage source, Semi Conductor devices

**Passive element:-** R, L, C

## Linearity property:-

① Homogenity

② Superposition

① Homogenity (Scaling property) → $\boxed{f(ax) = af(x)}$

Ex ① $f(x) = y = 7x$

$f(ax) = 7ax$

$= a\,7x$

$\boxed{f(ax) = af(x)}$ Homogenity

Ⅱ $f(x) = 3x^2$

$f(ax) = 3(ax)^2$

$= a^2 3x^2$

$\boxed{f(ax) \neq a f(x)}$ not homogenious

Ⅱ super position → (Additive property) $\boxed{f(x_1+x_2) = f(x_1)+f(x_2)}$

Ex ① $f(x) = 7x$

$f(x_1+x_2) = 7(x_1+x_2)$

$= 7x_1 + 7x_2$

$\boxed{f(x_1+x_2) = f(x_1)+f(x_2)}$ Addative property

Ⅱ $f(x) = 3x^2$

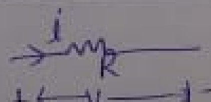
$f(x_1+x_2) = 3(x_1+x_2)^2$

$= 3(x_1^2 + x_2^2 + 2x_1x_2)$

$\boxed{f(x_1+x_2) \neq f(x_1)+f(x_2)}$ not superposition

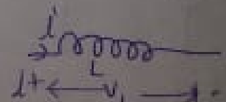
## Element R, L, C are linear element →

① R → $V = IR$



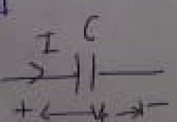

~~$V = L\frac{dq}{dt}$~~

Ⅱ L → $\left\{V_L = L\frac{dI}{dt}\right\}$



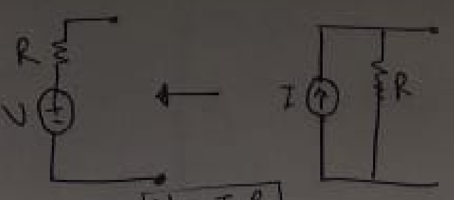

$\boxed{I = \frac{1}{L}\int V dt}$

Ⅲ C → $q = CV_C$




$\boxed{I = C\frac{dV_C}{dt}}$ $\boxed{V_C = \frac{1}{C}\int I dt}$

## Source Transformation :-




$\boxed{V = IR}$

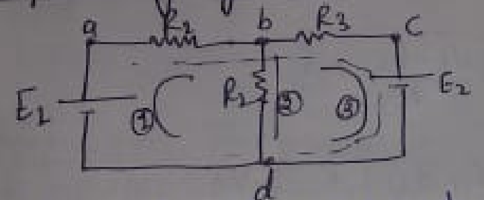
## Series & $\parallel^{el}$ Resistance :-

Series $\boxed{R_{eq} = R_1 + R_2}$ $\boxed{L_{eq} = L_1 + L_2}$

Parallel $\boxed{R_{eq} = \frac{R_1 R_2}{R_1 + R_2}}$ $\boxed{\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2}}$

$$\boxed{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} \cdots \frac{1}{R_n}}$$

## Loop Anyalysis :-




Node :- A node network is equipotential pt. where two or more element are connectd.

Ex → a, b, c, d

Junction → A junction network is equipotential pt. where three or more element are connected.

Ex → b, d.

Branch → A branch is that part of network which lies b/w junction

Ex → 3 branch ( )

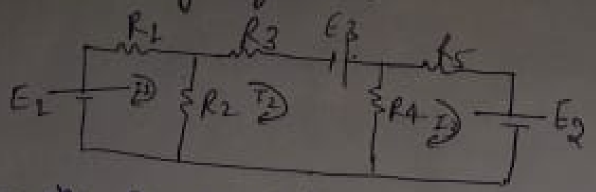
Loop → Any close path in the circuit is a loop.

Ex → 3 loop ( )

Mesh → Elementry loop are called mesh

Ex → 2 Mesh ( )

## Mesh Anyalysis →




Solⁿ By applying K.V.L in loop ①

$$-E_1 + I_1R_1 + (I_1 - I_2)R_2 = 0 \quad -(i)$$

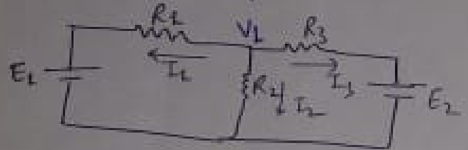
By applying K.V.L in loop ⑪

$$R_3 I_2 - E_3 + (I_1 - I_3)R_4 - (I_1 - I_2)R_2 = 0 \quad -(ii)$$

By applying K.V.L in loop ⑪⑪

$$R_5 I_3 + E_2 - (I_2 - I_3)R_4 = 0 \quad -(iii)$$

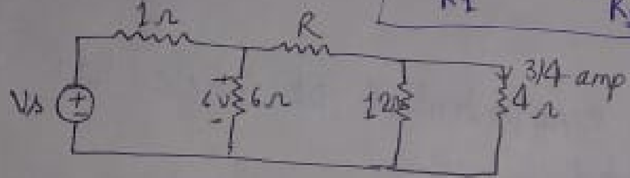
## Nodal Anyalysis :




$$I_1 + I_2 + I_3 = 0$$

$$\boxed{\frac{V_1 - E_1}{R_1} + \frac{V_1 - 0}{R_2} + \frac{V_1 - E_2}{R_3} = 0}$$

Ques →




find (i) R & Vs

(ii) power out of source (Vs)

Solⁿ (i) $V_{4\Omega} = \frac{3}{4} \times 4 = 3V$

$\boxed{V_{12\Omega} = 3V}$

$i_{12\Omega} = \frac{1}{4} amp$

$i_{total} (12\Omega \,\&\, 4\Omega) = 1 amp$

$i_{(6\Omega)} = \frac{6}{6} = 1 amp$

so $i_{total} = i_{(6\Omega)}$

so resistance should be equal

$$6 = R + \frac{12 \times 4}{12 + 4}$$

$$6 = R + 3$$

$$\boxed{R = 3\Omega}$$

$I_{total}$ (whole) $= 1 + 1 = 2 amp$

$V_{1\Omega} = 1 \times 2 = 2 Volt$

$V_s = 2 + 6$

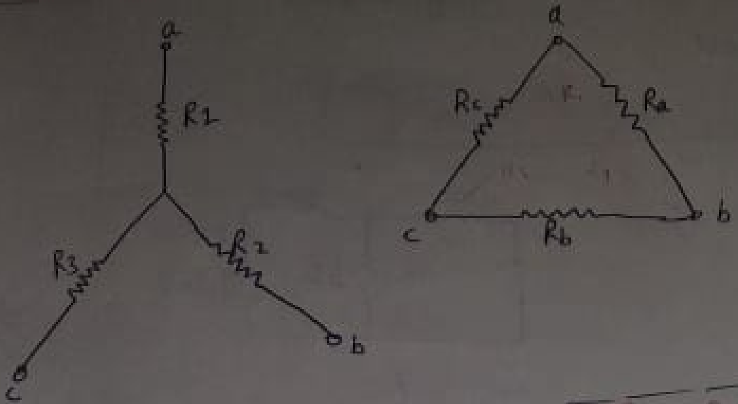
$\boxed{V_s = 8V}$

(ii) $P = vi$

$P = 8 \times 2$

$\boxed{P = 16 Watt}$

## Star - Delta Transformation :-




Proff for pt a & b

$$R_1 + R_2 = R_a \| (R_b + R_c)$$

$$R_1 + R_2 = \frac{R_a(R_b+R_c)}{R_a+R_b+R_c} \quad \text{—(i)}$$

$$R_2 + R_3 = \frac{R_b(R_c+R_a)}{R_a+R_b+R_c} \quad \text{—(ii)}$$

$$R_3 + R_1 = \frac{R_c(R_a+R_b)}{R_a+R_b+R_c} \quad \text{—(iii)}$$

eqn (i) + (ii) + (iii) then subtract from (i) & (ii) & (iii)

$$\boxed{\begin{aligned} R_a &= R_1 + R_2 + \frac{R_1 R_2}{R_3} \\ R_b &= R_3 + R_2 + \frac{R_2 R_3}{R_1} \\ R_c &= R_1 + R_3 + \frac{R_1 R_3}{R_2} \end{aligned}}$$

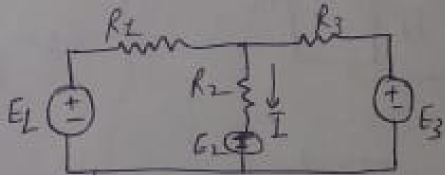
$$\boxed{\begin{aligned} R_1 &= \frac{R_a R_c}{R_a+R_b+R_c} \\ R_2 &= \frac{R_a R_b}{R_a+R_b+R_c} \\ R_3 &= \frac{R_b R_c}{R_a+R_b+R_c} \end{aligned}}$$

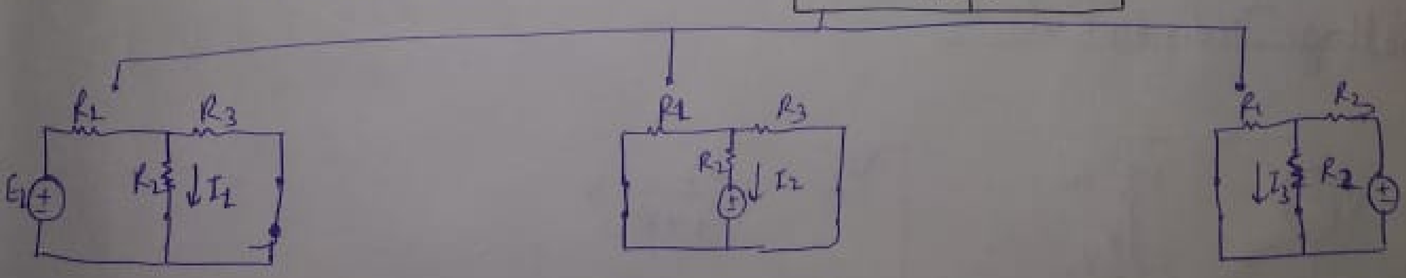
## Network Theorems :-

- Superposition Theorems
- Thevenins's Theorems
- Norton's Theorems
- Maximum power transfer Theorem

### (i) Superposition Theorems :-

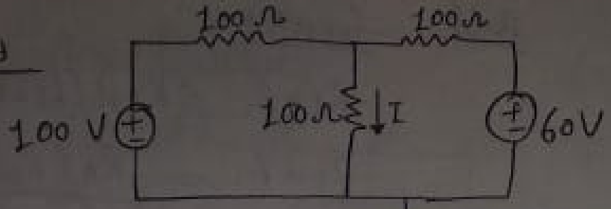
* Active linear bilatral network
* Two or more sources



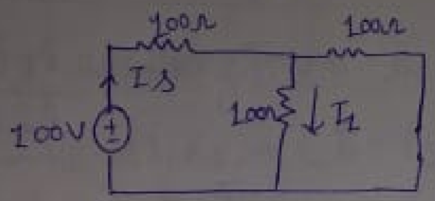

$$I = I_1 + I_2 + I_3$$

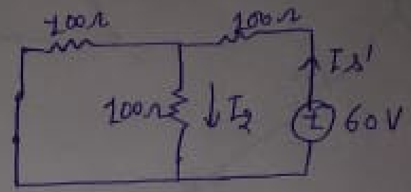
Qus →




Find I using superposition theorem

Solⁿ →




$i_s = \frac{100}{150}$

$i_s = 2/3$

$\boxed{I_1 = \frac{i_s}{2} = \frac{1}{3}}$ amp

$I_s' = \frac{60}{150}$

$I_s' = \frac{6}{15}$

$\boxed{I_2 = \frac{I_s'}{2} = \frac{3}{15}}$ amp

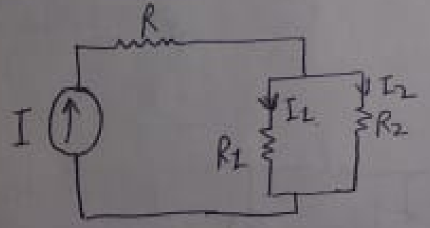
$I = I_1 + I_2$

$I = \frac{1}{3} + \frac{3}{15}$

$\boxed{I = \frac{8}{15}}$ amp

→ for varification solve by other method → find equal current.

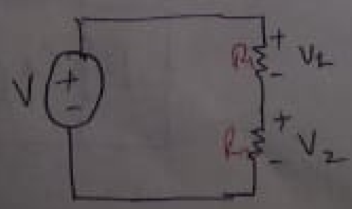
## Current Division Rule :




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

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

## Voltage Division Rule :

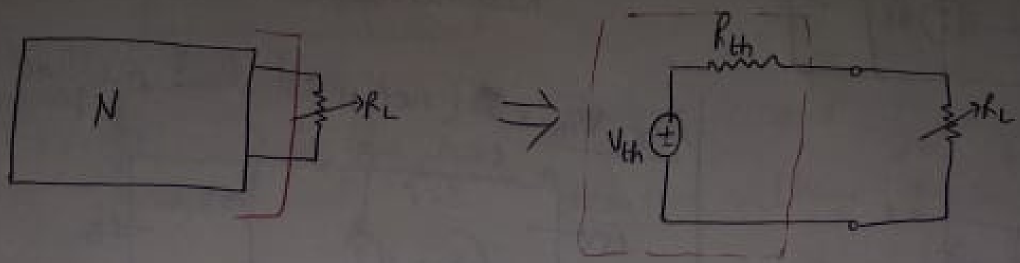



$$V_1 = \frac{R_1}{R_1+R_2} V$$

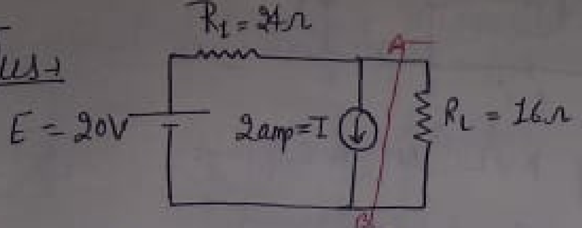
$$V_2 = \frac{R_2}{R_1+R_2} V$$

# Thevenins's Theorems :-

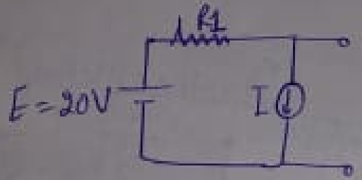




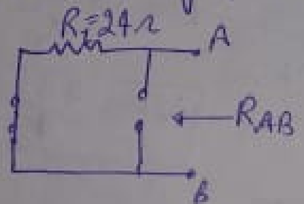

Ex
Ques:-




step 1 Remove the load Resistance & $V_s \rightarrow$ ~~open~~ short Circuit
Current source $\rightarrow$ O.C.

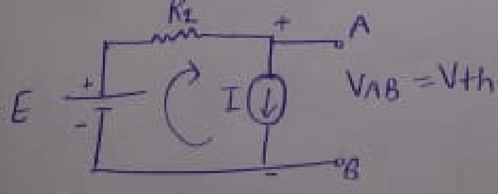



step 2 For finding the value of $R_{th}$
Replace battary & Current with short Circuit




$$\boxed{R_{AB} = R_{th} = R_1 = 24\Omega}$$

step 3 For finding the value of $V_{th}$

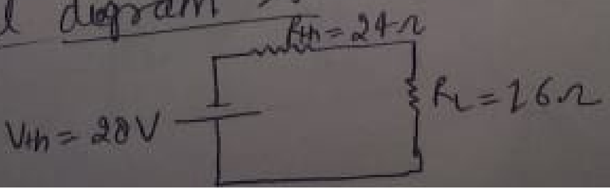



By using K.V.L

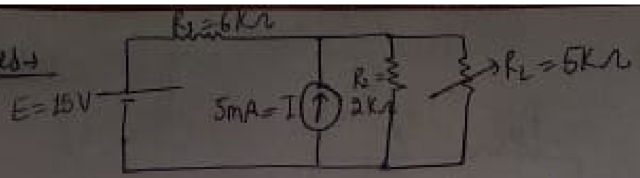
$$-E + IR_1 + V_{AB} = 0$$

$$\boxed{V_{AB} = E - IR_1} \qquad \boxed{V_{AB} = -28V}$$

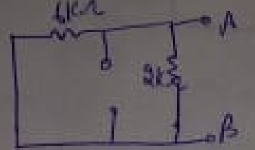
so final digram is



Ques→ Find the Current through load Resistance.



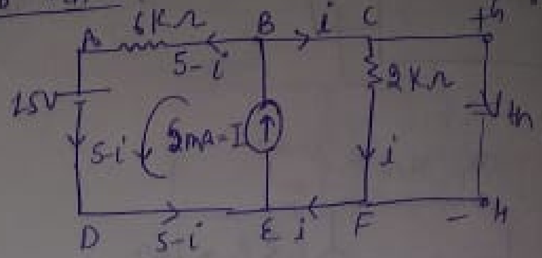

Solⁿ→ for $R_{th}$→




$$R_{AB} = R_{th} = \frac{6 \times 2}{6+2} = \frac{3}{2}$$

$$\boxed{R_{th} = \frac{3}{2} k\Omega}$$

for $V_{th}$→ (not used this method) generally




apply KVL in ACDF ÷

$$15 - 2i + 6(5-i) = 0$$

$$45 - 8i = 0$$

$$i = \frac{45}{8} mA$$

And apply K.V.L in ADGH

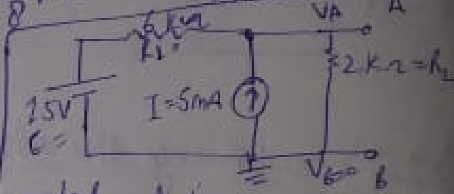
$$6(5-i) + 15 - V_{th} = 0$$

$$6\left(5 - \frac{45}{8}\right) + 15 = V_{th}$$

$$V_{th} = \cancel{6}^{3} \times \frac{-5}{\cancel{8}_{4}} + 15$$

$$\boxed{V_{th} = \frac{45}{4} = 11.25 \text{ Volt}}$$

"Another Method"

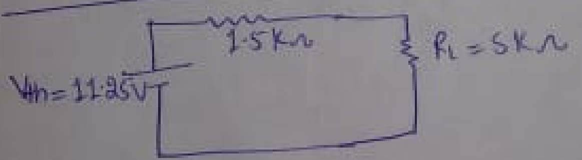



nodal analysis

$$\frac{V_A - E}{R_1} - I + \frac{V_A - 0}{R_2} = 0$$

$$\boxed{V_A = \frac{45}{4} = 11.25 \text{ Volt}}$$

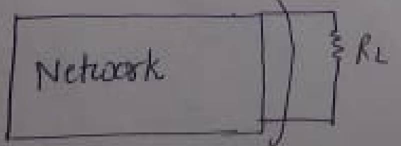
so equivalent circuit




$$i(R_L) = \frac{11.25}{6.5}$$

$$\boxed{i(R_L) = 1.730 \text{ amp}}$$ Ans

## Norton's Theorem ÷




⇒

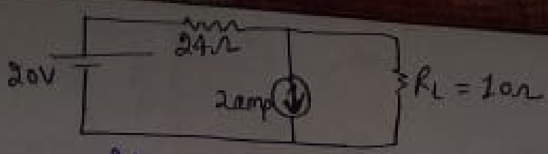

① $R_N$ is calculated same as $R_{th}$

① remove $R_L$

② $V_I$ → Short Circuit

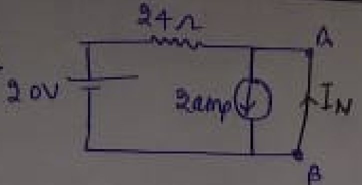
③ $I_I$ → Open Circuit

Ex→




$R_L \to$ S.C
$I_N \to I_{S.C}$

Sol^n→



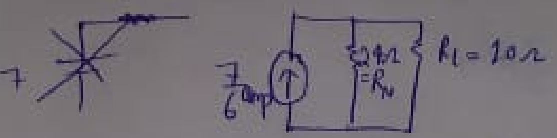

deactive current $\downarrow \frac{20}{24} = \frac{5}{6} = i_1$

deactive voltage $\uparrow 2\text{Amp} = i_2$

net $\uparrow \left(2 - \frac{5}{6}\right) = \frac{7}{6}$ amp

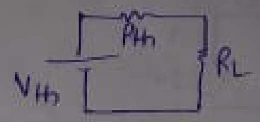
$$\boxed{I_N = \frac{7}{6}\text{amp}}$$

equivalent Norton's Circuit




$\Longrightarrow$

theorems Circuit

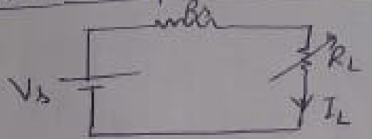



$$\boxed{I_N = \frac{V_{th}}{R_{th}}} \qquad \boxed{V_{th} = I_N \times R_N}$$

Interchange by source transformation

The type of circuit converted into other type of circuit is called dual Circuit.

Maximum power transfer theorem ÷




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

$$P_L\,(max) = I_L^2 R_L$$

$$\frac{dP_L}{dR_L} = \frac{d}{dR_L}\left(\frac{V_s}{R_s+R_L}\right)^2 R_L = 0$$

$$\frac{(R_s+R_L)\,(R_s+R_L-2R_L)}{(R_s+R_L)^4} = 0$$

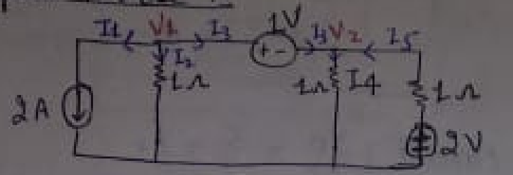
$$R_s - R_L = 0$$

$\boxed{R_s = R_L}$ condition for max^m power

& maximum power

$$\boxed{P_L = \frac{V_s^2}{4R_L}}$$

## Super Node ÷

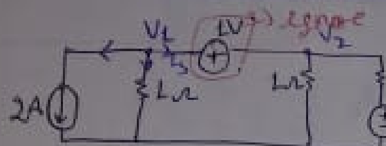



$I_1 + I_2 + I_3 = 0$ — (i)

$I_3 = I_4 + I_5$

by using eq^n ①

$\boxed{I_1 + I_2 + I_4 + I_5 = 0}$




$I_3 = \frac{8}{3}$ amp

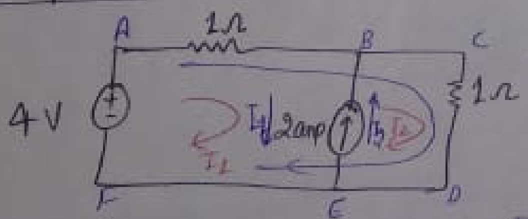
$(1V)P = VI = \frac{8}{3}$ amp

$2 + \frac{V_1 - 0}{1} + \frac{V_2 - 0}{1} + \frac{V_2 - 2}{1} = 0$ —(ii)

$V_2 + 1 = V_1$ — (i)

$\boxed{V_2 = -1/3 \quad V_1 = 2/3}$

## Super Mesh ÷




in ACDF Apply KVL

$-4 + I_1 \times 1 + I_2 \times 1 = 0$

$I_1 + I_2 = 4$ —(i)

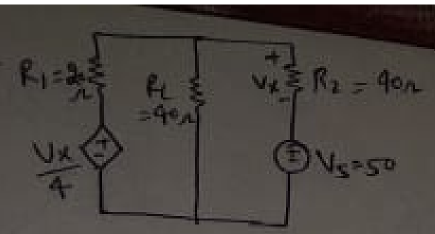
$I_2 - I_1 = 2$ — (ii)

$\boxed{I_2 = 3\text{amp} \quad I_1 = 1\text{amp}}$ Ans

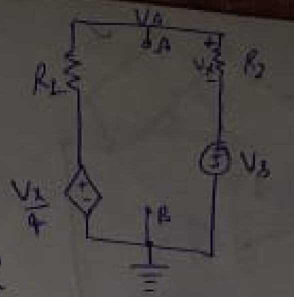
## Thevenins/Norton's (Dependent Source) ÷

At last page the question

Ques-1




for $V_{th}$




at 'A'

$$\frac{V_A - \frac{V_x}{4}}{R_L} + \frac{V_A - V_s}{R_2} = 0 \quad \text{—(i)}$$

& $V_x = V_A - V_s$

$V_x = V_A - 50$

Putting the value of $V_x$ in eqⁿ ①

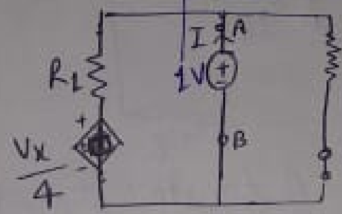
$$\frac{\frac{4V_A - V_A + 50}{4}}{20} + \frac{2(V_A - 50)}{2 \times 40} = 0$$

$\boxed{V_A = 10}$

$V_{th}$ $\boxed{V_{AB} = V_A = 10}$

For $R_{th}$

→ not necessary as 1 V




(source short circuit)

apply K.V.L at A

$$\frac{1 - \frac{V_x}{4}}{10} - I + \frac{1-0}{40} = 0$$

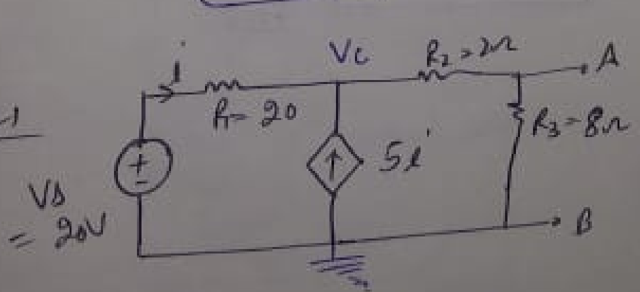
$$\frac{1 - \frac{1}{4}}{10} - I + \frac{1-0}{40} = 0$$

$\boxed{I = \frac{1}{16}}$

$R_{AB} = \frac{V}{I} = \frac{1}{I}$

$\boxed{R_{AB} = 16\,\Omega}$

Ques-1




solⁿ
$$\frac{V_c - V_s}{R_1} - 5i + \frac{V_c - 0}{R_2 + R_3} = 0$$

$$\frac{V_c - 20}{20} - 5i + \frac{V_c}{8+2} = 0$$

For $i$ → $i = \frac{V_s - V_c}{R_1} = \frac{20 - V_c}{20}$ —(ii)

Using ① + ②

$$\frac{V_c - 20}{20} - \left(\frac{20 - V_c}{4}\right) + \frac{V_c}{10} = 0$$

$\boxed{V_c = 15V}$

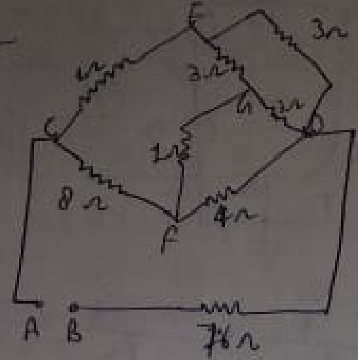
$I_{R_3} = \left(\frac{V_c}{R_2 + R_3}\right) = 1.5$

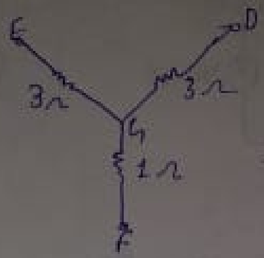
$V_{AB} = I_{R_3} \times R_3$

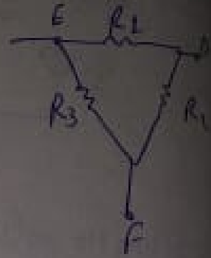
$V_{AB} = 1.5 \times 8$

$\boxed{V_{th} = V_{AB} = 12V}$ Ans

Qus-7





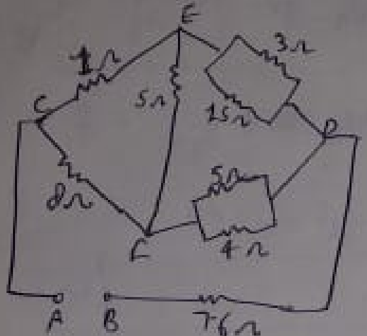


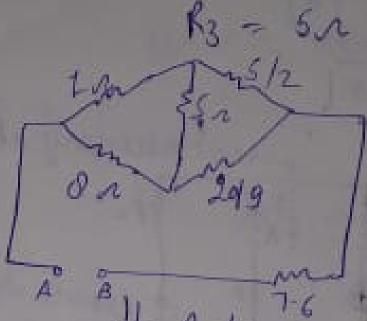
$$R_1 = 3+3+\frac{3\times3}{1} = 15\Omega$$

$$R_2 = 3+1+\frac{3\times1}{3} = \frac{15}{3} = 5\Omega$$

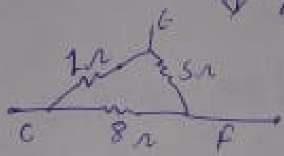
$$R_3 = 5\Omega$$

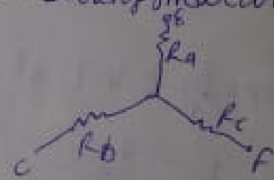
⇓ reduced to





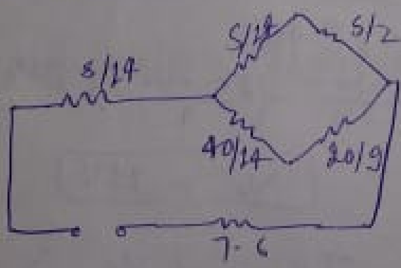
⇓ Δ to star transformation





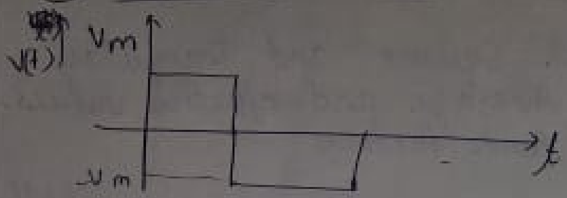
$R_a = \frac{5}{14}$, $R_b = \frac{8}{14}$, $R_c = \frac{40}{14}$

Equivalent circuit will be



$\boxed{R_{AB} = 10\Omega}$ Ans

## ② Square Wave form ÷




$$V_{avg} = \frac{1}{T/2}\int_0^{T/2} V_m\,dt$$

$$= \frac{V_m}{T/2}(t)_0^{T/2}$$

$$= \frac{V_m}{\cancel{T/2}}(\cancel{T/2}-0)$$

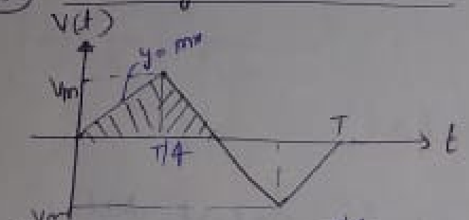
$$\boxed{V_{avg} = V_m}$$

$$V_{rms} = \sqrt{\frac{1}{T/2}\int_0^{T/2} V_m^2\,dt}$$

$$= \sqrt{\frac{V_m^2}{\cancel{T/2}} \times \cancel{T/2}}$$

$$\boxed{V_{rms} = V_m}$$

## ③ Triangular Waveform →




$$V_{avg} = \frac{1}{T/4}\int_0^{T/4} \underbrace{\frac{V_m}{T/4}\,t}_{y = mx}\,dt$$

$$y = \frac{V_m}{T/4}\,t$$

$$V_{avg} = \frac{V_m}{(T/4)^2}\int_0^{T/4} t\,dt$$

$$V_{avg} = \frac{V_m}{(T/4)^2}\left(\frac{t^2}{2}\right)_0^{T/4}$$

$$\boxed{V_{avg} = \frac{V_m}{2}}$$

$$V_{rms} = \sqrt{\frac{1}{T/4}\int_0^{T/4}\left(\frac{4V_m}{T}t\right)^2 dt}$$

$$= \sqrt{\frac{V_m^2}{(T/4)^3}\int_0^{T/4} t^2\,dt}$$

$$= \sqrt{\frac{V_m^2}{(T/4)^3} \times \left[\frac{t^3}{3}\right]_0^{T/4}}$$

$$= \sqrt{\frac{V_m^2}{\cancel{(T/4)^3}} \times \left(\frac{\cancel{(T/4)^3}}{3} - 0\right)}$$

$$\boxed{V_{rms} = \frac{V_m}{\sqrt{3}}}$$

## Form factor

$$\boxed{\text{form factor} = \frac{\text{RMS Value}}{\text{Avg. Value}}}$$

i) For Sine wave $= \dfrac{V_m/\sqrt{2}}{2V_m/\pi} = \boxed{\dfrac{\pi}{2\sqrt{2}}} = 1.11$

ii) For Square wave $= \boxed{1}$

iii) For triangular wave $= \dfrac{V_m}{\sqrt{3}} \Big/ \dfrac{V_m}{2} = \boxed{\dfrac{2}{\sqrt{3}}} = 1.154$

## Peak factor / Crest factor :-

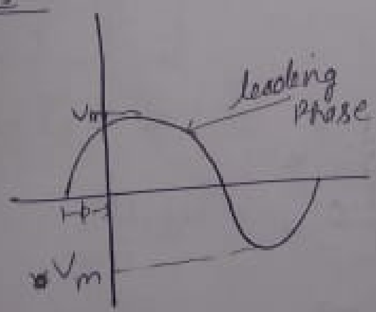
$$\boxed{\text{Peak factor} = \frac{\text{Maximum Value}}{\cancel{\text{Mean}}\ \text{RMS Value}}}$$

i) Sine Wave $= V_m / V_m\sqrt{2} = \sqrt{2}$

ii) Square Wave $= 1$

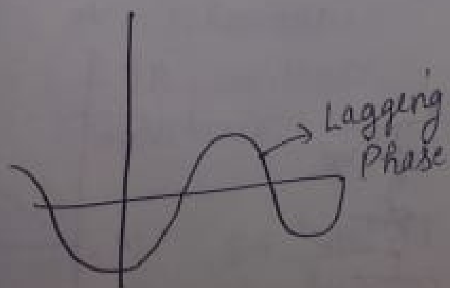
iii) Triangular Wave $= \dfrac{V_m}{\dfrac{V_m}{\sqrt{3}}} = \sqrt{3}$

## Phasors



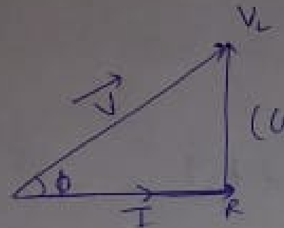

$v(t) = V_m \sin(\omega t + \underset{\uparrow \text{Phase}}{\phi})$

$$\boxed{\omega = 2\pi f = \frac{2\pi}{T}}$$

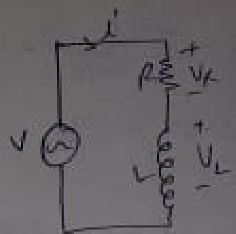


## Analysis of series, $\parallel^{el}$ and series $\parallel^{el}$ RLC →

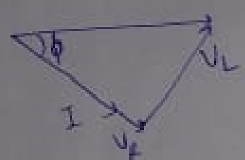
### ① R-L Circuit →



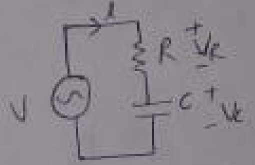

(Current as Reference)

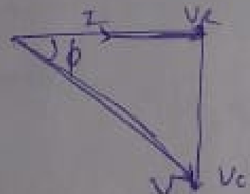



$V = \vec{V_R} + \vec{V_L}$

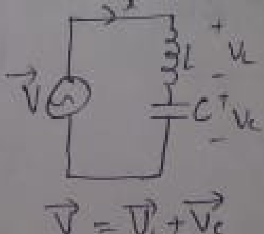


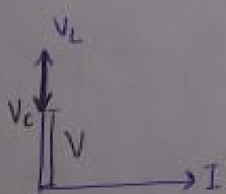

### ② R-C Circuit →



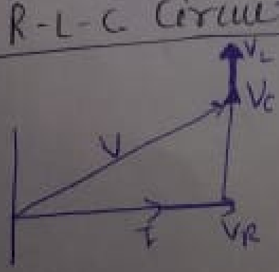

### ③ L-C-Circuit →

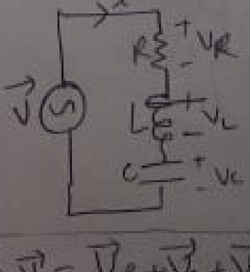


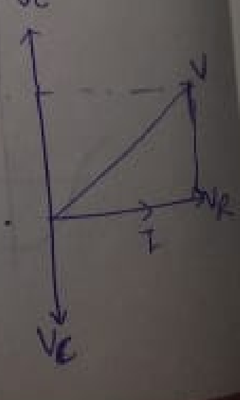

$\vec{V} = \vec{V_L} + \vec{V_C}$

### ④ R-L-C Circuit →



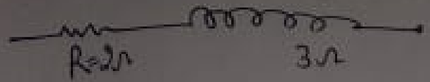




$\boxed{\vec{V} = \vec{V_R} + \vec{V_L} + \vec{V_C}}$



## Analysis of Series Circuit →

### ① R-L →




$\boxed{Z = R + jX_L}$

→ same as complex number "i" ($j$)
→ (Inductive Reactance) ($X_L$)
↳ $\omega L = 2\pi f L$

### ② R-C →

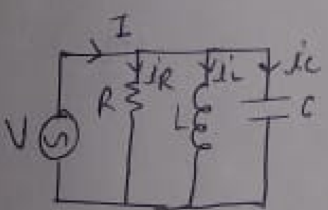
$\boxed{Z = R - jX_C}$

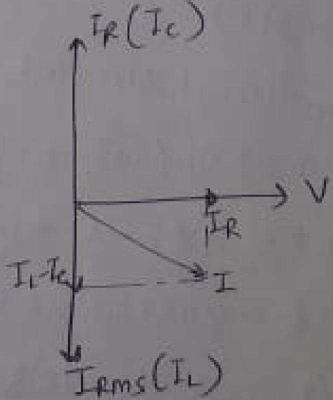
↳ Capacitive reactance $= \frac{1}{\omega C} = \frac{1}{2\pi f C}$

### ③ RLC →

$\boxed{Z = R + (X_L - X_C)j}$

## Parallel Circuit →




$\vec{I} = \vec{I_R} + \vec{I_L} + \vec{I_C}$

$Z = R // jX_L // jX_C$

or

$Z = R + jX$
↳ Reactance

$Y = G + jB$ → susptance
↳ Conductance

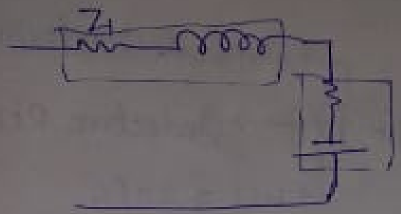
↓ admitance

$G = \frac{1}{R}$, $B \to \frac{1}{X_C}$

$Y = Y_1 + Y_2 + Y_3$

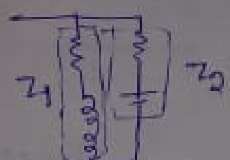
$Z = R + jX$ , $Y = G + jB$

<u>series →</u>




$Z = Z_1 + Z_2$

<u>Parallel →</u>




$Z = Z_1 \| Z_2 = \frac{Z_1 Z_2}{Z_1 + Z_2}$

or

$\frac{1}{Z_1} \to Y_1 \quad \frac{1}{Z_2} \to Y_2$

$Y = Y_1 + Y_2 \to Z = \frac{1}{Y}$

Power and Power Factor →

$P = VI$ ...... D.C. circuit

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

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

$P_i = V_i \times i_i$

$P(t) = v(t) \times i(t)$

$p = V_m I_m \sin \omega t \sin(\omega t - \phi)$ $\left(\because V = \frac{V_m}{\sqrt{2}} , I = \frac{I_m}{\sqrt{2}}\right)$

$p = VI[2\sin \omega t \sin(\omega t - \phi)]$

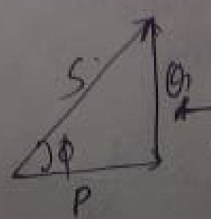
$p = VI[\cos\phi - \cos(2\omega t - \phi)]$

$p = VI[\cos\phi - \{\cos 2\omega t \cos\phi + \sin 2\omega t \sin\phi\}]$

$$\boxed{p = \underbrace{VI\cos\phi}_{P \text{ (active power)}}(1 - \cos 2\omega t) - \underbrace{VI\sin\phi}_{Q \text{ (Reactive power)}}\sin 2\omega t}$$

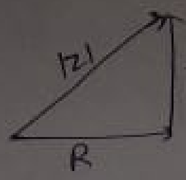
$S = \sqrt{P^2 + Q^2}$

$\boxed{S = VI = \text{Apparent power}}$




power Triangle

$Z = R + jX$




← Imbidence Tringle

$\boxed{|Z| = \sqrt{R^2 + X^2}}$

$p = P(1 - \cos 2\omega t) - Q\sin 2\omega t$

$$P_{avg} = \frac{\int_0^T v(t)\, i(t)\, dt}{T}$$

$$= \frac{\int_0^{2\pi} P(1 - \cos 2\omega t) - Q\sin 2\omega t\, d\omega t}{2\pi} \qquad \left(\because \int_0^{2\pi} \cos 2\omega t = \int_0^{2\pi} \sin 2\omega t = 0\right)$$

$$= \frac{P\int_0^{2\pi} d(\omega t)}{2\pi}$$

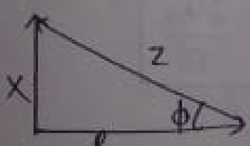
$$= \frac{P \times \cancel{2\pi}}{\cancel{2\pi}}$$

$\boxed{P_{avg} = P}$ ← active power $\qquad \boxed{S = VI^* = P + jQ}$

+ve for lagging power factor

$\vec{Z} = R + j(X_L - X_C) \qquad \vec{V} = \vec{V_R} + \vec{V_L} + \vec{V_C}$

<u>Power factor :-</u>

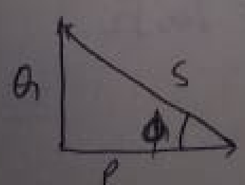



(Imbidence tringle)

$P.F = \cos\phi = \frac{R}{Z}$

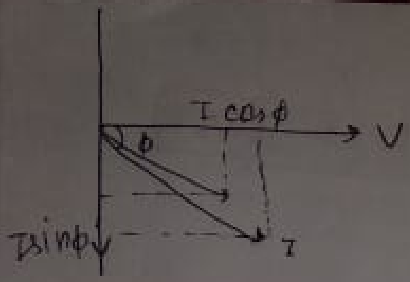
$P.F = \cos\phi = \frac{R}{\sqrt{R^2 + X^2}}$

$P.F. = \cos\phi = \frac{P}{S} = \frac{VI\cos\phi}{VI}$



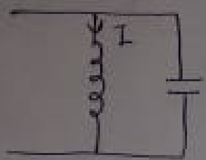

(Power tringle)

$P.F. = \cos\phi = \frac{P}{\sqrt{P^2 + Q^2}}$



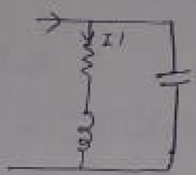

$P = VI\cos\phi$

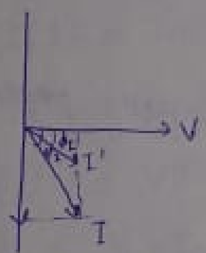
$\left\{ \phi\uparrow,\ \cos\phi \downarrow es \right.$ i.e. $\left. \phi \downarrow es \right\}$





$P = VI\cos\phi$




$(I' < I)$

$\cos\phi_1 = \frac{P_1}{S_1}$

$\cos\phi_2 = \frac{P_2}{S_2}$

$S_1 = P_1 + jQ_1$

**Ques→** $v(t) = 200\cos(314t - 30^\circ)$ find $V_{avg} = ?$ & $V_{rms} = ?$

**Soln→** $V_{avg} = \frac{1}{\pi}\int_0^{\pi} 200\cos(314t - 30^\circ)\,d\omega t$ or $\boxed{V_{avg} = \frac{2V_m}{\pi}}$

$= \frac{200}{\pi}\left[\sin(314t - 30^\circ)\right]_0^{\pi}$

$= \frac{200}{\pi} \times 2$

$\boxed{V_{avg} = \frac{400}{\pi}}$

$V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{200}{\sqrt{2}} = 100\sqrt{2}$

(2) $V(t) = 100\cos(314t - 30^\circ) - 200\sin(314t - 60^\circ)$

$\Rightarrow 100\cos(314t - 30^\circ) = 100(\cos 314t \cos 30^\circ + \sin 314t \sin 30^\circ)$

$\Rightarrow$ ~~200 sin~~ $= 50 \times 1.732 \cos 314t + 50\sin 314t \quad \text{—(i)}$

$200\sin(314t - 60^\circ) = 100\sin 314t - 100 \times 1.732 \cos 314t \quad \text{—(ii)}$

eq$^n$ (I) + (II)

$V(t) = 100\cos(314t - 30^\circ) - 200\sin(314t - 60^\circ) = 150\sin 314t - 86.6\cos 314t$

$V_{rms} = \sqrt{(150)^2 + (86.6)^2}$

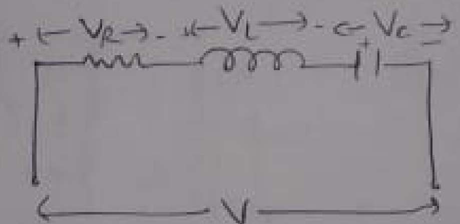
$\boxed{V_{rms} = 173.20}$ Ans or

$V(t) = 100\cos(314t - 30^\circ) - 200\cos(314t - 150^\circ)$

$V^2 = V_1^2 + V_2^2 + 2V_1V_2\cos 60^\circ$

$\boxed{V = 173.20}$

Ques→




$V_R = 6V$

$V_L = 12V$

$V_C = 4V$

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

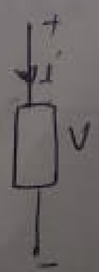
$V = \sqrt{36 + 64}$

$\boxed{V = 10 \text{ Volts}}$

Ques→

$V = 100\sin(\omega t - 30^\circ)$

$I = 20\sin(\omega t - 60^\circ)$



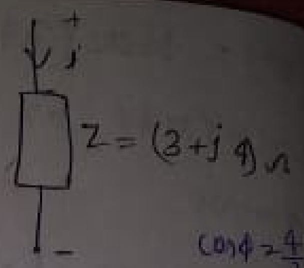

Sol$^n$→ $P = VI\cos\phi$

$P = \frac{100}{\sqrt{2}} \times \frac{20}{\sqrt{2}} \cos 30^\circ$

$\boxed{P = 866 \text{ Watt}}$

Ques $v(t) = 100\sin(\omega t - 30^\circ)$

$i(t) = 20\sin(\omega t - 60^\circ)$





$\cos\phi = \frac{4}{3}$

Sol$^n$: $P = VI\cos\phi$

$P = \frac{100}{\sqrt{2}} \times \frac{20}{\sqrt{2}} \times \frac{3}{5}$

$P = \frac{1200}{2} = 600$ Watt

$Q = VI\sin\phi$

$Q = 100 \times 20 \times \frac{4}{5}$

$Q = 800$ Volt amp (Var)

VAR → volt ampere reactive

or

$S = VI^* = \frac{100}{\sqrt{2}}\angle -30^\circ \times 10\sqrt{2}\angle +83$

$S = 1000\angle 53^\circ$

$$\boxed{S = \underbrace{1000\cos 53^\circ}_{P} + j\,\underbrace{1000\sin 53^\circ}_{Q}}$$

$$\boxed{S = 600 + 800j}$$

$I = 10\sqrt{2}\angle(-83^\circ)$

$I^* = 10\sqrt{2}\angle(83)$

for I: $I = \frac{V_{rms}}{Z}$

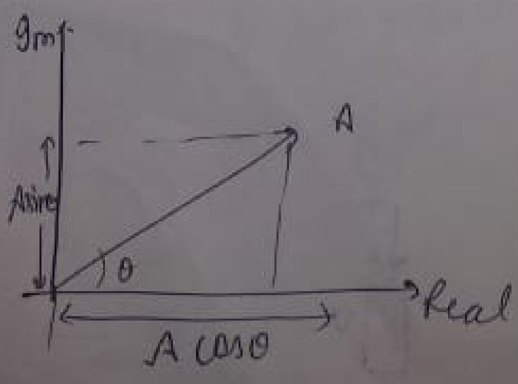
$I = \frac{\frac{100}{\sqrt{2}}\angle -30^\circ}{5\angle 53^\circ}$

$I = 10\sqrt{2}\angle -30^\circ - 53^\circ$

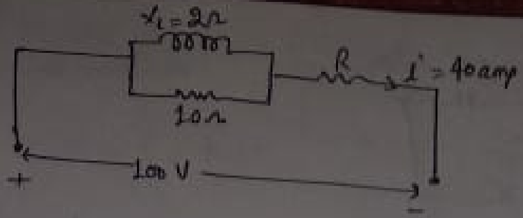
$$\boxed{I = 10\sqrt{2}\angle -83^\circ}$$

$VI^*$

$A\angle\theta = A\cos\theta + jA\sin\theta$



Qus-)




(i) Find $R = ?$

(ii) Power factor of circuits $= ?$

Sol$^n$ (i) $Z = R + 10 \| 2j$

$$Z = R + \frac{20j}{10+2j}$$

$$Z = R + \frac{20j(10-2j)}{104}$$

$$Z = \left(R + \frac{40}{104}\right) + \frac{200}{104}j$$

$$Z = \sqrt{\left(R + \frac{40}{104}\right)^2 + \left(\frac{20}{104}\right)^2}$$

$$\frac{100}{40} = \sqrt{\left(R + \frac{40}{104}\right)^2 + \left(\frac{20}{104}\right)^2}$$

$$\boxed{R = 1.21\Omega}$$

(ii) $Z = \left(1.21 + \frac{40}{104}\right) + \frac{j200}{104}$

$$\tan\phi = \frac{\frac{200}{104}}{1.21 + \frac{40}{104}}$$

$$\tan\phi = \frac{200}{1.21 \times 104 + 40}$$

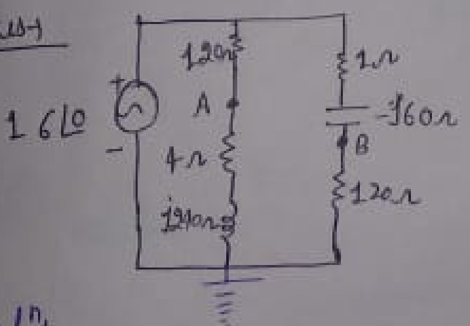
$$\boxed{\cos\phi = 0.638}$$

or

$$\cos\theta = \frac{R}{Z} = \frac{R + \frac{40}{104}}{\frac{100}{40}}$$

$$\boxed{\cos\phi = 0.638}$$

Qus-)




Find $V_{AB} = ?$

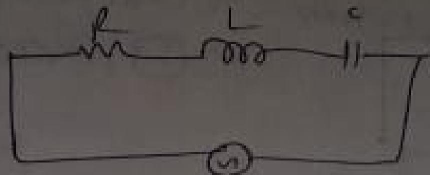
Sol$^n$:

$$V_A = \frac{4 + j240}{120+4+j240} \times 16 = 14.21 \angle 26.56$$

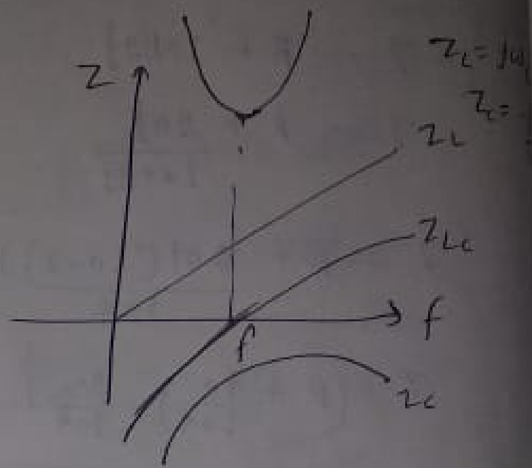
$$V_B = \frac{120}{120+1-j\times 60} \times 16 = 14.21 \angle 26.56$$

$\boxed{V_A - V_B = 0}$ Ans

## Resonance




$$Z = R + j\left(\omega L - \frac{1}{\omega C}\right)$$

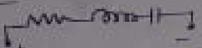



$$\omega L - \frac{1}{\omega C} = 0$$

$$\omega = \frac{1}{\sqrt{LC}} \qquad \boxed{I_0 = \frac{V}{R}}$$

$$\boxed{f = \frac{1}{2\pi\sqrt{LC}}}$$

## Selectivity →



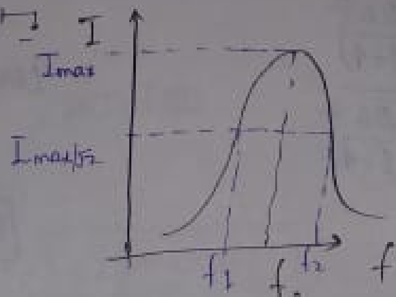
$$P_0 = I_{max}^2 R$$

$$P_1 = \left(\frac{I_{max}}{\sqrt{2}}\right)^2 R$$

$$\boxed{P_1 = \frac{P_0}{2}}$$

similarly

$$\boxed{P_2 = \frac{P_0}{2}}$$

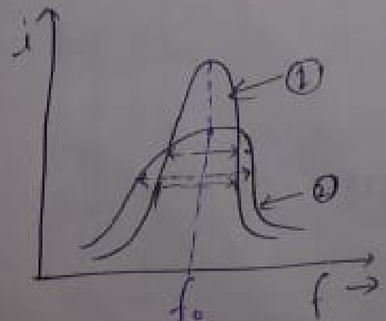



$f_1$ & $f_2$ are called half power frequency

Band width $= f_2 - f_1 = \Delta f$

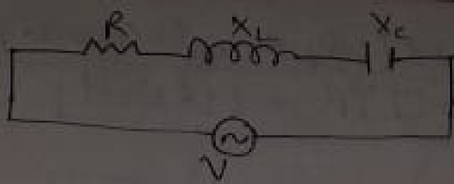
$$\text{Selectivity} = \frac{\text{Resonance freq}^n}{\text{Band width}} = \frac{f_0}{f_2 - f_1}$$

**Qus**




Band width ① > Band width ②
so ① graph has more selectivity than ②

## Quality factor :-




suppose circuit has resonance

$V = \underline{I_{max} R}$

$|V_L| = |V_c| = I_{max} X_L = I_{max} X_c$

**Voltage magnification :-** $= \frac{V_L}{V} = \frac{I_{max} X_L}{V} = \frac{I_{max} X_L}{I_{max} R} = \frac{X_L}{R} = \frac{\omega L}{R}$

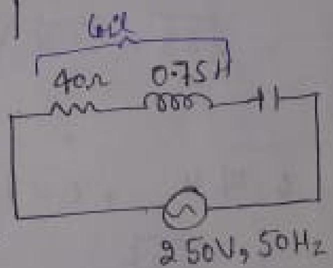
$= \frac{V_c}{V} = \frac{X_c}{R} = \frac{1}{\omega RC} \Rightarrow \frac{\omega_0}{\Delta\omega}$

Quality factor $(Q)$ = Voltage magnification

$$\boxed{Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 RC} = \frac{1}{R}\sqrt{\frac{L}{C}}}$$

$\omega_0 = \frac{1}{\sqrt{LC}}$

$Q = \frac{\frac{1}{\sqrt{LC}} L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$ | $Q = \frac{1}{\frac{1}{\sqrt{LC}} RC} = \frac{1}{R}\sqrt{\frac{L}{C}}$




Ques :- $f_0 = 55 Hz$
(Resonant freq$^n$)

Find ① the line current = ?

② Power factor ?

③ Power consumed ?

④ Voltage accross the coil ?

sol$^n$ :- ① $f_0 = \frac{1}{2\pi\sqrt{LC}}$ $\quad C = \frac{1}{L}\left(\frac{1}{2\pi f_0}\right)^2 = 11.165 \mu F$

$$\boxed{I = \frac{V}{|Z|} = \frac{250}{63.63} = 3.93 \text{ Amp}}$$

$|Z| = \sqrt{R^2 + (X_L - X_c)^2} = \sqrt{(49)^2 + (-41.98)^2} = 63.63$

(II) power factor $= \frac{R}{Z} = \frac{40}{63.63} = 0.629 = 0.63$

(iii) power Consumed (only R will Consumed power)

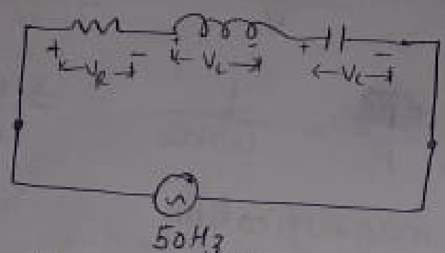
$$\boxed{P=(I)^2R = 618 \text{ Watt}}$$

(iv) Voltage accross coil $= I \times \sqrt{X_L + R^2}$

$$V_{coil} = 3.93 \times \sqrt{X_L^2+(40)^2}$$

$$\boxed{V_{coil} = 939.2} \text{ Volts}$$

Ques-




$V_R = 5$ Volt
$V_L = 8$ Volt
$V_C = 10$ Volt

Find $f_0$ (Resonance freq)
(ii) $V_{net} = ?$

$f_0 = \frac{1}{2\pi\sqrt{LC}}$

Sol^n (i) $X_L = \frac{V_L}{I} \Rightarrow L = \frac{V_L}{2\pi f I}$

$X_C = \frac{V_C}{I} \Rightarrow C = \frac{I}{2\pi f V_C}$ $\Rightarrow LC = \left(\frac{1}{2\pi f}\right)^2 \frac{V_L}{V_C}$

$$f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1 \times \cancel{2\pi} f}{\cancel{2\pi}}\sqrt{\frac{V_C}{V_L}} = 50\sqrt{\frac{\cancel{10}5}{\cancel{8}4}} = \frac{50\sqrt{5}}{2}$$

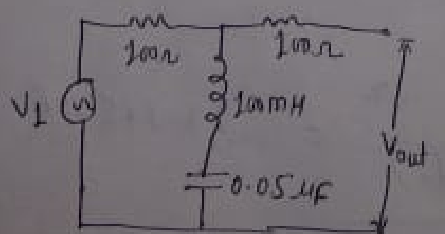
$$= 55.9 \text{ Hz}$$

(ii) $V_{net} = \sqrt{(5)^2+(10-8)^2} = \sqrt{29} = 5.38$ Volt Ans

Ques- $R = 10\Omega$, $L = 0.01$ H, $C = 10\mu F$ Series Circuit Find Quality factor

Sol^n- $Q = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{10}\sqrt{\frac{0.01}{1000 \times 10^{-6}}} = \frac{1}{10}\sqrt{10^3} = 3.16$ Ans

Ques-

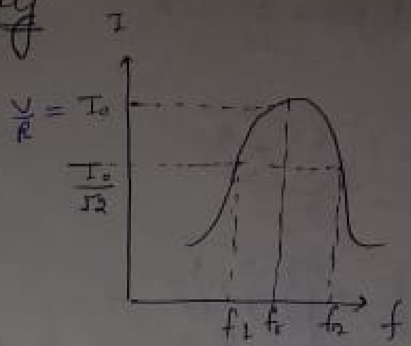



Find the frequency at which $V_{out} = 0$

Sol^n Vout is zero if $X_L = X_C \Rightarrow V_L = V_C$ so resonent freq

$$f = \frac{1}{2\pi\sqrt{LC}} = 2250 \text{ Hz Ans}$$

# Corner frequency | Edge Frequency




At $f_1$ the current -

$$\frac{I_0}{\sqrt{2}} = \frac{V}{\sqrt{R^2 + \left(\omega_1 L - \frac{1}{\omega_1 C}\right)^2}}$$

$$\frac{V}{R\sqrt{2}} = \frac{V}{\sqrt{R^2 + \left(\omega_1 L - \frac{1}{\omega_1 C}\right)^2}}$$

Compair

$$2R^2 = R^2 + \left(\omega_1 L - \frac{1}{\omega_1 C}\right)^2$$

$$\omega_1 L - \frac{1}{\omega_1 C} = \pm R$$

Consider -ve sign ( $\frac{1}{\omega_1 C} > \omega_1 L$ )

$$\omega_1 L - \frac{1}{\omega_1 C} = -R$$

$$\omega_1^2 LC - 1 = -R\omega_1 C$$

$$\omega_1^2 LC + R\omega_1 C - 1 = 0 \Rightarrow \omega_1^2 + \frac{R}{L}\omega_1 - \frac{1}{LC} = 0$$

$$\omega_1 = \frac{-\frac{R}{L} \pm \sqrt{\left(\frac{R}{L}\right)^2 - 4\times1\left(-\frac{1}{LC}\right)}}{2\times1} \Rightarrow \boxed{-\frac{R}{2L} \pm \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}} = \omega_1}$$

$$\Downarrow$$

so $\boxed{\omega_1 = -\frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}}$

-ve not possible because frequency is -ve.

At $f_2$ the current

$$\frac{I_0}{\sqrt{2}} = \frac{V}{\sqrt{R^2 + \left(\omega_2 L - \frac{1}{\omega_2 C}\right)^2}}$$

$$\frac{V}{\sqrt{2}R} = \frac{V}{\sqrt{R^2 + \left(\omega_2 L - \frac{1}{\omega_2 C}\right)^2}}$$

$$2R^2 = R^2 + \left(\omega_2 L - \frac{1}{\omega_2 C}\right)^2 \Rightarrow \pm R = \omega_2 L - \frac{1}{\omega_2 C}$$

At $f_2$ $X_L > X_C$ so taking +ve sign

$$\omega_2 L - \frac{1}{\omega_2 C} = +R$$

$$\omega_2^2 - \frac{R}{L}\omega_2 - \frac{1}{LC} = 0$$

$$\left[\begin{aligned} f_1 &= f_0 - \frac{\Delta f}{2} \\ f_2 &= f_0 + \frac{\Delta f}{2} \end{aligned}\right] \text{same as } \omega$$

$$\omega_2 = \frac{\frac{R}{L} \pm \sqrt{\left(\frac{R}{L}\right)^2 + \frac{4}{LC}}}{2}$$

$$\omega_2 = \frac{R}{2L} \pm \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}$$

-ve cannot consider due to -ve freq$^n$ so

$$\boxed{\omega_2 = \frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}}$$

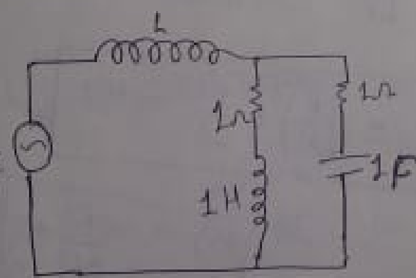
and

$$\boxed{\omega_1 = -\frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}}$$

Band weidth $\boxed{\Delta\omega = \omega_2 - \omega_1 = \frac{R}{L}}$

$$\boxed{\omega_1 \omega_2 = \frac{1}{\sqrt{LC}} = \omega_r^2}$$

Ques-1

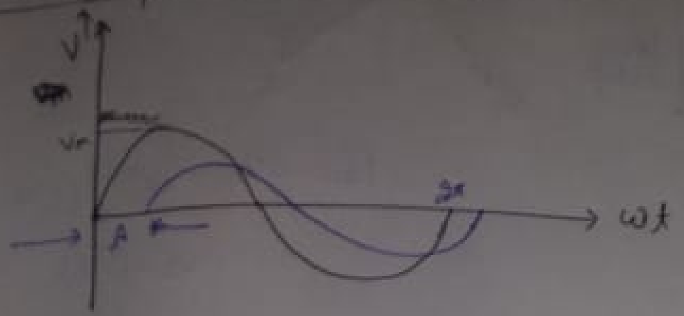



find Condition for Resonance?

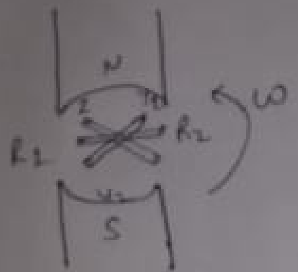
Sol$^n$,

# Unit - 3

## Three phase A.C Circuits

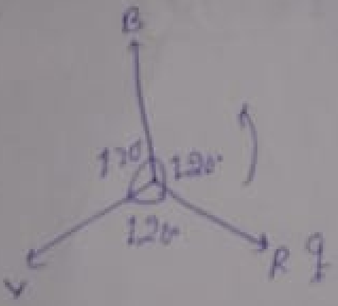


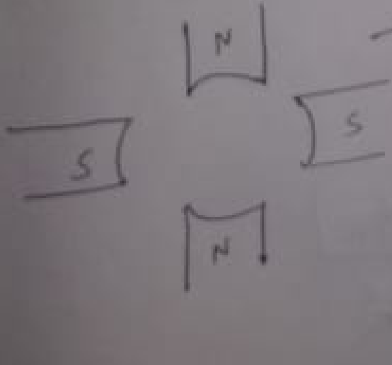





$\left[\frac{360^\circ}{n}\right]$

RYB RBY
YBR BYR
BRY YRB




→ No of poles are 4
$P = 4$

$$\theta_{mech} = \frac{\theta_{elec}}{P/2}$$

($\because$ P is no of poles here)

$V_R = V_m \sin \omega t$

or

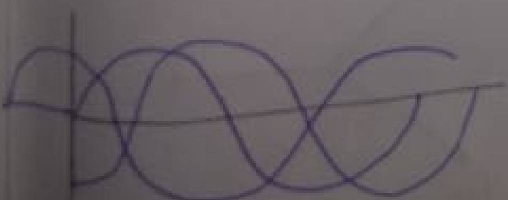
$V_Y = V_m \sin(\omega t + 120)$

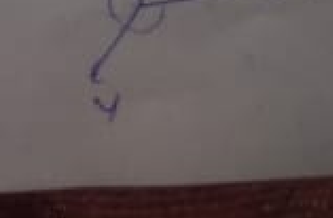
or

$V_B = V_m \sin(\omega t - 240^\circ)$

or

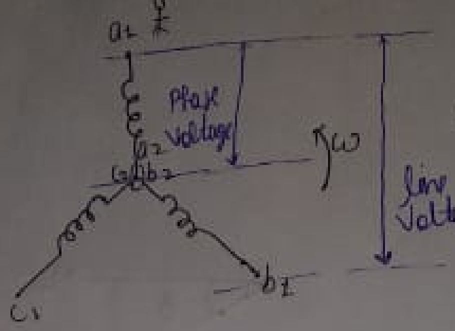
$V_B = V_m \sin(\omega t + 120)$

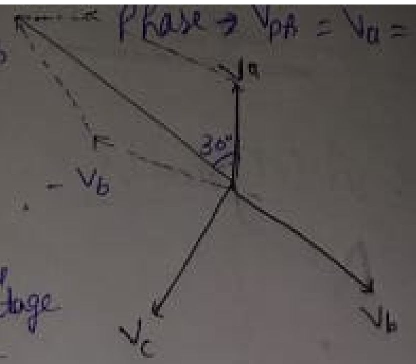




# Star | Delta Connection :-

Star →




Phase → $V_{ph} = V_a = V_b = V_c$

Line → $V_L = \underbrace{V_{ab}}_{V_a + (-V_b)} = V_{bc} =$

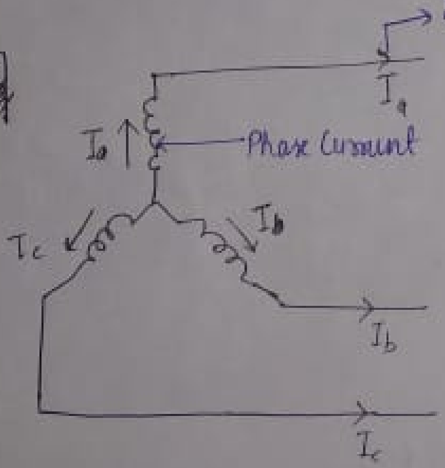
$$V_{ab} = \sqrt{V_a^2 + V_b^2 + 2V_a(+V_b)\cos 60°}$$

$$V_{ab} = \sqrt{V_a^2 + V_b^2 + \cancel{2}V_aV_b \times \frac{1}{\cancel{2}}}$$

$\because V_a = V_b$

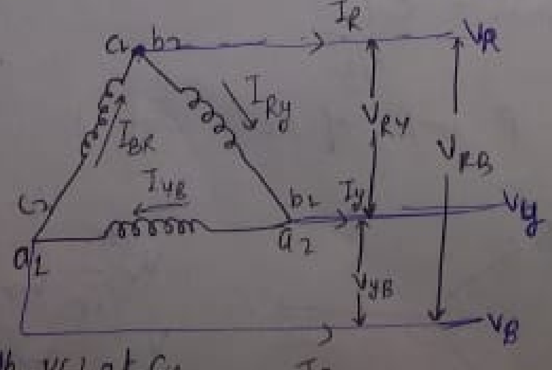
so $V_{ab} = \sqrt{3}\, V_a$

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

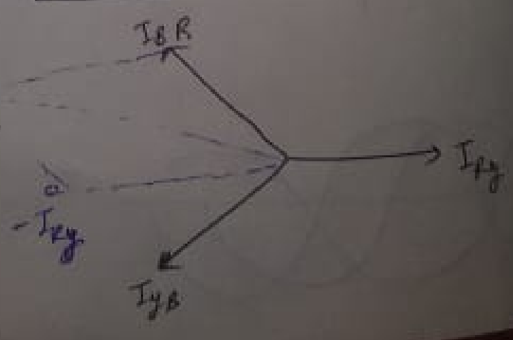



$$\boxed{I_L = I_{ph}}$$

## Δ-Connection ⇒




$$\boxed{V_L = V_{ph}}$$




~~KCL at~~ KCL at $c_2$

$-I_{BR} + I_{Ry} + I_R = 0$

$$\boxed{I_R = I_{BR} - I_{Ry}}$$

$$\vec{V}_R = V_{ph}\angle 0^\circ = V_{ph}(1 + j0)$$

$$\vec{V}_y = V_{ph}\angle 120^\circ = V_{ph}(\cos 120 + j\sin 120^\circ) = V_{ph}\left(-\frac{1}{2} + j\frac{\sqrt{3}}{2}\right)$$

$$\vec{V}_B = V_{ph}\angle 240^\circ = V_{ph}\left(-\frac{1}{2} - j\frac{\sqrt{3}}{2}\right)$$

Parallel supply -

$$\Rightarrow \boxed{\vec{V}_R + \vec{V}_y + \vec{V}_B = 0}$$